Micro–Computed Tomographic Evaluation of the Influence of Root Canal System Landmarks on Access Outline Forms and Canal Curvatures in Mandibular Molars

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Abstract

Introduction: This study investigated the influence of anatomic root canal system landmarks on access outline forms of mandibular molars and correlated these to the theoretical distance of orifice relocation and changes in canal primary curvature. **Methods:** Thirty relatively calcified human mandibular molars were selected and examined by micro–computed tomographic imaging. Three-dimensional volume reconstructions were made, root canal system landmarks identified, and plotted: canal orifices, canal position at the furcation level, and pulp horn location. Each landmark was separately projected onto the occlusal surface, and 3 access designs were respectively proposed: (1) minimally invasive, (2) straight-line furcation, and (3) straight-line radicular. For each access design, the theoretical distance of orifice relocation and canal primary curvature were determined. Data were submitted to 2-way repeated measures analysis of variance ($\alpha < 0.05$). **Results:** The orifice relocation distance required to obtain each type of access outline was greater for radicular-based accesses (0.97 ± 0.32 mm) than for furcation accesses (0.52 ± 0.30 mm, $P < .001$) and resulted in a greater change in canal primary curvature ($P < .001$; 15.9° ± 4.6° and 9.4° ± 4.3°, respectively). The canal primary curvature for each access outline type was statistically different from each other ($P < .0001$), whereas the minimally invasive access showed the highest mean angle (40.1° ± 8.4°) followed by the straight-line furcation (30.7° ± 7.5°) and the straight-line radicular accesses (24.2° ± 8.4°). **Conclusions:** The use of different landmarks to establish access outline designs affected the primary angle of curvature in relatively calcified mandibular molars. *(J Endod 2015;41:1888–1891)*

Key Words

Canal curvature, endodontic access cavity, root canal morphology

Given the high percentage of root canal treatment of mandibular molars among clinicians (1), understanding the outcomes of altering traditional access outline forms to recently proposed minimal shapes is essential. A previous investigation defined outline access forms based solely on the orifice location (2). Molar teeth were decoronated at the level of the pulpal floor with the orifice being projected onto schematic diagrams. The canal orifices were found located in a consistent pattern, resulting in a centered, constricted design. Decoronation could potentially influence the measured canal curvature because the position of the orifice does not take into account deposition of dentin subsequent to tooth eruption located coronally. The relationship of the pulp chamber to the crown in mandibular molars was previously examined using a sectioning technique (3). At the level of the cementoenamel junction, the pulp chamber was consistently located in the center of the tooth, found equidistant to the external surface of the tooth, suggesting a change in the previously accepted outline form was warranted. The effect of pulp chamber size, shape, and location should not be neglected when determining the location of primary curvatures. Cunningham and Senia (4) examined Weine type II and III systems to determine the prevalence of curvature in the clinical and proximal views. The authors identified the first curvature encountered as primary and further surmised coronal flaring that reduced the primary curvature would decrease the chances of canal preparation errors.

Multiple authors have studied methods for aiding canal preparation and minimizing iatrogenic outcomes in mandibular molars (5, 6). This was shown by the elimination of cervical dentin, present over the canal entrance, through orifice relocation by creating straight-line radicular access to the level of the midroot canal curvature (primary). The previously described access modifications (2) have been further reduced, largely as a result of magnification and the awareness to retain existing dentin (7). The authors state incomplete removal of the pulp chamber roof along with preservation of pericervical dentin is fundamental to the restorative success of the tooth. *Pericervical dentin* is defined as the dentin located above and below the alveolar crest, approximating a total height of 8 mm (7). Understanding the implications a convenience form versus restoratively driven access will have on canal curvature and instrumentation will require the clinician to make an informed decision based on tooth morphology.

No prior micro–computed tomographic (μCT) studies have evaluated the inter-relationships between the internal form of the pulp chamber, orifice locations, and other root canal system landmarks. The primary aim of this study was to plot 3 pulp space anatomic landmarks and apply them in the design of access cavity outlines for mandibular molars. The secondary aim was to determine the linear measurement of

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dentin removal required to relocate the orifice and the subsequent change affected on the canal primary angle of curvature for each access design.

Materials and Methods

Selection Criteria

Human mandibular first and second molars with fully formed apices and intact crowns were obtained from a bank of teeth and screened in clinical and proximal radiographic views (expert DC, Gendex, Hatfield, PA). Thirty teeth were selected based on the following inclusion criteria for chamber and root canal anatomy: radiographic pulp chamber height <2 mm, root length between 19 and 21 mm, and mesial roots with a common apical configuration.

μCT Visualization and Measurement

Each specimen was mounted and scanned at 75 kV and 100 μA through 720° of rotation around the vertical axis, resulting in a cross-sectional pixel size of approximately 30 μm. Each backscatter projection was a 16-bit addressable 1,024 × 1,024 area used to create a volume-rendered representation (VG Studio Max 2.2; Volume Graphics GmbH, Heidelberg, Germany).

The defined landmarks included the following (Fig. 1*A*): mesiobuccal (MB), mesiolingual (ML), distobuccal, and distolingual pulp horns; the center of each canal orifice at the level of the floor of the pulp chamber; the center of each canal at the furcation level; and the center of the canal primary curve in the maximum curvature view (8).

Access Outline Form Design

The chosen landmarks were visualized in the volumetric representation derived from a surface determination from the backscatter projections. The 3-dimensional model was viewed in the axial orientation and the level of transparency set at 30%, identifying the pulp horns, canal orifices, and the center of each canal at the furcation level. Individual markers were projected on the semitransparent occlusal surface and exported as an image for every sample. The collection of images were overlaid and aligned onto a separate ideal template derived from the occlusal surface of a mandibular molar. Three types of access outline form designs were derived based on the landmark positions:

1. *Minimally invasive:* Location of the orifices on the chamber floor (Fig. 1*B*)
2. *Straight-line furcation:* Furcation level (Fig. 1*C*)
3. *Straight-line radicular:* Position of the pulp horns (Fig. 1*D*)

Access-determined Orifice Relocation

The linear removal of dentin estimated for straight-line furcation or straight-line radicular access outline designs was determined from the line drawn from the center of the primary curve in the maximum curvature view through the MB and ML furcation level landmarks and extrapolated onto the occlusal surface or the corresponding pulp horn landmark, respectively. The horizontal distance from the center of each corresponding orifice on the chamber floor to each of the created lines was measured in millimeters. This quantification represents the amount of linear dentin removal required for orifice relocation for both access outline designs.

Access-determined Angle of Curvature

The volume rendering for each sample was rotated until the maximum curvature view was evident for both the MB and ML canals and the image exported (Fig. 2*A–C*). The canal primary angle of curvature was determined before and after orifice relocation for each access design (ImageJ 1.48 software; National Institutes of Health, Bethesda, MD) (9).

Statistical Analysis

A 2-way repeated measures analysis of variance was performed for the interactions between access design form, the canal location, the theoretical amount of dentin removal required for orifice relocation, and the resulting change in primary angle of curvature. The statistical significance was set to $\alpha < 0.05$.

Results

The proposed outline designs derived from the landmark locations resulted in schematic representations for the 3 proposed access forms (Fig. 3*A–C*). The mean primary angles in the maximum

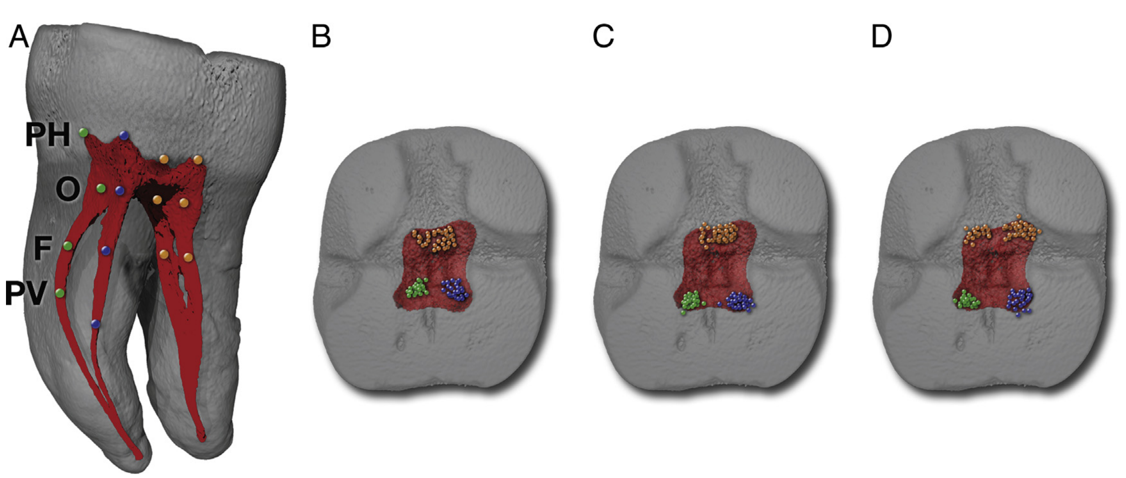

Figure 1. (*A*) Three-dimensional volumetric representation of μCT data showing selected landmarks: pulp horns (PH), center of canal orifices at the pulp chamber floor (O), center of canal at the furcation level (F), and center of primary curvature in the maximum view (PV). Projection of individual landmarks onto a semitransparent occlusal surface template of an ideal mandibular molar: (*B*) canal orifices, (*C*) canal position at the furcation level, and (*D*) pulp horns. *Green dots* represent MB landmarks, *blue dots* ML landmarks, and *orange dots* the DB and DL landmarks.