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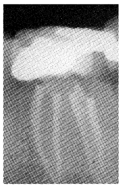

CASE REPORT

Anomalous mandibular premolars: a mandibular first premolar with three roots and a mandibular second premolar with a C-shaped canal system

B. M. Cleghorn[1], W. H. Christie[2] & C. C. S. Dong[3]

[1]Clinical Affairs, Department of Dental Clinical Sciences, Dalhousie University, Halifax, NS; [2]Division of Endodontology; and [3]Department of Restorative Dentistry, University of Manitoba, Winnipeg, MB, Canada

Abstract

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Aim To describe unusual variations in the root morphology and root canal systems of mandibular first and second premolar teeth extracted for orthodontic reasons.

Summary Normally mandibular first and second premolar teeth have single roots with single canals. A 15-year-old patient presented for orthodontic treatment and two mandibular premolar teeth were examined post-extraction. The mandibular first premolar exhibited three distinct, separate roots and the mandibular second premolar exhibited a C-shaped root canal system. The coronal morphology of each of the mandibular premolars revealed dimensions and anatomy within normal limits. The incidence of a three-rooted mandibular first premolar is approximately 0.2%.

Key learning points

- Thorough clinical and radiographic interpretation is important in recognizing anomalous root and root canal systems.
- The most common forms of root and canal systems and its aberrations must be understood to realize variations from normal do occur.
- Successful root canal treatment requires an accurate diagnosis of the root canal system using all available aids.
- Value of microcomputed tomography in the study of anatomy *ex vivo* and cone-beam tomography in clinical endodontics of complex premolar cases is increasing.

Keywords: anomalies, C-shaped, mandibular premolars, root canal.

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Correspondence: Blaine M. Cleghorn, DMD, MS, Faculty of Dentistry, Dalhousie University, 1210-5981 University Avenue, Halifax, NS B3H 3J5, Canada (Tel.: +902 494 2448; fax: +902 494 1757; e-mail: blaine.cleghorn@dal.ca).

Introduction

Knowledge of the morphology of the root and root canal systems of teeth and diagnostic imaging techniques are required for successful root canal treatment, especially in mandibular premolar teeth (England *et al.* 1991). Most dental textbooks on the anatomy and morphology of teeth describe the human dentition well, but sometimes fail to provide details on the range of variation in external root anatomy and internal root canal systems. Anomalous root and root canal morphology can be found associated with any tooth with varying degrees and incidence. Both the mandibular first and second premolars most often have a single root and a single canal, however, anomalies of the root and root canal systems as well as multiple canals have been reported in the literature (Baisden *et al.* 1992, Robinson *et al.* 2002).

This case reports on unexpected anomalies in root number and canal configuration of two mandibular premolars that had been extracted for orthodontic reasons. While the external root anatomy of these teeth was quite different from the average mandibular first or second premolar tooth, the unique internal canal anatomy was of the most interest. The use of a three-dimensional (3D) microcomputed tomography (micro CT) reconstruction of the pulpal space within the root and coronal areas outlines the anomalies clearly. The extracted mandibular first premolar exhibited three distinct roots and canals with a small furcation lateral canal, while the mandibular second premolar had a midroot single C-shaped canal system in a single root with a prominent buccal root groove.

Case

A 15-year-old male of East Indian descent was referred to the Graduate Orthodontic Clinic at the University of Manitoba, Canada for orthodontic diagnosis and treatment. The mandibular left second premolar and the mandibular right first premolar were extracted due to crowding according to the orthodontic treatment plan. Informed consent was obtained to collect the teeth for research purposes.

Conventional periapical radiograph films of both extracted teeth were made from a buccolingual and mesiodistal direction to show a two-dimensional view of the internal root canal system anatomy. The two extracted teeth were also subjected to nondestructive micro CT 3D imaging techniques to reveal the complex and anomalous internal canal system anatomy in relation to the external root and crown anatomy (Bjørndal *et al.* 1999, Brown & Herbranson 2007). Volume data sets of these extracted teeth were collected using digital photography, conventional radiography and ultra-high resolution micro CT. The micro CT scans of the two mandibular premolars were acquired courtesy of Dr Michael Flynn in the Department of Diagnostic Radiology at Detroit's Henry Ford Health Systems. The resolution of the scans is 0.03 mm. The *ex vivo* scanning system consists of a microfocus X-ray source (Feinfocus 160, Feinfocus USA Inc., Stamford, CT, USA), four computer controlled motorized stages (UNIDEX IV/4; Aerotech Inc., Pittsburg, PA, USA), and a digital radiograph detection apparatus (X-ray image intensifier – Thompson-CSF TH9428F coupled to a CCD camera – Cohu 4110, Cohu, San Diego, CA, USA). Image acquisition was managed by means of a Dell 433DE computer running SVR4 UNIX in a rotation only mode. The micro CT data were then transferred from the Imaging Lab and processed at the National Biocomputation Center at Stanford University. The scan data were then segmented in Amira (commercial scientific visualization software) to create the surface models of the dentine, enamel and pulp. Semi-automatic segmentation (voxel classification) techniques are used to identify the structures in the micro CT data. After the classification of the voxels, a mesh consisting of over 1 million polygons is generated using a modified Marching Cubes Algorithm. Post-processing surface smoothing and

Figure 1 Intra-oral photograph of the occlusal view of the mandibular arch illustrating 'normal' coronal morphology and dimensions of the mandibular premolars and other teeth.

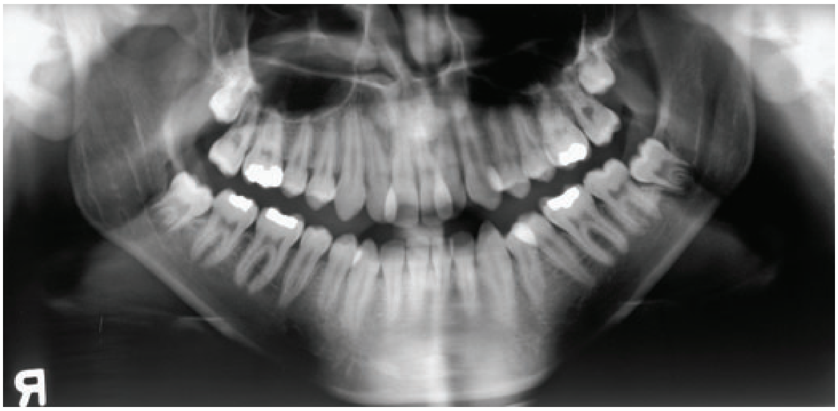

Figure 2 Panoramic radiograph illustrating some form of abnormal root and root canal system morphology associated with each of the mandibular premolars. The mandibular right first premolar has a shorter overall length because it divides into three root tips.

triangle reduction algorithms are used to reduce the number of polygons to generate manageable models (5000–100 000 polygons) for visualization. A proprietory viewer (Meshview) developed through Brown & Herbranson Imaging for use on the PC platform was used to allow basic visualization capabilities of the 3D models. The pulp, enamel and dentine could be made transparent to allow visualization of any of these tissues. Screen captures were made to produce the images in Figs 5, 6, 9 and 10 (Brown & Herbranson 2007).

The crowns of each of the mandibular first and second premolars had typical coronal anatomy in that cusp number and dimensions were within normal limits (Fig. 1). Upon examination of the panoramic radiograph taken for an orthodontic diagnosis, multiple canals were identified in the mandibular premolars and multiple roots in each of the mandibular premolars except for the mandibular left second premolar (Fig. 2). Neither single periapical films nor digital radiographic images were exposed for the mandibular premolar areas prior to the extractions because the teeth were asymptomatic. Gross examination of the two extracted teeth confirmed the initial panoramic radiographic diagnosis of anomalous root and root canal morphology.

Mandibular right first premolar

The mandibular right first premolar tooth is unusual (Figs 3–5) with its three well-formed roots (mesiobuccal, distobuccal and lingual). The three roots and corresponding root

Figure 3 Extracted mandibular right first premolar illustrating three distinct roots (mesiobuccal, distobuccal and lingual): (a) buccal view, (b) mesial view [Reprinted from Cleghorn *et al*. (2007a) with permission from Elsevier].

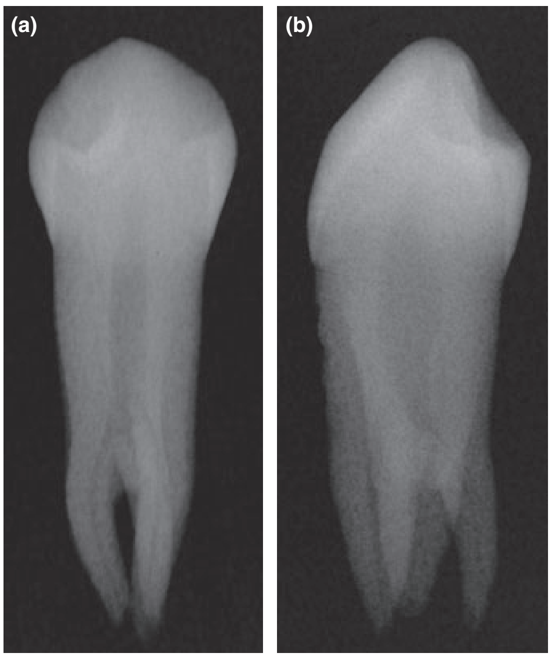

Figure 4 Post-extraction radiographs of the three-rooted mandibular first premolar shown in **Fig. 3**: (a) buccal view, (b) mesial view.

canals divide rather low down, in the middle to apical third of the root trunk. Three roots in the mandibular first premolar is a relatively rare occurrence (0.2%) in a review article of weighted studies (Cleghorn *et al*. 2007a). The internal canal morphology using 3D imaging

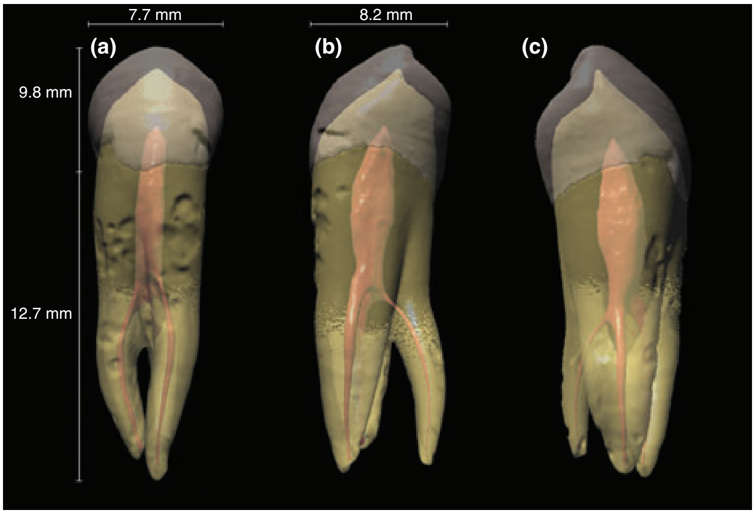

Figure 5 3D microcomputed tomography reconstruction of the three-rooted mandibular right first premolar: (a) buccal view, (b) mesial view and (c) distal view with coronal and root dimension bar overlaid (semi-transparent images of 3D modelling courtesy of Brown and Herbranson Imaging, Palo Alto, CA, USA).

technology is illustrated in Fig. 6. A prominent but delicate furcation canal is also present. It is not possible to identify this furcation canal from only a conventional radiograph film.

Mandibular left second premolar

This mandibular left second premolar exhibited a single root and a single apical foramen but had a prominent vertical root groove and depression on its buccal surface (Figs 7–9). Analysis of the *in vitro* radiographs (Fig. 8a,b) of the extracted tooth indicated the canal system was a Vertucci type III canal (1-2-1). However, 3D modelling of the tooth that isolates the pulp canal system illustrated a C-shaped canal morphology through the majority of the mid-canal system, which terminated in a single apical foramen (Fig. 10a–c). C-shaped canal systems in mandibular premolars are rare and although reports describing this type of canal system morphology exist in mandibular first premolar teeth, no case reports of this type of canal morphology in a mandibular second premolar were identified in an extensive literature review (Cleghorn *et al.* 2007b).

Discussion

This case report illustrates unusual morphology of the roots and root canal systems of the mandibular premolars in an adolescent patient. Coronal anatomy and dimensions were within normal limits and provided no indication of the complex morphology of the radicular portion in each of the premolars. Based on an examination of the panoramic radiograph (Fig. 2), the other mandibular premolars (mandibular left first premolar and the mandibular right second premolar) have multiple canals and multiple roots. There is a mesiodistal division of the main canal in the middle third of the root in each of these teeth. Using paralleling technique periapical radiographs, Serman & Hasselgren (1992) reported a high incidence (18.1%) of multiple roots and canals in mandibular premolar teeth in a series of radiographic surveys with mandibular first premolars involved in 15.7% of patients and mandibular second premolars in 7% of patients. Multiple roots or root canals were situated in both buccolingual and in mesiodistal orientations in that study. The mandibular

Figure 6 3D microcomputed tomography reconstructed image of the mandibular right first premolar pulp morphology. The fine accessory lateral canal is visible in the furcation area: (a) buccal view, (b) mesial view. (semi-transparent images of 3D modelling courtesy of Brown and Herbranson Imaging, Palo Alto, CA,USA).

left second molar in this patient appears to have a bifurcated mesial root but all of the remaining teeth in the dentition appear to have 'normal' root and root canal morphology based on the panoramic radiograph (Fig. 2). Baisden *et al.* (1992) in a microscopic study have described the deep groove on the mesial aspect of mandibular first premolar teeth that tended to form two canal systems and a C-shaped canal on the buccal root. Isolated case reports would suggest a rare incidence of C-shaped canal systems for the mandibular first premolar. An *in vitro* study (Sikri & Sikri 1994) of mandibular premolars reported an incidence of C-shaped canals of 10% in mandibular first premolars (n = 112) but none were reported in their group of mandibular second premolars (n = 96). The ethnic background of the patient in this case report is similar to the population in the above study. Robinson *et al.* (2002), using routine dental computer tomography scans, reported a similar incidence (10% of patients n = 120) with mandibular first premolar teeth with two canals and usually two foramina including one patient with three canals and three foramina, but the resolution was not sufficient to diagnose a C-shaped canal. An extensive review article by Jafarzadeh & Wu (2007) did not report any C-shaped mandibular second premolars. Based on the confirmation of the C-shaped canal system by the 3D modelling method, it is possible that previously published studies using radiographic techniques alone may have overlooked the actual morphology of the root canal systems of some

Figure 7 Extracted mandibular left second premolar exhibiting a prominent buccal root concavity and groove: (a) buccal view, (b) mesial view.

Figure 8 Radiographs of mandibular second premolar shown in **Fig. 6**: (a) buccal view showing apparent Vertucci Type III canal system, (b) mesial view showing single canal, single root.

teeth. *In vivo* case reports of mandibular first premolar teeth with three roots and three canals have been reported infrequently in the literature (Chan *et al.* 1992, Fischer & Evans 1992, Brown & Herbranson 2007). Case reports of three or more canals in a second premolar seem more frequent, some with serious clinical outcomes (Glassman 1987, Sachdeva *et al.* 2008).

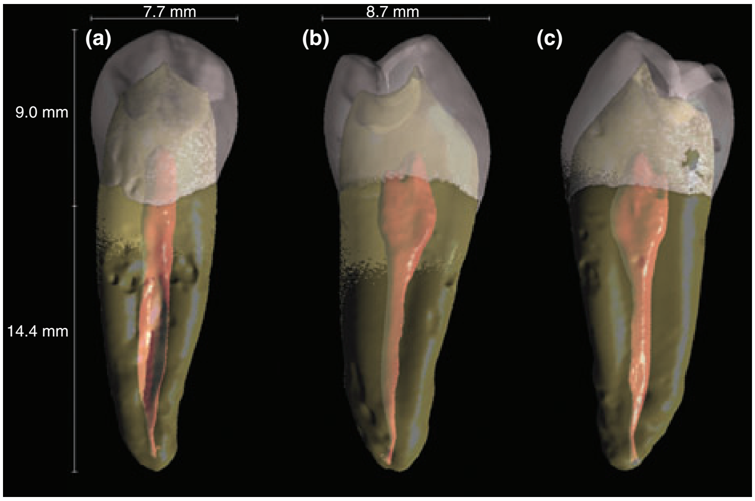

Figure 9 3D microcomputed tomography reconstruction of the semi-transparent image of the mandibular left second premolar: (a) buccal view, (b) mesial view and (c) distal view. Coronal and root dimension bars are overlaid. (semi-transparent images of 3D modelling courtesy of Brown and Herbranson Imaging, Palo Alto, CA,USA).

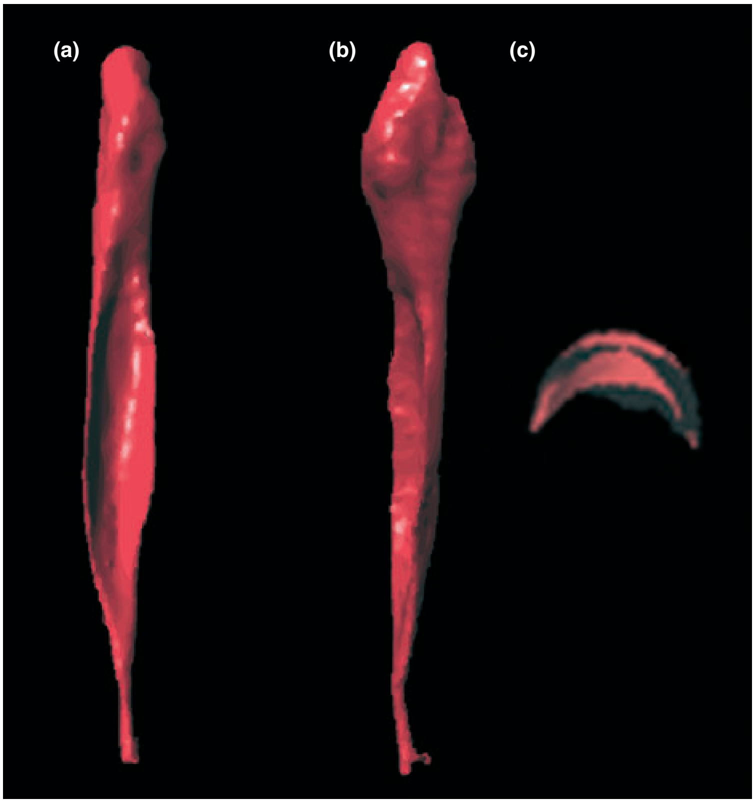

Figure 10 Mandibular left second premolar pulp morphology: (a) Buccal view with highlighting demonstrating midroot C-shape, (b) distobuccal view and (c) cross-section of pulp midroot illustrating C-shaped canal (Semi-transparent images of 3D modelling courtesy of Brown and Herbranson Imaging, Palo Alto, CA,USA).

The use of the computerized X-ray microtomography in reconstructing root anatomy has been described by Bjørndal *et al.* (1999). A strong correlation was found between the external morphology of the roots and the internal shape of the root canal systems using this *ex vivo* method. The 3D modelling of tooth anatomy is a valuable teaching tool for dental students and practitioners alike. The research value of *ex vivo* micro CT is in its ability to accurately represent the internal and external morphology without destruction of the tooth. Nielsen *et al.* (1995) have used an early micro CT technique to show canal systems and apical foramen shapes before and after instrumentation and filling. Bergmans *et al.* (2001) have also used microcomputed tomography to evaluate root canal instrumentation on a small sample of teeth and describe examples of hardware and software needed for this process. A study by Matherne *et al.* (2008) found that cone-beam computed tomography was better than other digital radiography techniques in identifying multiple root canal systems in mandibular incisor, mandibular first premolar and maxillary first molar teeth.

Microcomputed tomography reconstruction could be a valuable research tool not only to study tooth anatomy, but also to evaluate and compare instrumentation techniques *ex vivo* (Bergmans *et al.* 2001, Peters *et al.* 2003, Loizides *et al.* 2007). Description on the advantages and limitations of the use of high-resolution tomography can be found in the discussion by Peters *et al.* (2001).

Volumetric or cone-beam CT may eventually have routine *in vivo* clinical applications in *Endodontics* (Cotton *et al.* 2007, Nair & Nair 2007). Nair & Nair (2007) however, caution that data acquired by large area sensors should be read by board-certified radiologists so that occult pathology and incidental findings are not missed. In their opinion, advanced training is required in the interpretation of pathology or incidental findings in the larger areas of regional anatomy captured in these 3D images.

Conclusions

Reports in the literature vary greatly with respect to root canal and root morphology of mandibular premolar teeth compared with the standard description of one root, one canal found in texts on Dental Anatomy. Three-rooted mandibular first premolar teeth, similar to the tooth described in this case report, occur in patients occasionally and may be reported in the literature.

The mandibular premolar teeth can present with extremely complex root and canal system morphology, and if not considered during treatment can lead to difficulties when performing root canal treatment. The use of *in vitro* micro CT is a valuable tool in studying the variations that may occur in root canal anatomy.

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