Impacts of Contracted Endodontic Cavities on Instrumentation Efficacy and Biomechanical Responses in Maxillary Molars

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Abstract

Introduction: Recently, we reported that in mandibular molars contracted endodontic cavities (CECs) improved fracture strength compared with traditional endodontic cavities (TECs) but compromised instrumentation efficacy in distal canals. This study assessed the impacts of CECs on instrumentation efficacy and axial strain responses in maxillary molars. **Methods:** Eighteen extracted intact maxillary molars were imaged with micro–computed tomographic imaging (12-μm voxel), assigned to CEC or TEC groups (n = 9/group), and accessed accordingly. Canals were instrumented (V-Taper2H; SSWhite Dental, Lakewood, NJ) with 2.5% sodium hypochlorite irrigation, reimaged, and the proportion of the modified canal wall determined. Cavities were restored with bonded composite resin (TPH-Spectra-LV; Dentsply International, York, PA). Another 28 similar molars (n = 14/group) with linear strain gauges (Showa Measuring Instruments, Tokyo, Japan) attached to mesiobuccal and palatal roots were subjected to load cycles (50–150 N) in the Instron Universal Testing machine (Instron, Canton, MA), and the axial microstrain was recorded before access and after restoration. These 28 molars and additional 11 intact molars (control) were cyclically fatigued (1 million cycles, 5–50 N, 15 Hz) and subsequently loaded to failure. Data were analyzed by the Wilcoxon rank sum and Kruskal-Wallis tests (α = 0.05). **Results:** The overall mean proportion of the modified canal wall did not differ significantly between CECs (49.7% $\pm$ 12.0%) and TECs (44.7% $\pm$ 9.0%). Relative changes in axial microstrain responses to load varied in both groups. The mean load at failure for CECs (1703 $\pm$ 558 N) did not differ significantly from TECs (1384 $\pm$ 377 N) and was significantly lower ($P < .005$) for both groups compared with intact molars (2457 $\pm$ 941 N). **Conclusions:** In maxillary molars tested *in vitro*, CECs did not impact instrumentation efficacy and biomechanical responses compared with TECs. *(J Endod 2016;42:1779–1783)*

Key Words

Endodontic cavity, fracture strength, instrumentation efficacy, minimally invasive, root strain

Significance

Fracture after endodontic treatment is an ongoing concern. Modern dentistry has seen a trend towards minimally invasive treatments. In endodontics, removal of tooth structure increases the susceptibility of teeth to fracture that gave rise to the concept of contracted cavities.

Endodontic treatment aims to retain teeth in health and function for the long-term (1), but teeth may fracture, necessitating extraction (2–4). A fracture risk factor is loss of dentin, including that associated with drilling of endodontic cavities (4). Traditional endodontic cavities (TECs) emphasize straight-line pathways into canals to enhance instrumentation efficacy and prevent procedural errors (5, 6). The associated removal of pericervical dentin (7, 8) can impact biomechanical responses of teeth (9–14). Increased cuspal flexure associated with TECs (9,12–14) may lead to increased strain at the crown and root surfaces (11–13), which, in turn, may increase the susceptibility of treated teeth to fracture under functional loads (4, 9). These biomechanical effects are undesirable, but they may be moderated in the short-term by restoration of endodontic cavities with bonded composite resin (12,15–18).

Contracted endodontic cavities (CECs), inspired by concepts of minimally invasive dentistry (19), emphasize tooth structure preservation including pericervical dentin (7, 8). We previously reported (20) that CECs, compared with TECs, improved fracture strength under a continuous load in unrestored mandibular premolars and molars but not in maxillary incisors, and compromised instrumentation efficacy in distal canals of mandibular molars but not in premolars and incisors. These results, suggesting that the impact of CECs varied in different tooth types when unrestored, might not be extrapolated to restored maxillary molars in which the morphology is distinctly different. Also, unlike available data on fracture strength of intact mandibular molars (21), respective data on maxillary molars are lacking. Therefore, this study assessed the impacts of CECs on canal instrumentation efficacy and biomechanical responses in maxillary molars

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restored with bonded composite resin. We tested the null hypotheses that CECs would not impact instrumentation efficacy, axial root strain, or fracture strength after cyclic fatigue.

Materials and Methods

After research protocol approval by the University of Toronto Research Ethics Board, 59 extracted human noncarious, mature, intact, maxillary molars were stored in 0.1% thymol solution at room temperature until used. The absence of preexisting cracks was verified under the operating microscope. Crown dimensions, length, and canal curvature of teeth, determined by 2 perpendicular radiographic exposures, were considered for matching teeth allocated into groups.

Sample and Groups

The sample size was estimated based on studies comparing fracture strength for TECs and CECs (20) and the proportion of untouched canal wall (20, 22–24), both with 10 teeth per group. Accordingly, for analysis with $\alpha = 0.05$ and 80% power, at least 10 teeth were allocated for each of the following groups: CEC (experimental), TEC (control), and intact (negative control for fracture strength testing) for different aspects of the study.

Instrumentation Efficacy

A subset of 20 teeth assigned to the CEC and TEC groups was imaged with micro–computed tomography (micro-CT) (SkyScan 1172; Brüker MicroCT, Kontich, Belgium) at 12-μm voxel size, 70-KVp beam energy, 10 frames/view, and 400-millisecond exposure, and the canals were captured (pretreatment volumes). Mineral density was calibrated with mineral analogue rods and ReCon software (Brüker MicroCT) used for 3-dimensional (3D) reconstruction.

Eighteen teeth (1 tooth/group was lost during processing) were accessed under the operating microscope. In the CEC group (n = 9), endodontic cavities were drilled with high-speed Endoguide burs (EG1A; SSWhite Dental, Lakewood, NJ). Cavities were accessed at the central fossa and extended only as necessary to access canal orifices while preserving pericervical dentin and part of the chamber roof or "soffit" (7, 8) (Fig. 1*A*). In the TEC group (n = 9), endodontic cavities were drilled with tapered high-speed diamond burs (F392-016; Axis Dental, Coppell, TX) following conventional guidelines (5, 6). Outline and pericervical dentin were modified as needed until all orifices could be visualized in the same field of view.

Canals were negotiated with size 10 K-type files (Flexofile; Dentsply Maillefer, Ballaigues, Switzerland) to the major apical foramen and the working length established 0.5 mm shorter. After initial preparation with PathFile instruments (Dentsply Maillefer), canals were instrumented with V-Taper2H rotary instruments (SSWhite Dental) to size 20/v06 and 30/v06 in buccal and palatal roots, respectively. These heat-treated instruments were precurved to facilitate placement into canals. New instruments were used for each tooth. Intermittent irrigation with 5 mL 2.5% sodium hypochlorite was applied with ProRinse side-vented 30-G needles (Dentsply International, York, PA).

Instrumented canals were captured with micro-CT (post-treatment volumes) as described previously. Reconstructed 3D volume data were converted from a bitmap image file to the Digital Imaging and Communications in Medicine format and processed with Scanco 3D morphometry analysis software (Scanco Medical, Brüttisellen, Switzerland). Coronal canal boundaries were set at orifice levels. Isthmus pathways in mesiobuccal roots were excluded. Where a wide isthmus was present, canal boundaries were set at the transition between the main canal and the isthmus. Customized script for algorithm-based registration (20, 22, 24) was used to process pre- and post-treatment volumes with a precision of 1 ± 1 voxel. Accordingly, dentin removal depth ≥24 μm was determined as a modified canal wall (MCW) surface.

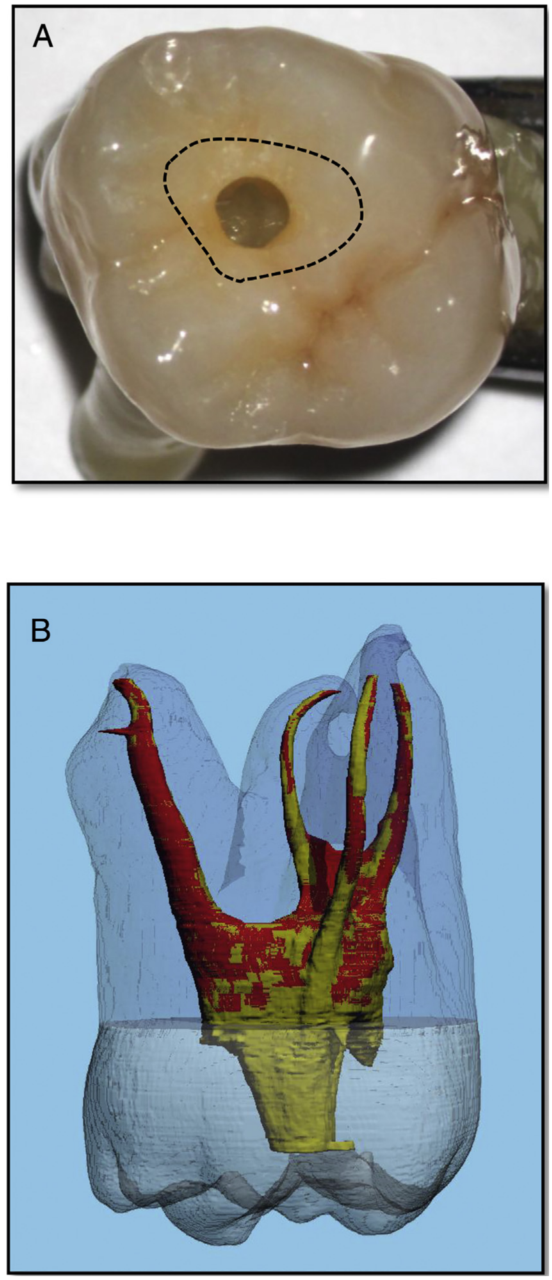

Figure 1. CEC in a maxillary molar. (*A*) The occlusal view; for comparison, a TEC is outlined with a dotted line. (*B*) The distal view of registered 3D reconstructed micro-CT images showing the root canals (*red*) pretreatment and (*yellow*) post-treatment. The pulp chamber and endodontic cavity within the coronal tooth portion are not color coded.

Biomechanical Responses

Another subset of 28 teeth was used to record apicocoronal axial strain under simulated physiologic occlusal stresses (10, 11). Teeth were mounted up to 3 mm apical to the cementoenamel junction in customized cylinders fabricated with self-curing resin (SR Ivolen; Ivoclar Vivadent, Schaan, Lichtenstein), with a 0.2-mm-thick lining of