Apical Morphology of the Palatal Roots of Maxillary Molars by Using Micro–Computed Tomography

Lindsey Meder-Cowherd, DDS, Anne E. Williamson, DDS, MS, William T. Johnson, DDS, MS, Dragos Vasilescu, MS, Richard Walton, DMD, MS, and Fang Qian, PhD

Abstract

Introduction: The apical constriction (AC) has been a traditional landmark as an end point of canal preparation and obturation. However, the morphology and incidence of this structure have not been definitively determined. The purpose of this study was to determine these factors by using a noninvasive technology, micro–computed tomography. **Methods:** Forty extracted maxillary molar palatal roots were separated and mounted. Each root was scanned with micro–computed tomography. Slices from the scan were computer reconstructed by using special software. This rendered each root three-dimensionally "transparent." Roots were rotated, and the apical canal region was selected. In 2 sessions, trained evaluators identified the AC as to (1) presence (single and tapered) or (2) absence (flaring, parallel, and delta). Evaluator agreement was assessed by Cohen's kappa. Descriptive frequencies were determined for apical constriction presence and morphology. **Results:** Interagreement and intra-agreement of evaluators were good. In regard to frequency of occurrence, most (65%) canals did not demonstrate an AC. The morphology, in order of most to least, was parallel 35%, single 19%, flaring 18%, tapering 15%, and delta 12%. **Conclusions:** From the noninvasive evaluation of our sample it was concluded that an AC was usually not present and that this apical canal region was variable. If this is true with other tooth groups, the AC should not be used as an anatomical marker for preparation and obturation. *(J Endod 2011;37:1162–1165)*

Key Words

Apical constriction, micro-computed tomography, palatal root

The morphology of the apical third of the root canal system is complex. This is a critical area to appropriately clean, shape, and adequately seal. Although the apical morphology of canals varies, an overall understanding of common anatomies of this area is helpful to better understand the requirements necessary for treatment (1). Different methodologies have been used to study apical canal anatomy. The most used technique has been to expose the apical few millimeters of the canal system by grinding and then examining with a light dissecting microscope (1–4) or with the scanning electron microscope (5). Variations in anatomy were reported within and between these studies.

In 1955 in a frequently quoted classic report, Kuttler (2) examined a large number of apical regions. He apparently introduced the term *apical constriction*, meaning the point close to the apical foramen at which the canal was of the smallest diameter, reportedly an average of approximately 1 mm from the root apex. This apical constriction has been widely accepted and presumed to be the best location to clean and shape and to obturate (5). The important location for the constriction would be within the apical 3 mm; this is the preferred area to prepare and to obturate the canal (6).

Other investigators (3, 4) had similar findings as Kuttler (2), but with variations. Dummer et al (3) approached their analyses with the assumption that a constriction was present; they characterized and identified different shapes and distances and numbers of constrictions, including some canals with an absence of a most narrow point. Although the above studies presented interesting findings and variations, they have a common problem, lack of three-dimensional (3D) examinations. Grinding and then examining only 1 surface gives perspective of only 2 dimensions of a 3D object. What appears to be the anatomy in one plane will give very different perspectives in other planes. In addition, the action of grinding to expose a tiny canal might alter the structural anatomy, resulting in an inaccurate representation.

The universal presence of a constriction in the apical region is questionable. Studies (2, 3) that described this region in detail approached their analysis from a standpoint that there is always a constriction or "minor diameter." However, at least in one report (3), some of the descriptions could be interpreted as no constriction, that is, flaring and parallel. The frequency of occurrence of the apical constriction is yet to be clarified.

Very sophisticated technology, micro–computed tomography (micro-CT) scanning, has been applied in endodontic anatomical research (7). This method of examination renders the root "transparent," allows a 3D interpretation, and also gives a less altered view of the constrictions, because no sectioning is necessary to evaluate apical canal morphology.

From the Department of Endodontics, University of Iowa College of Dentistry, Iowa City, Iowa.

Address requests for reprints to Dr Lindsey Meder-Cowherd, Department of Endodontics, University of Iowa College of Dentistry, S435 Dental Science Building, Iowa City, IA 52242. E-mail address: anne-williamson@uiowa.edu

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Objectives

The purpose of this study was to noninvasively apply micro-CT to characterize the apical canal morphology of the palatal roots of maxillary molars. Reconstructed 3D micro-CT demonstrates the nature of the apical canal anatomy and the presence or absence, as well as the shape and location (when present), of these constrictions. Specifically determined were (1) the incidence of the occurrence of an apical constriction and, when present, and (2) the morphology of the constriction.

Materials and Methods

Materials

Forty recently extracted maxillary first and second molars were used. No demographic information was available relative to these teeth. The teeth were stored in a mixture of water and thymol. The teeth were soaked in 6% sodium hypochlorite for 30 minutes for surface disinfection and soft tissue removal. The palatal root of each was then sectioned approximately 10 mm from the apex with a diamond separating disk.

Methods

The roots were prepared for micro-CT scanning. Each was placed on a Styrofoam base with horizontal orientation, 4 to a row. A Styrofoam cover matching the dimensions of the base was taped over the base to sandwich all roots and eliminate risk of dislodgement during each scan. A 4 × 4 cm area was available for each scan, allowing 8 roots per scan. The Micro-CAT II (Siemens Pre-Clinical, Knoxville, TN) micro-CT scanner was used for a total of 5 scans. After all scans were complete, individual slices were cropped by using MatLab (The MathWorks, Inc, Natwick, MA). 3D image processing of the cropped slices was performed by using Analyze (AnalyzeDirect, Inc, Overland Park, KS) and Image J (National Institutes of Health, Bethesda, MD) computer programs. The processing steps included basic thresholding of the images and adjacent 3D surface rendering.

By computer reconstruction, the roots were rendered transparent; therefore, both the root surface and the canal were visible. Each root was rotated. One investigator selected the plane of apical one-third that was most representative in both a mesial/distal and a buccal/lingual dimension.

Evaluation

Examinations of the apical constriction morphology were performed by 5 trained endodontists. Each evaluator underwent a calibration session to standardize examining methods. A Microsoft Power Point (Microsoft Corp, Redmond, WA) presentation included buccal/lingual and mesial/distal views of each tooth to be evaluated. Each endodontist viewed the 40 teeth at 2 separate sessions to assess intrarater agreement. Evaluators were asked to choose from 5 different shapes to categorize the constriction morphologies of each buccal/lingual and mesial/distal view: single constriction, tapering, flaring, parallel, or delta (Fig. 1). Horizontal red lines were imposed in the apical region (approximately 1–3 mm) where a constriction might or might not be present. These were the areas analyzed.

To provide data for statistical analysis, evaluators examined and categorized the morphology between the red lines. The data were subdivided into (1) presence (single and tapering) or (2) absence (flaring,

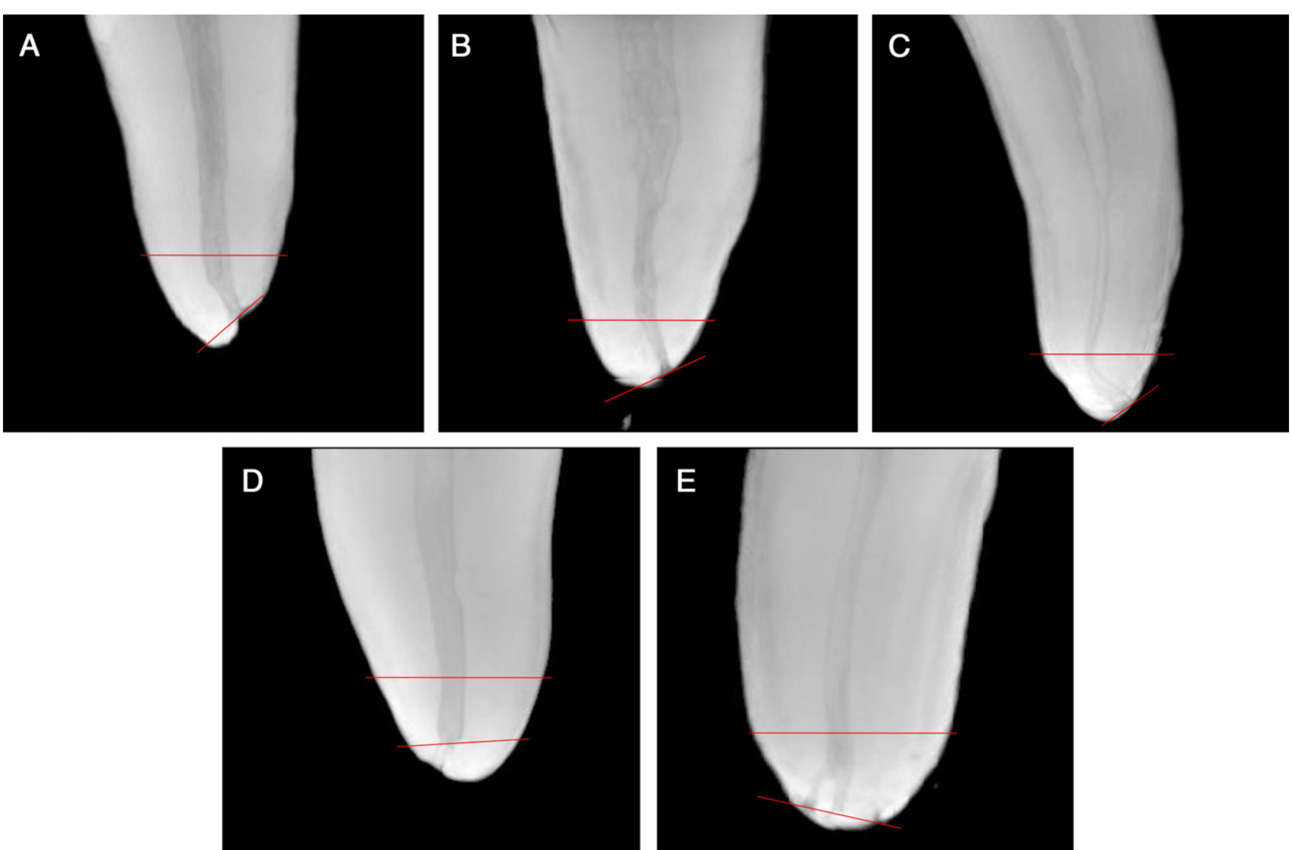

Figure 1. (*A*) Single constriction; (*B*) tapering; (*C*) flaring; (*D*) parallel; (*E*) delta.

parallel, and delta). Findings from both observation sessions were combined into averages.

Results from the evaluators were collected and analyzed. The Cohen kappa was used as a measure of agreement between intraobservers, adjusting for chance agreement. Descriptive frequency tables were also generated.

Results

The simple unweighted kappa coefficient was 0.56 (95% confidence limits, 0.50–0.62), and it indicated a moderate (adequate) level of agreement for 5 evaluators. When considering tooth surface separately, kappa coefficient was 0.53 for the buccal/lingual view and 0.59 for the mesial/distal view; both indicated moderate (adequate) intraobserver agreement.

Incidence (Presence) of an Apical Constriction

The frequency distribution showed the majority (65%) to not demonstrate the presence of a constriction in the apical 1–3 mm (flared, parallel, or delta) (Fig. 1*C–E*). The fewest (35%) had a constriction (single, tapering) (Fig. 1*A* and *B*).

Morphology

The morphology frequencies in order of most to least common were (1) parallel (35%), (2) single (19%), (3) flaring (18%), (4) tapered (15%), and (5) delta (12%) (Table 1).

Discussion

Clinically, the most interesting and important finding in our sample was the frequent absence of an apical constriction. Also of interest, but less important, was the variation in anatomy of the apical constriction when present. Previous studies (3, 5) that examined this canal region have also described variations in the anatomy of the apical constriction. However, these investigations did not include a finding of no apical constriction. Possibly, and as indicated by their objectives statement, these authors assumed that an apical constriction was always present. Their goal was to describe the morphology.

Although there are older publications (8, 9) that describe the apical canal region, the landmark article by Kuttler (2) established the apical constriction as a definitive structure with a specific anatomy. However, even though the Kuttler sample was large, the methodology of injecting ink and grinding each canal to reveal a longitudinal view gives limited information. Not only would the procedure be technically difficult, but only one plane can be assessed. This would be true of the other related studies. Dummer et al (3) had the most comprehensive study to date. Their technique and that of Green (1) of canal exposure was by grinding and examining the apical canal under a dissecting microscope. Again, this would not provide a total view (360 degrees) and assessment but depended on an interpretation from one plane of what the morphology would be in all planes. In fact, this is usually not the case. We noted frequent significant changes in shape when rotating to show different planes.

A decided advantage of our noninvasive technique was that by using cone beam tomography and special computer software, the root was rendered transparent, revealing the canal within. Furthermore, the root was rotated, thereby giving a 360-degree view of the canal. Interestingly, the apical canal morphology usually varied as the root was rotated. The most representative view was selected to include in the analysis.

An important question is whether other roots from other tooth groups give similar results, that is, absence of and inconsistency with the apical constriction. It is likely that our sample of maxillary molar palatal roots would have similarity to other groups. Other investigators (6, 10–12) examined other tooth and root groups and found varying morphologies. For example, Dummer et al (3) examined anterior and premolar teeth; Green (1) and Morroquin et al (4) included all tooth groups, as did Kuttler (2). All found variations.

Although the article by Kuttler (2) includes a very interesting diagram of the apical canal in younger and older persons, it is uncertain as to how this was generated. In the article, it is not specified how the numbers, shapes, and apparent averages were determined. Interestingly, another figure shows a number of drawings of some wide variations observed in the samples. Accordingly, this figure is much more representative of reality than the classic Kuttler diagram. Interestingly, an earlier study (8) was published in 1929. Wide variability and even absence of a constriction were noted. The classic Kuttler diagram, therefore, represents a composite of the averages; the raw data indicate considerable variation within his very large sample.

Although not part of the aims of our study, there were interesting side observations. One was the deviation of the foramen from the true apex. Consistent with other reports (2, 13, 14), another finding was the variability in canal dimension as the tooth rotated. This indicated that the apical canal was often not round but could be ribbon, oval, or very irregular. These variations have been reported in other studies (6, 11, 12).

Assuming that other tooth groups are similar in their apical canals with variations in size, shape, and apical constriction (either absent or irregular), the clinician cannot assume that there are any consistencies. The apical constriction is often not present; therefore, it is an unreliable landmark. Working length, that is, the end point of canal preparation, should be based on measured lengths short of the radiographic apex to confine instruments, materials, and irrigants to the canal space (6). Also, it is erroneous to assume that the classic diagram by Kuttler (2) somehow represents a majority or even a significant minority of apical canal anatomies.

Our results likely indicate the true nature of the morphology of the constriction in all canals; this refutes the common perception of the apical constriction. If one were using purely tactile methods for length determination of preparation (15), having a parallel constriction 35% of the time might lead to frequent overpreparation (or underpreparation) because of inadequate resistance met from a parallel or flaring constriction.

As a methodology, results from our study indicate that micro-CT scanning can be a useful tool for observation and evaluation of the apical constriction. Other 3D aspects of canal morphology can also be determined by using this noninvasive technology.

TABLE 1. Descriptive Morphologic Frequencies

Constriction type	Occurrence (%)
Single	19
Tapering	15
Flaring	18
Parallel	35
Delta	12

Conclusions

According to our sample of maxillary molar palatal roots (supplemental videos 1 through 9 are available at www.jendodon.com), the findings showed that the apical canal anatomy was variable. In a significant percentage, an apical constriction was not present. When there was a constriction, it had different shapes. Therefore, if this is true with other tooth groups, the apical constriction should not be used as an anatomical marker for canal preparation and obturation.

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Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jendodon.com (doi:10.1016/j.joen.2011.05.012).

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