Cone-beam Computed Tomography Analysis of the Root Canal Morphology of Maxillary First and Second Premolars in a Spanish Population

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Abstract  
Introduction: We investigated the root canal configuration of maxillary premolars in a Spanish population by using cone-beam computed tomography. Methods: Images of 804 maxillary first and second premolars were obtained from 620 patients who underwent cone-beam computed tomography scanning during preoperative assessment (before implant surgery, orthodontic treatment, dentoalveolar trauma diagnosis, or difficult root canal treatment). We determined tooth position, number of roots, root canal configuration (Vertucci’s classification), number of root canals, and number of apical foramina per root and used the χ² test to analyze the correlation between root number and tooth position. Results: In the maxillary first premolar group (n = 430), 46% (n = 198) had 1 root, 51.4% (n = 221) had 2 roots, and 2.6% (n = 11) had 3 roots. Most exhibited a type IV canal configuration (n = 227, 52.8%). Single-rooted teeth had a more variable canal configuration, whereas most 2-rooted teeth showed a type IV configuration (n = 215, 97.3%). In the maxillary second premolar group (n = 374), 82.9% (n = 310) had 1 root, 15.5% (n = 58) had 2 roots, and 1.6% (n = 6) had 3 roots. The majority of single-rooted second premolars exhibited a type I configuration (n = 147, 47.2%). Overall, type VIII canals were only observed in 3-rooted teeth. No statistical correlation was evident between root number and gender or tooth position. Conclusions: There was a high frequency of 2-rooted and single-rooted teeth among maxillary first and second premolars, respectively. The canal morphology of single-rooted teeth was highly variable. (J Endod 2015;41:1241–1247)  

Key Words  
Cone-beam computed tomography, maxillary premolars, root morphology, Spanish population  

The root canal system is complex, individual to each tooth, and can harbor a rich microbial flora (1–3). A lack of knowledge of root canal anatomy and/or technical skill may result in a failure to identify all root canals and/or inadequate instrumentation, which can lead to endodontic treatment failure (4, 5). Therefore, a thorough understanding of root canal anatomy and the use of diagnostic imaging are essential before embarking on endodontic treatment (6). 

Several studies (7–19) have reported that maxillary premolars have a highly variable internal canal configuration, which can vary according to race and geographic origin (8, 9, 12). The reported prevalence of maxillary first premolars with 1 root ranges from 22% to 66%, with 2 roots from 33% to 84%, and with 3 roots from 0% to 6% (7, 8, 11, 12, 16, 17, 20). Maxillary second premolars usually have 1 root, with either 1 or 2 root canals (10, 12, 20, 21). Significant anatomic variation has also been observed among maxillary second premolars (22–24). Hence, variability in root number and canal configuration in these teeth poses a challenge to the clinician during root canal treatment. 

Although intraoral periapical radiography is conventionally used to examine root canal morphology in vitro (25), superimposition of structures and image distortion are drawbacks to the use of this technique (26). Changing the horizontal angle of the x-ray tube can sometimes highlight the complexities of the canal system in maxillary premolars (27), but this is not always possible (for example, in patients with a shallow palatal vault). Cone-beam computed tomography (CBCT) imaging allows a 3-dimensional evaluation of teeth and their adjacent structures (26). CBCT has been successfully used to identify second mesiobuccal canals in maxillary molars (28) and distolingual root canals in mandibular first molars (29–31). Neelakantan et al (32) reported that CBCT can detect the root canal system as accurately as the staining and clearing techniques used to study extracted teeth and more accurately than intraoral periapical radiography. Several other studies (33–35) have also concluded that CBCT is more accurate in determining the root canal anatomy of teeth than intraoral periapical radiography. 

To date, there has been no detailed examination of the roots and canal systems of maxillary first and second premolars in a Spanish population. In this study, we evaluated the root canal morphology of maxillary first and second premolars in this population by using CBCT.  

Sample Selection  
Images of maxillary premolars were obtained between June 2013 and July 2014 from patients referred to Universitat Internacional de Catalunya (St Cugat del Vallés, Barcelona, Spain). Address requests for reprints to Dr Miguel Roig, Dentistry Faculty, Universitat Internacional de Catalunya, C/Josep Trueta s/n, 08195 Sant Cugat del Vallés, Barcelona, Spain. E-mail address: montserratmercade@gmail.com  
0099-2399/$ - see front matter  
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Barcelona, Spain) who required CBCT scans as part of the treatment-planning process. The indications for CBCT scanning included the assessment of bone volume for dental implant planning, diagnosis of dentoalveolar trauma, management of impacted teeth before orthodontic treatment, and treatment planning before nonsurgical and surgical endodontic treatment. The Institutional Ethics in Research Committee (Universitat Internacional de Catalunya) approved the design of this study, and all patients gave written informed consent to participate. In accordance with data protection of minors, the Institutional Ethics Committee in Research Committee does not allow the use of CBCT data from persons younger than 18. A total of 804 CBCT images of maxillary premolars (430 first and 374 second premolars) from 620 patients (416 from 362 men and 388 from 258 women) were selected for this investigation, according to the following criteria:

1. Availability of scans of the maxillary first and/or second premolars
2. Complete root formation
3. Absence of root resorption, calcification, or periapical lesions
4. Absence of root canal fillings, posts, or crown restorations
5. Availability of a clear and complete view of the relevant teeth

**Image Acquisition**

CBCT images were obtained by using a ProMax 3Ds (Planmeca OY, Helsingfors, Finland). The operating parameters were 8 mA and 84 kV, with an exposure time of 12 seconds. The smallest possible field of view was used (5 × 8 cm), and the voxel size was 0.075 mm. All CBCT exposures were performed with the minimum exposure necessary for adequate image quality. The as low as reasonably achievable protocol was strictly followed. Data were reconstructed with slices at 0.2-mm intervals, positioned parallel to the horizontal axis of the alveolar process, and the teeth under examination were placed in the center of the volume.

**Image Evaluation**

Images were assessed by 2 calibrated endodontists who were trained by using example CBCT images. Before analyzing the experimental material, the 2 examiners were asked to grade 50 sample CBCT images. During the experiment, the examiners assessed the CBCT images independently and then compared readings. They were able to scroll through the axial, coronal, and sagittal views of each tooth.

In the event of disagreement, the case was discussed until a consensus was reached. A second session for the analysis of intraexaminer reliability took place 4 weeks after the first assessment.

The following information was recorded and analyzed:

1. Tooth position relative to the left or right side
2. Root number and canal configuration, classified by using Vertucci’s criteria (36) (Fig. 1)
3. The number of apical foramina per root

The number of roots detected in the axial plane of the CBCT images was classified in accordance with Pécora et al (9):

1. **Single-rooted teeth**: Teeth with a clear single root and teeth with 2 independent canals that seemed to have 2 roots, which were actually fused
2. **Multi-rooted teeth**: 2-rooted teeth possessing bifurcated roots, regardless of whether they were partial or complete, and 3-rooted teeth, with 3 completely independent roots from the chamber floor, or bifurcations at any position along the buccal or palatal roots

Differences in tooth position (right or left) were determined by using the $\chi^2$ test and were considered significant if the $P$ value was <.05. Intraexaminer and interexaminer agreements were calculated by using the Cohen kappa coefficient.

### Results

Table 1 shows the number of roots of maxillary first and second premolars according to gender. Of the maxillary first premolars, the majority (52.3%, $n = 113$) of the 212 teeth from male patients had 2 roots, and the remaining had 1 (43.9%, $n = 93$) or 3 roots (2.8%, $n = 6$). The majority (50.5%, $n = 108$) of the 218 teeth from female patients also had 2 roots, and the remaining presented 1 (48.2%, $n = 105$) or 3 roots (2.3%, $n = 5$). Of the maxillary second premolars, most (83.3%, $n = 170$) of the 204 teeth from male patients had 1 root, and the remaining had 2 (15.2%, $n = 31$) or 3 roots (1.5%, $n = 3$). Most (82.4%, $n = 140$) of the 170 teeth from female patients also had 1 root, and the remaining presented 2 (15.8%, $n = 27$) or 3 roots (1.8%, $n = 3$). No significant differences were observed between the number of roots in both maxillary first and second premolars and gender ($P > .05$).

**Table 1. Prevalence of Roots (% of teeth) According to Gender**

<table>
<thead>
<tr>
<th>Tooth position</th>
<th>One root (%)</th>
<th>Two roots (%)</th>
<th>Three roots (%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary first premolars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>93 (43.9)</td>
<td>113 (52.3)</td>
<td>6 (2.8)</td>
<td>212</td>
</tr>
<tr>
<td>Female</td>
<td>105 (48.2)</td>
<td>108 (50.5)</td>
<td>5 (2.3)</td>
<td>218</td>
</tr>
<tr>
<td>Total</td>
<td>198 (46.0)</td>
<td>221 (51.4)</td>
<td>11 (2.6)</td>
<td>430</td>
</tr>
<tr>
<td>Maxillary second premolars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>170 (83.3)</td>
<td>31 (15.2)</td>
<td>3 (1.5)</td>
<td>204</td>
</tr>
<tr>
<td>Female</td>
<td>140 (82.4)</td>
<td>27 (15.8)</td>
<td>3 (1.8)</td>
<td>170</td>
</tr>
<tr>
<td>Total</td>
<td>310 (82.9)</td>
<td>58 (15.5)</td>
<td>6 (1.6)</td>
<td>374</td>
</tr>
</tbody>
</table>
Table 2 shows the frequency distribution of the number of roots according to tooth position. Of 430 maxillary first premolars, 198 (46%) had 1 root, 221 (51.4%) had 2 roots, and 11 (2.6%) had 3 roots. Of the 2-rooted maxillary first premolars, 43% (n = 95) bifurcated from the pulp chamber floor, forming 2 independent roots, whereas the remaining 57% (n = 126) bifurcated at different levels in the apical third. No correlation was found between root number and tooth position in the maxillary first premolars (P = .28). Of 374 maxillary second premolars, 310 (82.9%) had 1 root, 58 (15.5%) had 2 roots, and 6 (1.6%) had 3 roots. Of the 2-rooted maxillary second premolars, 36.2% (n = 21) bifurcated from the pulp chamber floor, forming 2 independent roots, whereas the remaining 63.8% (n = 37) had fused roots. No correlation was found between root number and tooth position in the maxillary second premolars (P = .75).

Table 3 shows the prevalence of different root canal types. The most prevalent root canal type among maxillary first premolars was type II (n = 227, 52.8%), followed by type I (n = 108, 25.1%) and type III (n = 44, 10.2%). Types III, V, VI, VII, and VIII were also found, but more rarely. Single-rooted first premolars had a more variable canal configuration; 54.5% (n = 108) had a type I configuration, the frequencies of types II (n = 44, 22.2%) and III (n = 19, 9.6%) were lower, and types IV, V, VI, and VII together accounted for 13.6%.

Most 2-rooted first premolars exhibited a type IV canal configuration (n = 215, 97.3%). Type VIII canals were only observed in 3-rooted teeth. Type I (n = 147, 39.3%) was the most prevalent root canal type in maxillary second premolars, followed by type II (n = 84, 22.5%) and type IV (n = 74, 19.8%). Types III (n = 27, 7.2%), V (n = 16, 4.3%), VI (n = 12, 3.2%), VII (n = 8, 2.1%), and VIII (n = 6, 1.6%) occurred less often. The majority of single-rooted second premolars had a type I canal configuration (n = 147, 47.4%), followed by type II (n = 84, 27.1%) and type III (n = 27, 8.7%). Types IV, V, VI, and VII together accounted for 16.8%. Type IV (n = 49, 84.5%) was the predominant canal configuration among 2-rooted second premolars, whereas a type VIII configuration was only found in 6 second premolars (1.6%). Figures 2 and 3 show a selection of root canal types detected in axial sections.

Maxillary first premolars with 1, 2, or 3 apical foramina accounted for 39.8% (n = 171), 57.7% (n = 248), and 2.6% (n = 11), respectively. Of the single-rooted maxillary first premolars, 86.4% (n = 171) had 1 foramen per root, and 13.6% (n = 27) had 2, whereas all 2-rooted and 3-rooted teeth had only 1 foramen per root. Maxillary second premolars with 1, 2, or 3 apical foramina accounted for 69% (n = 258), 29.4% (n = 110), and 1.6% (n = 6), respectively. Of the single-rooted maxillary second premolars, 83.2% (n = 258) had 1 foramen per root, and 16.7% (n = 52) had 2 foramina per root. As observed for the maxillary first premolars, all 2-rooted and 3-rooted second premolars had only 1 foramen per root.

Regarding interexaminer agreement, the Cohen kappa values after the training session were 0.993 and 0.995 for the first and second assessments, respectively. The overall Cohen kappa value for intraexaminer agreement was 0.998. In summary, there was a very good intraexaminer and interexaminer agreement.

### Discussion

A sound knowledge of root canal morphology and its anatomic variations is indispensable for successful root canal treatment. To our knowledge, this is the first study to use CBCT in vivo to assess the root and canal morphology of maxillary premolars in a Spanish population.

In maxillary first premolars, the frequency of 1-rooted teeth (n = 198, 46%) was lower than that reported in Brazilian, Singaporean, and different Chinese subpopulations (9, 11, 17, 37). These frequencies were similar to those reported in some studies (25, 38, 39) but much higher than findings reported elsewhere (7, 8, 12–16, 40) (Table 4). These differences in root canal anatomy highlight the influence of ethnic background on the root morphology of maxillary premolars.

The frequencies of 2-rooted (n = 221, 51.4%) and 3-rooted (n = 11, 2.6%) teeth were similar to those reported by Pineda and Kuttler (25), Pécora et al (9), and Neelakantan et al (16). Many case reports have described maxillary first premolars with 3 roots (40, 41), termed radicular premolars and generally considered a Caucasian trait (42).

### Table 2. Frequency Distribution of Number of Roots According to Tooth Position

<table>
<thead>
<tr>
<th>Tooth position</th>
<th>One root (%)</th>
<th>Two roots (%)</th>
<th>Three roots (%)</th>
<th>Total</th>
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<tr>
<td>Maxillary first premolars</td>
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<tr>
<td>Right</td>
<td>95 (47.9)</td>
<td>98 (49.5)</td>
<td>5 (2.5)</td>
<td>198</td>
</tr>
<tr>
<td>Left</td>
<td>103 (44.4)</td>
<td>123 (53.0)</td>
<td>6 (2.6)</td>
<td>232</td>
</tr>
<tr>
<td>Total</td>
<td>198 (46.0)</td>
<td>221 (51.4)</td>
<td>11 (2.6)</td>
<td>430</td>
</tr>
<tr>
<td>Maxillary second premolars</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>147 (79.9)</td>
<td>33 (17.9)</td>
<td>4 (2.2)</td>
<td>184</td>
</tr>
<tr>
<td>Left</td>
<td>163 (85.8)</td>
<td>25 (13.2)</td>
<td>2 (1.1)</td>
<td>190</td>
</tr>
<tr>
<td>Total</td>
<td>310 (82.9)</td>
<td>58 (15.5)</td>
<td>6 (1.6)</td>
<td>374</td>
</tr>
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</table>

### Table 3. Prevalence of Root Canal Types

<table>
<thead>
<tr>
<th>No. of roots</th>
<th>I (%)</th>
<th>II (%)</th>
<th>III (%)</th>
<th>IV (%)</th>
<th>V (%)</th>
<th>VI (%)</th>
<th>VII (%)</th>
<th>VIII (%)</th>
<th>Total</th>
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<td></td>
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<tr>
<td>One</td>
<td>108 (54.5)</td>
<td>44 (22.2)</td>
<td>19 (9.6)</td>
<td>12 (6.1)</td>
<td>6 (3.0)</td>
<td>4 (2.0)</td>
<td>5 (2.5)</td>
<td>—</td>
<td>198</td>
</tr>
<tr>
<td>Two</td>
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<td>—</td>
<td>—</td>
<td>221</td>
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<tr>
<td>Three</td>
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<td>—</td>
<td>—</td>
<td>11 (100)</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>108 (25.1)</td>
<td>44 (10.2)</td>
<td>19 (4.4)</td>
<td>227 (52.8)</td>
<td>8 (1.9)</td>
<td>7 (1.6)</td>
<td>6 (1.4)</td>
<td>11 (2.6)</td>
<td>430</td>
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<tr>
<td>Maxillary second premolars</td>
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<tr>
<td>One</td>
<td>147 (47.4)</td>
<td>84 (27.1)</td>
<td>27 (8.7)</td>
<td>25 (8.1)</td>
<td>13 (4.2)</td>
<td>8 (2.6)</td>
<td>6 (1.9)</td>
<td>—</td>
<td>310</td>
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<tr>
<td>Two</td>
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<td>—</td>
<td>—</td>
<td>49 (84.5)</td>
<td>3 (5.2)</td>
<td>4 (6.9)</td>
<td>2 (3.4)</td>
<td>58</td>
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<tr>
<td>Three</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
<td>6 (100)</td>
<td>6 (1.6)</td>
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<td>374</td>
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<tr>
<td>Total</td>
<td>147 (39.3)</td>
<td>84 (22.5)</td>
<td>27 (7.2)</td>
<td>74 (19.8)</td>
<td>16 (4.3)</td>
<td>12 (3.2)</td>
<td>8 (2.1)</td>
<td>6 (1.6)</td>
<td>1243</td>
</tr>
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</table>

*Vertucci’s classification of canal system.
In other studies of the root canal morphology of maxillary second pre-molars, the percentages of 1-, 2-, and 3-rooted teeth range from 69% to 90%, 13% to 30%, and 0% to 1%, respectively (10, 12, 19).

The majority of maxillary second premolars examined in this study ($n = 310$, 82.9%) had 1 root, whereas 15.5% had 2 roots, and 1.6% had 3 roots (Table 4). The discrepancy in the distribution of root forms between previous reports and this study may be due to differences in populations, evaluation techniques, and/or sample size.

**Figure 2.** CBCT in the axial plane revealed the different root forms of the maxillary first premolars (arrows indicate the examined teeth): (a and b) coronal; (c) middle; and (d) apical thirds.
The proportion of maxillary first premolars with different numbers of root canals was consistent with the findings of previous studies that used the clearing technique (12, 36), the radiologic technique (37), or plastic casts (7); 2-root canals were most common, followed by 1-root and then 3-root canals (Table 3). Among single-rooted teeth, 39.4% \((n = 78)\) had a complex root canal system with bifurcation and/or combination (types II, III, V, VI, and VII). In contrast, most 2-rooted \((n = 215, 97.3\%)\) and all
3-rooted teeth had 1 simple and independent canal in each root. However, it is important to note that 57% ($n = 126$) of 2-rooted teeth bifurcated at different levels in the apical third of the root; hence, clinicians may believe there is only 1 root canal when using a microscope, when in fact the roots are divided apically. Concerning the internal root canal configuration of maxillary second premolars, 39.3% ($n = 147$) of the teeth studied had 1 root canal (type I), whereas 19.8% had 2 separate root canals (type IV). These 2 canal types are relatively easy to identify and treat. Conversely, teeth with a complex root canal system (types II, III, V, VI, VII, and VIII) are difficult to identify and treat with cleaning, shaping, and obturation. In this study, 6 maxillary second premolars displayed 3 canals with a complex internal anatomy. Awareness of the existence of this type of root canal system is critical to successful root canal treatment.

Morfis et al (45) used scanning electron microscopy to demonstrate that maxillary premolars exhibit a high frequency of multiple apical foramina. As reported by Gutiérrez and Aguayo (44) and Tian et al (17), the number of foramina per root tended to be more variable and multiple in single-rooted maxillary first premolar teeth compared with 2-rooted teeth. Our study showed that 13.6% ($n = 27$) of single-rooted maxillary first premolars had multiple foramina, whereas 2-rooted and 3-rooted teeth had, on average, 1 apical foramen per root. These findings are similar to those of maxillary second premolars, among which 83.23% ($n = 258$) of single-rooted teeth had 1 foramen per root, and 16.77% ($n = 52$) had 2. To ensure the integrity of the original morphology of the root canals, teeth with filling materials with the potential to create artifacts and with resorptions and/or periapical lesions that can destroy the root apices were excluded from this study (45).

Micro–computed tomography scanning (46) and the staining and clearing technique (12, 21, 36) provide precise information on root canal systems, but they can only be used on extracted teeth. CBCT imaging is a noninvasive technique that is reportedly as accurate as the modified canal staining and clearing technique for evaluating root canal systems (32). Unlike conventional radiography, CBCT scanning provides 3-dimensional images in axial, sagittal, and coronal sections, avoiding geometric distortion and anatomic superimposition at a relatively low radiation dose when using a CBCT scanner with a small field of view and appropriate exposure parameters (6). Previous investigations (17–19) on the root canal anatomy of maxillary premolars by using CBCT scanning have yielded varied results. This may be explained in part by differences in CBCT resolution, radiographic interpretation, and sample size.

Several studies (17–19, 29, 31, 45, 47) have demonstrated the quality of CBCT imaging and its clinical applications in the study of root canal morphology before clinical endodontic treatment. When abnormal findings are evident on traditional periapical films and/or variations are detected with magnification in the clinical setting, it may be impossible to evaluate the root canal system effectively (30, 51). In these situations, it is sensible to use CBCT for further diagnosis.

**Conclusions**

Most maxillary first premolars in a Spanish population were 2-rooted with 2 root canals, whereas maxillary second premolars tended to be single-rooted with 1 root canal. *In vitro* CBCT analysis is a noninvasive and clinically effective tool for examining root and canal morphology that may ultimately improve the outcome of endodontic treatment.

**Acknowledgments**

The authors deny any conflicts of interest related to this study.

**References**