Evaluation of root anatomy of permanent mandibular premolars and molars in a Korean population with cone-beam computed tomography

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ABSTRACT
Objective: The purpose of this study was to investigate the root/number of roots and morphology of mandibular premolars and molars in a Korean population, and to evaluate the prevalence of three-rooted mandibular first molars having distolingual (DL) roots, three-rooted mandibular second molars, and C-shaped roots in mandibular second molars.

Methods: Serial axial cone-beam computed tomography (CBCT) images of the mandibles were collected from 430 Korean patients. The total number of roots in the mandibular premolars and molars was counted, and the incidence and the correlations between left- and right-side occurrences and between males and females were analyzed.

Results: The majority of mandibular first premolars and second premolars had one root (99.9% and 99.4%, respectively). Three-fourth of first molars (77.4%) had one mesial and one distal root, and the incidence of a three-rooted tooth having DL root was 22.3%. A little more than half the number of mandibular second molars (54.5%) were two-rooted. Finally, 2.3% of the second molars had three roots having one DL root, and 41.3% had C-shaped roots.

Conclusion: There was a high prevalence of three-rooted mandibular first molars and C-shaped roots in mandibular second molars among a Korean population, detected using CBCT, and the results showed similarities with previous reports about other Asian populations. It may be suggested that CBCT is a practical method of evaluating the number and shape of teeth. Data regarding the occurrence and morphology of the roots may provide useful information to dental practitioners. (Eur J Dent 2013;7:94-101)

Key words: Cone-beam computed tomography; C-shaped root; distolingual root; mandibular premolar; mandibular molar; radix entomolaris

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INTRODUCTION
Many studies have shed insight on particular trends in the number and morphology of roots of mandibular premolar and molars amongst different races, and information regarding the number of roots and shape is important for dental procedures such as surgical extractions, periodontal treatments, orthodontic movements, and root canal treatments. A number of studies have reported that the number of roots and root canal types may vary according to ethnicity, and a literature search reveals that comparatively few studies have evaluated the root anatomy of mandibular premolars and molars in ethnic populations using cone-beam computed tomography (CBCT).

CBCT is advancement in CT imaging, and it has potential applications for the imaging of high-contrast structures in the head and neck, as well as dentomaxillofacial regions; it has been applied in periodontal evaluations; endodontics, including assessment of periapical pathology and periodontal surgical planning; orthodontic evaluations; and dentoalveolar trauma evaluation. The CBCT scanner can collect volume data by means of a single rotation with a cone-shaped x-ray beam and two-dimensional detectors, and CBCT is capable of providing images of high diagnostic quality, with shorter scanning times and lower radiation dosages compared to those of conventional CT scans.

Recently, a study was conducted to investigate the incidence of distolingual (DL) roots in the mandibular molars using CBCT scans, and it was suggested that this method may be a practical tool for noninvasive and 3-dimensional reconstruction imaging for use in morphologic analyses and endodontic applications.

The main purpose of this study was to investigate the root and morphology of Korean mandibular premolars and molars, and to evaluate the prevalence of three-rooted mandibular first molars having distolingual root (radix entomolaris), three-rooted mandibular second molars, and C-shaped (gutter-shaped) roots in mandibular second molars.

MATERIALS AND METHODS
CBCT images of mandibular first premolars, second premolars, first permanent molars, and second premolars were collected from patients who visited the Dental Hospital at Seoul St. Mary’s Hospital, Seoul, Korea, between March 2008 and June 2011. We evaluated 430 patients aged 38.1±18.1 (n=236 females and 194 males; Table 1). This study was approved by the Institutional Review Board.

The axial thickness was 0.4 mm, the voxels were isotropic, and the obtained data were analyzed with M-view™ (Seoul, Korea). Serial axial CBCT images were evaluated continuously by moving the toolbar from the floor of the pulp chamber to the apex to determine the number of roots and their morphology. To evaluate the bilateral occurrence of 3-rooted mandibular first molars, 3-rooted mandibular second molars, and C-shaped mandibular second molars, we only evaluated patients who had bilateral mandibular first molars or bilateral mandibular second molars (Figure 1-6).

Statistical Analysis
The total number of roots, the incidence, and the correlations between left- and right-side occurrences and between males and females were
Number of roots in a Korean population

analyzed with commercially available software (PASW Statistics 18, SPSS Inc., Chicago, IL, USA). Statistically significant differences were evaluated using the chi-square test, with significance set at \( P<.05 \).

**RESULTS**

The numbers and percentages of mandibular premolars and molars evaluated in this study population are shown in Table 2.

### Mandibular first premolars and second premolars

In total, 790 teeth (99.9\%) were detected to have a one-rooted mandibular first premolar. Only one tooth (0.1\%) had a two-rooted mandibular first premolar. The overall occurrence of the roots between female and male participants and the occurrence on the left side and the right side did not display any significant difference (\( P>.05 \); Table 3 and 4).

| Age Range | Male | Female | Total number of patients in each age group | % of Total Patients |
|-----------|------|--------|------------------------------------------|--------------------|
| -19       | 25   | 18     | 43                                       | 10                 |
| 20-29     | 69   | 79     | 148                                      | 34,4               |
| 30-39     | 28   | 38     | 66                                       | 15,3               |
| 40-49     | 14   | 30     | 44                                       | 10,2               |
| 50-59     | 24   | 30     | 54                                       | 12,6               |
| 60-69     | 20   | 30     | 50                                       | 11,6               |
| 70-       | 14   | 11     | 25                                       | 5,8                |
| Total     | 194  | 236    | 430                                      | 100                |

Table 1. Descriptive statistics of study population according to the age and gender.
In addition, 784 mandibular second premolars were one-rooted (99.4%), and five second premolars (0.6%) were two-rooted teeth. There were no significant differences between females and males regarding the overall occurrence of the roots (P>.05). Likewise, the occurrence on the left side and the right side did not show any statistically significant difference (P>.05; Tab. 3 and 4).

**Mandibular first molars**

The majority of first molars (77.4%) had one mesial and one distal root (Table 3 and 4). One hundred sixty-two mandibular first molars (22.3%) had DL roots, and two first molars (0.3%) were one-rooted teeth.

The bilateral incidence of three-rooted mandibular first molars was similar between male (n=28) and female subjects (n=25; P>.05; Table 5). Regardless of gender, the overall occurrence on the left side and the right side showed a statistically significant difference (P=.011). The right mandibular first molar (tooth n=90, 13.5%) had a higher incidence of being a three-rooted tooth when compared with the left side (tooth n=59, 8.9%).

**Mandibular second molars**

Most mandibular second molars (54.5%) were two-rooted teeth with one mesial and one distal root; 2.3% of the second molars had three roots having one DL root, and one tooth (0.1%) had three roots (Table 2).

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**Table 2. Number and percentage of mandibular premolars and molars in study population.**

| Teeth on both sides | Tooth on right side only | Tooth on left side only | Total teeth | Total Patients | % Total Patients |
|---------------------|--------------------------|-------------------------|-------------|----------------|-----------------|
| P1                  | 387                      | 774                     | 14          | 797            | 410             | 95.3           |
| P2                  | 377                      | 754                     | 20          | 789            | 412             | 95.8           |
| M1                  | 333                      | 666                     | 35          | 726            | 393             | 91.4           |
| M2                  | 330                      | 660                     | 31          | 710            | 380             | 88.4           |

**Table 3. Classification of permanent mandibular premolars and molars by root number and topology (right and left side).**

| P1 (n=797) | P2 (n=789) | M1 (n=726) | M2 (n=710) |
|------------|------------|------------|------------|
| Rt | Lt | Total | Rt | Lt | Total | Rt | Lt | Total | Rt | Lt | Total |
| n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| 1 Root | 395 | 49.6 | 401 | 50.3 | 796 | 100 | 394 | 49.9 | 390 | 49.4 | 784 | 100 | 1 | 0.1 | 1 | 0.1 | 2 | 0.3 | 5 | 0.7 | 8 | 1.1 | 13 | 1.8 |
| 1 Root (C-shape) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 Root | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Root (D-2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Root (M-2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 396 | 49.7 | 401 | 50.3 | 797 | 100 | 397 | 50.3 | 392 | 49.7 | 789 | 100 | 368 | 50.7 | 358 | 49.3 | 726 | 100 | 361 | 50.8 | 349 | 49.2 | 710 | 100 |

P1: mandibular first premolar; P2: mandibular second premolar; M1: mandibular first molar; M2: mandibular second molar; Rt: right, Lt: left.

**Table 4. Classification of permanent mandibular premolars and molars by gender.**

| P1 (n=797) | P2 (n=789) | M1 (n=726) | M2 (n=710) |
|------------|------------|------------|------------|
| M | F | Total | M | F | Total | M | F | Total | M | F | Total |
| n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % | n | % |
| 1 Root | 358 | 44.9 | 438 | 55 | 796 | 99.9 | 356 | 45.1 | 428 | 54.2 | 784 | 99.4 | 1 | 0.1 | 1 | 0.1 | 2 | 0.3 | 3 | 0.4 | 10 | 1.3 | 11 | 1.5 |
| 1 Root (C-shape) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 Root | 0 | 0 | 1 | 0.1 | 1 | 0.1 | 1 | 0.1 | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Root (D-2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 Root (M-2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 358 | 44.9 | 439 | 55.1 | 797 | 100 | 359 | 45.5 | 430 | 54.5 | 789 | 100 | 365 | 47.5 | 382 | 52.5 | 727 | 100 | 337 | 47.5 | 373 | 52.5 | 710 | 100 |
roots with two mesial roots. In total, 293 teeth (41.3%) had C-shaped roots (Table 3 and 4).

The bilateral incidence of a three-rooted mandibular second molar having one DL root was similar between females (n=2) and males (n=2; Table 5). The right mandibular second molars (tooth n=6) had a similar incidence of being a three-rooted tooth when compared with the left side (tooth n=7).

The bilateral incidence of a C-shaped mandibular second molar having one DL root was higher in females (n=77) than in males (n=45; P<.05). The right mandibular second molar (n=146, 22.1%) had a similar incidence of having a C-shaped root when compared with the left side (n=135, 20.5%; P=.512; Tab. 5).

**DISCUSSION**

This study used CBCT to evaluate the number of roots and the morphology of premolars and molars in 430 Korean individuals.

**Mandibular first premolars and second premolars**

Almost all of the mandibular first premolars (99.9%) were reported to be single-rooted, and only 0.1% had two roots; these results are similar to the findings of a previous report, which showed the incidence of one root and two roots to be 98% and 0.2%, respectively.10 The majority of mandibular second premolars (99.4%) had one root, and the incidence of two roots was extremely rare (0.6%). Previous studies have found that almost all of the second premolars were single-rooted (99.6%), and the incidences of two roots and three roots were 0.3% and 0.1%, respectively.11

**Mandibular first molars**

In this study, the majority (77.4%) of 726 mandibular first molars had two roots located mesially and distally, and 22.3% of mandibular first molars had an additional root located distolingually. When present, the additional root in a mandibular molar is usually located distolingually, and this additional DL root is called the radix entomalaris.12 It is considered to be a normal morphologic variant and may be identified as a Mongolian trait.13 It is reported that the Mongoloid population exhibits significantly more mandibular first molars with three roots than other populations, with a 3:1 ratio when compared with Caucasians and African Americans; this variation could be considered a genetically determined characteristic.13 This result was similar to the evaluation of a Western Chinese population by CBCT, showing that 25.8% of the pool of cases examined had an extra DL root in the mandibular first molars.3

Unilateral or bilateral occurrence of an additional root in the first permanent molar has been studied.14 In some reports, all three-rooted molars occurred unilaterally.12 The incidence rates of bilateral and unilateral three-rooted first molars in Korean individuals in the present study were 15.9% and 6.5%, respectively. If the incidence was calculated using three-rooted molars as the denominator, the bilateral and unilateral distribution increased to 71.1% (106/149) and 28.9% (43/149), respectively. The bilateral occurrence rates of previous studies conducted among Asian populations were 57.0% (Japan),15 61.0% (Hong Kong),16 68.6% (Taiwan),17 and 88.0% (Taiwan).18

| Table 5. Analysis of gender distribution in unilateral and bilateral cases of (1) mandibular first molars with two distal roots in patients having bilateral mandibular first molars, (2) mandibular second molars with two distal roots in patients having both mandibular second molars, and (3) mandibular second molars with C-shaped roots in patients having both mandibular second molars. |
| --- | --- | --- |
| | M1 (n=666) | M2 (n=660) |
|  | Male | Female | Total | Male | Female | Total | Male | Female | Total |
| Bilateral | site | 28 | 25 | 53 | 2 | 2 | 4 | 4 | 45 | 77 | 122 |
| n | 56 | 50 | 106 | 4 | 4 | 8 | 90 | 154 | 244 |
| % | 8,4 | 7,5 | 15,9 | 0,6 | 0,6 | 1,2 | 13,6 | 23,3 | 37 |
| P-value | 0,56 | - | 0 |
| Rt | n | 20 | 17 | 37 | 0 | 2 | 2 | 11 | 13 | 24 |
| % | 3 | 2,6 | 5,6 | 0 | 0,3 | 0,3 | 1,7 | 2 | 3,6 |
| Lt | n | 3 | 3 | 6 | 3 | 0 | 3 | 2 | 11 | 13 |
| % | 0,5 | 0,5 | 0,9 | 0,5 | 0 | 0,5 | 0,3 | 1,7 | 2 |
| Total | n | 79 | 70 | 149 | 7 | 6 | 13 | 103 | 178 | 281 |
| % | 11,9 | 10,5 | 22,4 | 1,1 | 0,9 | 2 | 15,6 | 27 | 42,6 |
| P-value | 0,461 | 0,782 | 0 |
Several investigators have reported a gender predilection of the distolingual root in the mandibular first molar. Many studies have found male predominance, but some studies have also reported that the prevalence is greater among females. In the present study, there was no significant difference according to gender (female vs. male, P = .461).

Topologic predilection for the presence of the DL root in the mandibular first molar may be a controversial issue. Many previous studies have identified a predilection for the right side, but some investigators have reported the opposite. The present study showed a predilection for the occurrence of DL roots on the right side for first molars.

**Mandibular second molars**

In the case of mandibular second molars, the majority (54.5%) of 710 teeth had two roots located mesially and distally, and 2.3% of mandibular first molars had an additional root located distolingually. In a very rare case (0.1%), an additional root was detected at the mesiobuccal side, and this root is called the radix paramolaris. According to previous reports, the incidence of two separate roots is similar to the finding of the present study; past research has demonstrated 54.0% among Thai study participants and 58.2% among Burmese participants. There was a similar predilection for the occurrence of additional DL roots on the right side and left side for second molars (P = .077), and the prevalence of the DL root showed no statistically significant difference between genders (P = .782).

C-shaped roots occurred in 41.3% of mandibular second molars in this study. It is reported that the radiographic appearance of a C-shaped root in mandibular second molars may differ, depending on the exact morphology and orientation of the root. The percentage of C-shaped roots in the mandibular second molars varied significantly between previous studies, which have reported 6.0% in Sri Lanka, 10.0% in the Sudan, 10.6% in Saudi Arabia, 10.9% in Thailand, and 22.4% in the Burmese population. A higher incidence of C-shaped roots was reported among Chinese and Korean populations. Furthermore, 31.5% of the mandibular second molars had C-shaped roots from Hong Kong, and 32.7% of the mandibular second molars in the Korean population under clinical evaluation had C-shaped canals, in addition, using CT, C-shaped canals were found in 98 teeth (44.5%) out of 220 teeth in this Korean population. Root and root canal anatomy of mandibular second molars from Hong Kong populations revealed a higher incidence of C-shaped canals (52%). The C-shaped root canal system is an anatomical variation found mostly in mandibular second molars, more frequently in Asians than in other racial groups. The incidence rates of bilateral and unilateral C-shaped root in the second molars in Korean individuals in the present study were 37.0% and 5.6%, respectively. If the incidence was calculated using C-shaped second molars as the denominator, the bilateral and unilateral distribution increased to 86.8% (244/281) and 13.2% (37/281), respectively. This study showed that the prevalence was greater in female subjects compared to male subjects (tooth n=178; P=.05). However, there were similar incidence rates of additional DL roots on the right side (tooth n=146) and left side (tooth n=135) for the second molars (P=.512).

Understanding the anatomy of roots of permanent premolars and molars may help dental practitioners performing both endodontic and periodontal procedures. This knowledge may help the operator during diagnosis and treatment for endodontic therapy. It was reported that a significantly higher magnitude of periodontal parameters (probing depth and clinical attachment loss) at the distolingual site of molars with the DL root than in molars without the DL root in molars with advanced periodontitis; and it is plausible that an additional root may also be a contributing factor to localized periodontal destruction. C-shaped roots may have narrow root grooves that are predisposed to localized periodontal disease.

**CONCLUSIONS**

The root number and morphology of 430 Korean mandibular molars were examined using CBCT. There was a high prevalence of three-rooted mandibular first molars and C-shaped roots in mandibular second molars from this Korean population, identified using CBCT, and the results showed similarities with previous studies of Asian populations. CBCT may be a practical method to evaluate the number and shape of teeth and to compare the results of previous studies regarding the occurrence of these types of teeth among
different ethnic groups; in addition, CBCT can be used to collect data regarding the occurrence and morphology of the roots, thus offering useful information to dental practitioners.

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