Complicated Root Canal Morphology of Mandibular First Premolar in a Chinese Population Using the Cross Section Method

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Abstract
The purpose of this study was to assess the canal anatomy and morphology of mandibular first premolars in a Chinese population. Eighty-two extracted mandibular first premolars with intact roots were collected and stored in a glutaraldehyde solution. The teeth were embedded in clear resin and the root length was measured. The roots were sectioned perpendicular to the long axis at 3, 6, 9, and 12 mm from the apex. The resected root surfaces were polished, rinsed, dried, and stained with methylene blue. Digital photographs of the cross-sectional root surfaces were taken at 24X. The incidence of multiple canals and varied morphology was determined by two independent examiners. The results indicated that 54% of the mandibular first premolars demonstrated a single canal. Twenty-two percent contained two canals and 18% percent had C-shaped configuration. The C-shaped root canal occurred predominantly in the 3 and 6 mm sections with one or two canals coronally. A unique finding was that the circumferential canal (apical delta), which was characterized by a single canal splitting into 3 or 4 canals. The incidence of circumferential canal was 6% and occurred only in the apical 3 mm cross-sections. Identification of the unique apical canal configuration and high incidence of multiple canals in mandibular first premolars may explain endodontic treatment failure in this tooth group. (J Endod 2006;32:932–936)

Key Words
Circumferential canal, C-shaped canal, mandibular first premolar, root canal morphology

Materials and Methods
Mandibular first premolars extracted because of caries, periodontal diseases, trauma or for orthodontic reasons were collected from the Department of Oral and Maxillofacial Surgery of Taipei-Veteran General Hospital. Eighty-two mandibular left and right first premolars with mature and intact root structure and devoid of fractures were utilized in this study. Each tooth was individually stored in Gidal-Dur (2.3% glutaraldehyde, Veterans Pharmaceutical Plant, Taiwan) for disinfection. The teeth were then placed in 2.5% NaOCl solution for 1 day to remove organic substances. Photographs of the mesial, distal, buccal, and lingual surfaces for each premolar were taken using a digital camera (Digital Camera E990, Nikon Co., Japan) at a distance of 70 mm. Any groove or depression on root surfaces, apical bifurcation, or other anatomic variations were recorded.

The root length from cementoenamel junction to apex for each tooth was measured. Then, each tooth was embedded in clear resin (Orthoresin, Detrey Densply S.A., England). Starting from root apex, each tooth was sectioned perpendicular to the long axis at 3, 6, 9, and 12 mm using an electric trimmer (Whip Mix, Co., USA). Each section was polished with sand paper under running water, dried and stained with methylene blue. Digital photographs of root surfaces at 3, 6, 9, and 12 mm were made at 24X magnification under a surgical microscope (OPMI PRoCdent; Zeiss, Germany) using the mounted digital camera (Coolpix 990, Nikon, Japan).
All the cross-sectional images of the mandibular first premolar roots were examined on a computer screen by two endodontists. The images for each tooth were evaluated from the most apical section to the most coronal section. The number of canals and morphologic configuration of the root canal system for each tooth was determined and classified. Disagreement in the interpretation of sections was discussed between two evaluators until a consensus was reached.

The presence of more than one canal in any cross-section of the root was classified as complicated. Premolars exhibiting two canals with oval, round, or dumbbell-shaped canals were classified as type II, III, or IV according to Weine (10). Two additional morphologic configurations of the complicated root canal system were noted and classified as a C-shaped canal and circumferential canal.

Teeth with the presence of C-shaped configuration in any one cross-sections of the root were placed in this category. The C-shaped canals were sub-classified in the following categories according to Fan’s classification (11) for the mandibular second molar. Category I (C1): the shaped was an uninterrupted C with no separation or division. Category II (C2): the canal shape resembled a semicolon resulting from a discontinuation of the C outline. Category III (C3): two or three separated canals and a discernible isthmus linking them.

The unique finding of circumferential canals is reported in this study for the first time. Circumferential canals presented as single canal in the center and 3 or 4 canals at the circumference when viewed in cross-section. It was a single canal splitting into several canals (apical delta) at apical 3 mm from sagittal view.

### Results

The results were summarized in Table 1. Only 54% (44/82) of the mandibular first premolars in this investigation had a single root canal. The other 46% of the mandibular first premolars demonstrated varied and more complicated root canal systems. There were 18 (22%) premolars with two canals, 15 (18%) with a C-shaped canal configuration, and five (6%) with previously unreported circumferential canals. The 18 two-canal premolars included five teeth (6%) with type II morphologic configuration of the complex root canal system. The C-shaped canals were further classified into three categories: C1 (1%), C2 (1%), and C3 (16%). The circumferential canals were also classified into two categories: C1 (1%) and C2 (1%).

### Table 1. Canal number and configuration

<table>
<thead>
<tr>
<th>Canal configuration</th>
<th>No. of tooth</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single canal</td>
<td>44</td>
<td>54%</td>
</tr>
<tr>
<td>Complicated canal</td>
<td>38</td>
<td>46%</td>
</tr>
<tr>
<td>2-canal</td>
<td>18</td>
<td>22%</td>
</tr>
<tr>
<td>Type II</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Type III</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Type IV</td>
<td>8</td>
<td>10%</td>
</tr>
<tr>
<td>C-shaped canal</td>
<td>15</td>
<td>18%</td>
</tr>
<tr>
<td>C1</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>C2</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>C3</td>
<td>13</td>
<td>16%</td>
</tr>
<tr>
<td>Circumferential canal</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 1. A representative mandibular first premolar with a C-shaped canal, classified as C3, three separate canals with discernible isthmus apically, single canal coronally, a deep folding groove on proximal lingual area; (A) 3 mm from apex; (B) 6 mm from apex; (C) 9 mm from apex.

Figure 2. One of the C-shaped root canal on a mandibular first premolar, classified as C3, multiple separate canals with discernible isthmus apically, single canal coronally, a deep groove on proximal lingual area; (A) 3 mm from apex; (B) 6 mm from apex; (C) 9 mm from apex.
ogy, five teeth (6%) with type III morphology, and eight teeth (10%) with type IV morphology.

All C-shaped configuration premolars had an associated groove or concavity on the external root surface (Figs. 1-3). The groove or concavity frequently presented on the proximal lingual area of the middle root and did not always extend to the root apex (Fig. 3A). The C-shaped morphology was found in apical 3 mm and/or 6 mm level cross-sections with their coronal sections demonstrating a single oval or two canals in an oval-shaped root (Fig. 1-3).

All mandibular first premolars with the circumferential canal configuration had a blunt root tip. In each case, the root exhibited a single canal in the coronal sections with division into multiple canals at the circumference being noted in the apical 3 mm cross-section (Figs. 4 and 5).

Discussion

Different methods have been used to study the root canal morphology of mandibular first premolar (1–5, 7–10). In a radiographic study, Walker found 34% southern Chinese had two canals and 2% had three canals (5). While the radiographic method is noninvasive, it presents a two dimensional image of a three dimensional object and does not reveal the complexity present in the root canal system. The transparent method can demonstrate the structure and continuity of root canal system from pulp chamber to root apex. The cross section method combined with the magnification used in this study clearly exposed the complexity of root canal system and provided impressive images of the C-shaped and circumferential canals.

Serial axial computed tomography (CT) has been used to investigate the C-shaped canals in mandibular secondary molars (12) and may be a technique for future studies involving mandibular premolars. A combination of CT followed by the transparent method or cross sectional evaluations would be interesting.

In the study conducted by Baisden et al., 15 (14%) mandibular first premolars revealed a C-shaped canal. Thirteen of those C-shaped canal premolars were also classified as type IV; two were also classified as type I canal. They noted that C-shaped canals in mandibular premolars were associated predominantly with type IV canals (7). In our study, the C-shaped canal was classified independently since C-shaped canals were found not only associated with bifurcation but also trifurcation or quadrafurcation (Fig. 1A, 2).

The C-shaped morphology in mandibular second molars is mostly found coronally and within 3 mm below the cementoenamel junction (11). The location of the C-shaped morphology in the mandibular first premolar is quite different. In this study, the location of C-shaped canal was found at apical 3 mm and/or 6 mm level cross-sections. Coronal, it could be single oval or two canals. Therefore, C-shaped canals would be difficult to detect from coronal approach. An additional consideration was the finding that the corresponding groove of C-shaped canal

Figure 3. One of the C-shaped root canal on a mandibular first premolar, classified as C2, a semicolon apically, two canals coronally, a groove on mesial wall; (A) 3 mm from apex; (B) 6 mm from apex; (C) 9 mm from apex.

Figure 4. (A–C) Three circumferential canals at 3 mm from apex from three mandibular first premolars.
on the external root surface was varied. Some were deep and folding grooves, while others were not distinguished or just like shallow concavities.

For C-shaped root canal in mandibular second molar, Fan et al. investigated features of C-shaped mandibular second molars and the cross-sectional shapes of their root canal systems in 58 extracted mandibular second molars from a Chinese population. Teeth were scanned at 0.5-mm increments using micro-CT and observed at 11 levels. Most orifices 98.1% were found within 3 mm of the cementoenamel junction. Most specimens demonstrated an orifice with an uninterrupted C-shape. The ratio of the deepest part of the external groove to the buccal-lingual thickness was about 48% (11).

Jin et al. investigated the prevalence and configuration of the C-shaped canal using CT in 200 teeth. The authors compared the thickness of the remaining tooth structure from the center of the canal to the outer surface of the deepest groove. C-shaped canals were found in 44.5% of the teeth and almost all the grooves were directed lingually (99%). The continuous C-shaped canal was the most frequently found (49%). The authors found the thinnest remaining tooth structure in the groove area of the C-shaped mandibular second molar was not different from that of the danger zone of normal mandibular second molar at the three levels (12). In contrast Chai and Thong studied the cross sectional morphology of 20 mandibular molars with C-shaped configurations. Cross-sectional evaluations showed that 27% were a complete C, 64% demonstrated an incomplete C, and 9% were non-C. The mean value for the minimum width of the lingual canal wall was 0.58 ± 0.21 mm and the buccal wall was 0.96 ± 0.26 mm, suggesting a risk of perforation on the thinner lingual wall. The buccal and lingual canal walls were frequently narrower at mesial locations (13).

Many complicating factors make the C-shaped configuration of the mandibular first premolar difficult to treat. It would be clinically relevant to know the mean value for the minimum widths of C-shaped canal wall in mandibular first premolars. Anatomically the diameter and width of mandibular first premolar is much smaller than mandibular second molars. The small size of mandibular first premolar limits the coronal access to the complex root canal system that, unlike the mandibular second molar, is found apically.

The identification of circumferential canals is also clinically important. All the mandibular first premolars in the circumferential canal category demonstrated multiple canals in the apical 3 mm section. Failure of root canal treatment of mandibular first premolars in cases where there appears to be a simple anatomical configuration could be related to tissue and bacteria in apical delta. Based on findings in this study, root-end resection of more than 3 mm might be considered when treating failed cases surgically. In addition, the operator should carefully examine the resected root-end for circumferential openings using the microscope.

Slowey thought that mandibular premolars were probably the most difficult teeth to treat endodontically (14). The varied anatomy and morphology in mandibular first premolar implies cleaning and shaping will be difficult. In this study, the results revealed only 54% of the mandibular first premolar in the Chinese population had a single canal. Twenty-two percent contained two canals. The other 24 % had either C-shaped canals or circumferential canals. The clinician should view this tooth group as complex and use all available armamentaria to achieve a successful outcome. Failure to recognize anatomical complexities will result in treatment failure. In nonsurgical treatment, clinicians should employ microscopy, angled preoperative and working length radiographs, and apex locators to ensure a positive outcome. Surgical intervention may be required when nonsurgical treatment fails. Microscopy should be employed. Because the most varied configuration was located within 3 to 6 mm from root apex in our study, root end resection for more than 3-mm may be considered when variations are identified.

Acknowledgments

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References