Evaluate root and canal morphology of primary mandibular second molars in Chinese individuals by using cone-beam computed tomography

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KEYWORDS
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Background/Purpose: More detailed knowledge of root and canal morphology is important in order to improve the success in the endodontics of primary teeth. The purpose of this study was to evaluate the root and canal morphology of primary mandibular second molars (PMSMs) in a Chinese population using cone-beam computed tomography (CBCT).

Methods: CBCT images, which had been obtained previously in the West China Hospital of Stomatology at Sichuan University, Chengdu, China between May 2009 and December 2011, were screened retrospectively. Finally, 283 individuals—207 male and 76 female with a mean age of 7.2 years (range 3–10 years)—and 487 PMSMs with clear images of root and canal morphology were enrolled. The number of roots and morphology of canals were recorded. The patient’s gender, and the symmetry and frequency of three roots in PMSMs were analyzed.

Results: The majority of PMSMs had two (72.28%) or three roots (27.52%). The symmetrical incidence of three-root PMSMs in this Chinese population was 50.65%. There is no difference between genders in the prevalence of an extra root and the incidence of symmetry (p > 0.05). Of the individuals enrolled, 25.26% of PMSMs had three canals and 73.31% had four canals. The root canal systems of the PMSMs in the present study were categorized into seven variants.

Conclusion: This study indicated that three-rooted PMSMs occur frequently in the Chinese population. There was no difference between the two genders on incidence and symmetry. The majority of PMSMs have three to four canals and the diversity of the root canal variants should
Introduction

Caries is the most common chronic disease in children. It is five times more prevalent than the next most common disease, asthma.1 Compared with the permanent teeth, primary teeth have a thinner layer of mineralized tissue between the external and internal surfaces, which leads to rapid involvement of the dental pulp by advancing caries.2 Once the dental pulp is nonvital or irreversibly inflamed, pulpectomy is needed to conserve the primary tooth, for the maintenance of arch length, and the spatial development of permanent teeth. However, as primary teeth may show bizarre internal geometry of the root and canal system, such as connections involving furcation and horizontal anastomoses, endodontic treatment of primary teeth involving cleaning, shaping and obturation of the root canal system is considered highly complicated. To improve the success of endodontics in primary molars, more detailed knowledge of root and canal number and morphology is needed.

Many techniques can be used to research root and canal morphology of teeth, such as computerized tomography,3 clearing technique,4–6 radiographs,7,8 and operating microscope.9 Recently, cone-beam computed tomography (CBCT) images have been found to be useful and accurate in evaluating root and canal morphology in permanent mandibular and maxillary molars.10–14 As an emerging technology in endodontics, CBCT has a lower radiation dose and a higher resolution than traditional computed tomography scans.15 It has proved useful in detecting periapical lesions16 and root canal morphology in the maxillary region.10–12,15 CBCT, as a non-invasive tool, can provide three-dimensional images of the dentoalveolar regions for disease diagnosis and morphological evaluation in endodontics.17,18 There have been few studies using this technique, however, involving primary teeth. The present study aimed to identify the root and canal morphology of the primary mandibular second molars (PMSMs) of Chinese children using CBCT.

Materials and methods

Samples

Children aged 3–10-years-old, referred to the West China Hospital of Stomatology at Sichuan University, Chengdu, China, between May 2009 and December 2011 were enrolled in this study. The CBCT images were taken for valid diagnostic reasons or treatment, such as ectopic impacted teeth, odontogenic tumor or maxillofacial trauma. In order to ensure the integrity of the original morphology of the root canals, PMSMs with no periapical lesions, no obvious root absorption, that were fully developed, and were untreated were included. The cases that the three examiners could not reach a consensus on when analyzing the CBCT images were excluded. Finally, 283 patients—207 male and 76 female with a mean age of 7.2 years (range: 3–10-years)—and 487 PMSMs with clear images of root and canal morphology were enrolled. Informed consent was obtained from all of the children’s parents and this study was approved by the Ethics Committee of the West China Hospital of Stomatology.

Radiographic techniques

The CBCT images were taken by a 3D Accuitomo machine (Morita, Kyoto, Japan) at 80 kV and 3.0 mA, with a field of view of 60-mm and a voxel size of 0.1 mm. The slice thickness was 1-mm and the exposure time was 17 seconds. Scans were made according to the manufacturer’s recommended protocol and all of the images were taken by a licensed radiologist, with the minimum exposure necessary for adequate image quality. The lowest radiation dose and field were guaranteed.

Evaluation of the image

The CBCT images were analyzed with inbuilt software (i-Dixel one volume viewer 1.5.0) using a Dell Precision T5400 workstation (Dell, Round Rock, TX, USA) and a 32-inch Dell LCD screen with a resolution of 1280 × 1024 pixels in a dark room. The contrast and brightness of images could be adjusted using the image-processing tool of the software to ensure optimal visualization. A professional oral radiologist and two pediatric dentists concurrently evaluated all of the images to reach a consensus in the interpretation of the radiographic findings. The teeth included were investigated radiographically by CBCT to determine the number of roots, the number of canals per root and variations in the morphology of the root canal systems.

Statistical analysis

Statistical analysis was performed by SPSS version 16.0 (Statistical Package for Social Sciences Inc., Chicago, IL). The experimental data obtained in this paper were presented as categorical variables. The frequency of the numbers of roots and canals was determined and the gender of the individual, the symmetry and frequency of numbers of roots and canals was determined and the gender of the individual, the symmetry and frequency of three roots in PMSMs were compared by the chi-squared test, with a significance level of p < 0.05.

Results

The number of roots and their morphology

Of the 487 PMSMs examined, 72.28% (352/487) had two separate roots, while 27.52% (134/487) had three roots. Only one PSM had four roots. The prevalence of three-rooted
PMSMs did not differ significantly between the two genders \((p > 0.05)\), see Tables 1 and 2. Of the patients enrolled in the present study, 32.86\% (93/283) had three roots. Of the 77 patients who had bilateral three-rooted PMSMs, 50.65\% (39/77) had perfect symmetry in the root and canal numbers in both sides, and there was no significant difference between the ratios in males and females \((p > 0.05)\), see Table 2.

Among these, 38 patients had three separate roots, with two canals in the mesial root and one canal in the distobuccal and distolingual roots; and only one individual had three separate roots—a mesial, a distobuccal and a distolingual root, with one canal in each root.

### The number and morphology variants of canals

In total, 25.26\% (123/487) of PMSMs had three canals, 73.31\% (357/487) had four canals, 0.82\% (4/487) had two canals, and only three teeth had five canals, see Table 1. All of the PMSMs analyzed in this study, except one tooth, had only one mesial root. The majority of the PMSMs (97.74\%; 475/486) had two root canals in the mesial root, and the others had only one canal. Among the 352 PMSMs that had only one distal root, 34.09\% (120/352) had one canal and 65.91\% (232/352) had two canals. All of the PMSMs that had two distal roots had a single canal in each distal root with the exception of three teeth, which had two canals in the distolingual root.

There were seven variants found in the root canal morphology of the PMSMs (see Table 1 and Fig. 1):

- **Variant 1**: Two separate roots, a mesial and a distal root, with one canal in each root.
- **Variant 2**: Two separate roots, with two canals in the mesial root and one canal in the distal root.
- **Variant 3**: Two separate roots, with two canals in the medial root and two canals in the distal root.
- **Variant 4**: Three separate roots—a mesial, a distobuccal and a distolingual root—with one canal in each root.
- **Variant 5**: Three separate roots, with two canals in the mesial root, one canal in distobuccal root and one canal in the distolingual root.
- **Variant 6**: Three separate roots, with two canals in the mesial root, two canals in the distobuccal root and one canal in the distolingual roots.
- **Variant 7**: Four separate roots, with one canal in each root.

### Discussion

In the present study, we used CBCT to evaluate the numbers of roots and canals in 487 PMSMs in 283 Chinese individuals. Although the most accurate information about the tooth and canal could be obtained from teeth extracted in vitro, to get details on primary teeth in vivo is very difficult, which limited the sample size. For in vivo study, conventional radiography is the technique most frequently used. However this technique has limitations because the images of the roots and root canals always overlap, so it is difficult to see the buccolingual aspect. \(^{19}\) Although an angled view (vertically and horizontally) may be helpful, \(^{20}\) this is often difficult to achieve, especially with children. Several studies have suggested that CBCT is a good option when studying the root and canal morphology of permanent

### Table 1

Distributions and percentages of the seven categories of variants in the root canal anatomy of primary mandibular second molars.

<table>
<thead>
<tr>
<th>Variant</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>0.82</td>
</tr>
<tr>
<td>2</td>
<td>116</td>
<td>23.82</td>
</tr>
<tr>
<td>3</td>
<td>232</td>
<td>47.64</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>1.44</td>
</tr>
<tr>
<td>5</td>
<td>124</td>
<td>25.46</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>0.62</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>487</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Variant 1**: Two separate roots, a mesial and a distal root, with one canal in each root.

**Variant 2**: Two separate roots, with two canals in the mesial root and one canal in the distal root.

**Variant 3**: Two separate roots, with two canals in the medial root and two canals in the distal root.

**Variant 4**: Three separate roots—a mesial, a distobuccal and a distolingual root—with one canal in each root.

**Variant 5**: Three separate roots, with two canals in the mesial root, one canal in distobuccal root and one canal in the distolingual root.

**Variant 6**: Three separate roots, with two canals in the mesial root, two canals in the distobuccal root and one canal in the distolingual roots.

**Variant 7**: Four separate roots, with one canal in each root.

### Table 2

Distribution and prevalence of 3-rooted primary mandibular second molars by gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Molars examined N</th>
<th>Molars with 3 roots N (%)</th>
<th>Individuals examined N</th>
<th>Individuals with 3 roots N (%)</th>
<th>Individuals with bilateral symmetry in 3 roots N</th>
<th>Individuals with bilateral symmetry in 3 roots and in canal numbers N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>351</td>
<td>103 (29.34)</td>
<td>207</td>
<td>70 (33.82)</td>
<td>56</td>
<td>31 (55.36)</td>
</tr>
<tr>
<td>Female</td>
<td>136</td>
<td>31 (22.79)</td>
<td>76</td>
<td>23 (30.26)</td>
<td>21</td>
<td>8 (38.10)</td>
</tr>
<tr>
<td>Total</td>
<td>487</td>
<td>134 (27.52)</td>
<td>283</td>
<td>93 (32.86)</td>
<td>77</td>
<td>39 (50.65)</td>
</tr>
</tbody>
</table>

*p-value* \(>0.05\)

*Calculated by Chi-square test.*
teeth because it can provide information in three dimensions. It is relatively straightforward to determine the root and canal numbers in the horizontal image, so this study provides reliable information about the predilection of the occurrence of additional roots and valuable information on numbers of canals in the PMSMs of Chinese individuals.

Although there had many case reports on the occurrence of three-rooted primary molars, there are a few studies on the prevalence of this anatomical variant. Jorgensen reported that only seven (0.67%) out of 1041 PMSMs extracted from Danish patients had an extra root. Liu et al found that 6% of PMSMs had extra distal root by using vertical bitewing radiography. In the present study, the incidence of three-rooted PMSMs was much higher (27.52%), which agrees with results found in a study on a Korean population (27.80%) using digitalized periapical radiographs. The overall prevalence of the patients with such
teeth was 32.86%, which is higher than 10% reported by Liu et al. This variation in the incidence of the three-rooted variation can be attributed to multiple factors, such as sample size, study designs, methods of analysis, and population studied.

Studies of permanent teeth always showed a high prevalence of bilateral symmetry. Tu et al. reported the bilateral incidence of a symmetrical distribution of three-rooted mandibular first permanent molar to be 53.65%. Studies showed that 70–81% individuals are found to have a C-shaped canal in the contralateral permanent mandibular tooth if a C-shaped canal is present in a PMSM on one side.14

However, studies of primary teeth give a lower prevalence of bilateral symmetry of both first (17.67%) and second (28%) mandibular molars.7,8 In the present study, of the 77 patients who had bilateral PMSMs CBCT images, 50.65% (39/77) had symmetrical three-rooted PMSMs, which is higher than previous studies, but similar to the value obtained in several studies of permanent first molars in Asians.21

Several investigators have reported gender predilection for an additional root in permanent molars, but these results have varied in different studies. Some studies found the prevalence of an additional root had male predominance, others reported no difference between the sexes or rather more in females.22–24 The incidence of three-rooted PMSM did not differ with gender (p > 0.05) in the present study, which agrees with results reported by Liu et al.7

Variations in root and canal morphology are reported to be racially related. Three-rooted mandibular first molar and C-shaped mandibular second molars were reported to be more common in races of Mongoloid origin.14 Previous studies found the incidence of primary tooth anomalies also had a racial characteristic.4,25–28 In the present study, 32.86% of the population studied had three-rooted PMSMs, which suggests that the additional root is probably a normal racial and morphological variation rather than an abnormality in this Chinese population.

It is difficult to detect the canal morphology of primary teeth by conventional radiography because the image of the canal often overlaps in the two-dimensional image. There are a few studies about the canal morphology of primary teeth using extracted teeth with a limited number of samples. The physiological or pathological root desorption means that there is rarely a chance to study primary molar teeth with sound roots. Studies of permanent teeth have suggested that CBCT is an excellent method for the three-dimensional evaluation of root canal morphology, and cross-sectional CBCT images can give a clear outline of the root canal. In the present study, CBCT was used to determine the number of canals in PMSMs. A majority (98.57%) of the PMSMs had three or four canals, which consistent with previous studies.4,24 Although Bagherian et al. reported all the 22 extracted PMSMs of an Iranian population had two canals in the mesial root, we found that 2.26% (11/487) of PMSMs in the Chinese population had only one canal.

Interestingly, several variations were found in PMSM, such as PMSMs that had one mesial root and two distal roots and one or two canals in the distobuccal root and one canal in distolingual root. Only one PMSM with four roots and a separate canal in each root was found in the present study. This physiology has been reported in previous studies and found in a permanent mandibular first molar.13 Although the incidence of these variations is low, pediatric dentists should pay attention when performing clinical procedures.

Although many studies, as well as the present study, have clearly indicated that CBCT is helpful in the evaluation of the root and canal system, CBCT cannot be routinely used in all cases of nonsurgical endodontic treatment because overexposure to radiation is a risk. Until further evidence is available, CBCT should be considered only when it has been determined that conventional radiographic techniques are yielding limited information and that further details are required for diagnosis and planning treatment, while ensuring that the patient’s radiation exposure is kept as low as possible.

CBCT is an effective tool for the detection of the root and canal system of primary teeth. Three-rooted PMSMs occur frequently in the Chinese population and have no relationship with gender. If a PMSM has an accessory root, there is a high probability that the PMSM on the opposite side will also have one. Again, there is no difference between two sexes where this is the case. The majority of PMSMs have three to four canals and the diversity of the root canal variants should be considered when performing clinical procedures. The present study provides information on canal variation type and the incidence of three-rooted PMSMs, which could help pediatric dentists improve their endodontic diagnostic and treatment skills.

References


