Mesiobuccal root canal anatomy of Korean maxillary first and second molars by cone-beam computed tomography

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Objective. The aim of this study was to investigate the types of canal configurations and the incidence of a second mesiobuccal (MB2) canal in Korean maxillary molar mesiobuccal (MB) roots by analyzing cone-beam computed tomographic (CBCT) images.

Study design. Three-dimensional CBCT images of 458 maxillary first molars and 467 second molars from 276 Korean patients were analyzed to determine the incidence of an MB2 canal, the types of canal configurations, and the correlations between the incidence of an MB2 canal and age, gender, and tooth position.

Results. The incidence of 2-canaled MB roots was 71.8% in first molars and 42.2% in second molars, with the most common configurations being Weine types III and II. The frequency of an MB2 canal decreased with age in both molars (P < .05).

Conclusions. Types III and II canal configurations were the most prevalent in the 2-canaled MB roots of Korean maxillary molars. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:785-791)

The main objective of an endodontic treatment is to complete a thorough mechanical and chemical cleansing of the entire root canal system and its obturation with inert filling materials. Therefore, a better understanding of the root canal system and its frequent variations is very important for successful endodontic therapy. In the literature, the mesiobuccal (MB) root of maxillary permanent molars has generated more research and clinical investigation than any other root owing to its more complex root canal anatomy and common variations, especially regarding the prevalence of a second mesiobuccal (MB2) canal and the types of canal configurations.

Certain factors contribute to the wide variations reported in the incidence of an MB2 canal in maxillary molar MB roots. These include race, age, and gender of the population studied, as well as the methods of research. The laboratory methods used to analyze root canal morphology include sectioning, clearing techniques, conventional radiographs, micro-computed tomography (MCT) techniques, and scanning electron microscopic observation of the pulpal floor. The techniques used in clinical studies include inspection during endodontic treatment with or without magnification tools, radiography, and reviews of patient records. Currently, technologic advances have been developed allowing a study that is accurate, nondestructive, and feasible in vivo.

CBCT systems have been designed specifically to produce undistorted 3-dimensional (3D) information on the maxillofacial skeleton, as well as 3D images of the
teeth and their surrounding tissues. These systems are promising and are eminently more suitable than MCT scans, which are limited to ex vivo applications only and are not suitable for patient care. Currently, specific endodontic applications of cone-beam computed tomography (CBCT) are being identified and, as the technology becomes more prevalent in the field of endodontics, will be able to provide valuable diagnoses and morphologic analyses of the root canal system. Therefore, the aim of the present study was to investigate the incidence of the MB2 canal in the MB roots of the maxillary first and second molars in a Korean population by gender, tooth position, and age by using patients’ CBCT images taken for oral surgery and implant placement. The root canal configurations of the MB roots were also assessed.

MATERIAL AND METHODS
This study was approved by the Institutional Review Board of Yonsei Dental Hospital, Yonsei University, Seoul, Republic of Korea. Among the CBCT images taken of patients who visited the Yonsei Dental Hospital from August 2009 to July 2010 for implant surgery and surgical removal of deeply impacted teeth (including third molars and supernumerary teeth), high-quality CBCT images from 276 patients (169 men and 107 women) were screened, and images of 458 maxillary first and 467 second molars were evaluated retrospectively. The mean age of the patients was 37.7 years of age, ranging from 18 to 76 years. For the maxillary first molar, 200 of the subjects had bilateral molars, 58 had unilateral molars, and 18 had no first molar. For the maxillary second molar, 206 of the subjects had bilateral molars, 55 had unilateral molars, and 15 had no second molar. Images of subjects who had maxillary molars with a completely formed MB root and had not had endodontic treatment, a post, or a crown were selected for analysis.

CBCT scans
The CBCT system used in this study was a Volux system (Genoray, Seongnam, Republic of Korea), and the scan settings were 85 kVp, 80 mA, 8.5 cm scan field of view, and 0.167 mm³ voxel size. Tomography sections of 0.167 mm in the axial, coronal, and sagittal planes were created. The data were exported into DICOM file format.

3D Reconstruction and image analysis
Three-dimensional images of the maxillary first and second molars were displayed using OnDemand3D software (Cybermed, Seoul, Republic of Korea). The presence of an MB2 canal and the types of canal configurations present in the MB root were evaluated using the OnDemand3D toolbar by carefully rolling downward through the images from the pulp chamber to the apex at the axial tomographic slices. Selecting and moving the cursor on 1 image to change the center of view altered the reconstructed slices in 3 orthogonal planes (axial, coronal, and sagittal). These views were used to examine the root canal system. All the images were analyzed by 1 endodontist, and the assessment was performed once a week for 2 weeks. The incidence of an MB2 canal was evaluated and the canal configurations of the MB roots were classified into 5 categories. Types I to IV matched the Weine classification as follows: type I: a single root canal extending from the pulp chamber to the apex; type II: separate root canals leaving the pulp chamber and joining short of the apex to form 1 canal; type III: 2 separate and distinct root canals leaving the pulp chamber and joining short of the apex to form 1 canal; type IV: 1 canal leaving the pulp chamber and dividing into 2 separate and distinct canals with separate apical foramina. Type V followed the Yoshioka classification and was defined as a root canal configuration having >2 canals.

The maxillary molars with a bilateral existence were used for analysis of the bilateral occurrence of MB2 canals. The relationships between gender and tooth position (right or left) and the incidence of an MB2 canal were assessed using Fisher exact test, and the relationship between age and the incidence of an MB2 canal was assessed using Pearson r correlation, with statistical significance set at α = .05.

RESULTS
Analysis of CBCT images of the MB canal system in the maxillary first molars showed that 70.5% of the MB roots had 2 canals, 28.2% had a single canal, and 1.3% had 3 canals (Table I). The type III canal configuration

<table>
<thead>
<tr>
<th>No. of teeth (%)</th>
<th>Maxillary first molar</th>
<th>Maxillary second molar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>129 (28.2)</td>
<td>270 (57.8)</td>
</tr>
<tr>
<td></td>
<td>152 (33.2)</td>
<td>111 (23.8)</td>
</tr>
<tr>
<td></td>
<td>160 (34.9)</td>
<td>68 (14.6)</td>
</tr>
<tr>
<td></td>
<td>11 (2.4)</td>
<td>15 (3.2)</td>
</tr>
<tr>
<td></td>
<td>6 (1.3)</td>
<td>3 (0.6)</td>
</tr>
</tbody>
</table>

Values within parentheses are percentages of total number of teeth examined.
was the most prevalent in the MB roots of first molars (Fig. 1). For maxillary second molars, 57.8% of the MB roots had a single canal, 41.6% had 2 canals, and 0.6% had 3 canals. In the 2-canaled MB roots, the type II canal configuration was the most prevalent (Fig. 2). Teeth with types II-V configurations of the MB root were regarded as having an MB2 canal. In total, 71.8% of the maxillary first molars and 42.2% of the maxillary second molars had an MB2 canal.

Table II shows the numbers of MB2 canals and their frequency in maxillary molars according to age. The frequency of MB2 canals decreased with age in both maxillary molars. For the relationship between age and number of canals in the MB roots, Pearson $\gamma$ correlation produced a value of $\gamma = -0.160$ for maxillary first molars and a value of $\gamma = -0.260$ for maxillary second molars, which indicates an inverse correlation between the age of the subject and the incidence of an MB2 canal ($P < .05$).

Table III shows that there was a significant relationship between gender and the incidence of an MB2 canal only in maxillary second molars (48.7% in men and 30.8% in women; $P < .05$). Tooth position (right or left) was not significantly correlated with the incidence of an MB2 canal in either the first or second molars ($P > .05$). However, 73.4% of the first molars and 52.0% of the second molars with an MB2 canal occurred bilaterally.

**DISCUSSION**

The present study provides detailed anatomy of the MB root canal of Korean maxillary molars based on a retrospective analysis of CBCT images. Regarding the types of canal configurations, the type III canal configuration was the most prevalent in the MB roots of first molars. The high prevalence of the type III configuration (2 canals with 2 separate foramina), which is a typical mongoloid trait,\(^9\) conforms to the findings of earlier studies in Burmese, Indian, Japanese, Mexican, and Thai populations.\(^9\)\(^-\)\(^12\)\(^,\)\(^17\) This is in contrast to results for Chinese\(^8\) and caucasian\(^1\)\(^,\)\(^13\) teeth, in which most of the MB2 canals joined the main canal and exited through 1 apical foramen (type II) in the 2-canaled MB roots of first molars. These differences in canal configuration highlight the influence of ethnicity on the anatomy of the maxillary first molar root canal.

Unlike the type of canal configuration in first molars, type II was the most common configuration in the 2-canaled MB roots of maxillary second molars. This is in agreement with the results of Eskoz and Weine\(^31\) and Singh et al.\(^32\) but differs from studies by Alavi et al.,\(^11\) Imura et al.,\(^33\) and Neelakantan et al.,\(^9\) who reported a high prevalence of the type III configuration in MB roots of second molars. Interestingly, many studies have shown the incidence of the type III canal configuration in the 2-canaled MB roots of second molars to
be lower than that in first molars. The significance of having the type II or III canal configuration is important during endodontic treatment. In MB roots with a type II canal anatomy, if the canals join near the apex and one of the 2 canals has not been cleaned properly, the chance of treatment failure will increase. On the other hand, if a patient has an MB root with type III canal configuration, clinicians

Table II. Number and frequency of additional canals in the mesiobuccal roots of the maxillary first and second molars by age

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>10-20</th>
<th>20-30</th>
<th>30-40</th>
<th>40-50</th>
<th>50-60</th>
<th>&gt;60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary first molar</td>
<td>44/54 (81.5)</td>
<td>129/178 (72.5)</td>
<td>59/69 (85.5)</td>
<td>41/58 (70.7)</td>
<td>42/71 (59.2)</td>
<td>14/28 (50)</td>
</tr>
<tr>
<td>Maxillary second molar</td>
<td>37/52 (71.2)</td>
<td>85/177 (48)</td>
<td>31/66 (46.9)</td>
<td>19/67 (28.4)</td>
<td>17/69 (24.6)</td>
<td>8/36 (22.2)</td>
</tr>
</tbody>
</table>

Values within parentheses are percentages of total number of teeth examined.

Table III. Number and frequency of additional canals in the mesiobuccal roots of the maxillary first and second molars by gender and tooth position

<table>
<thead>
<tr>
<th>Gender</th>
<th>Tooth position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Maxillary first molar</td>
<td>(n = 277)</td>
</tr>
<tr>
<td>Maxillary second molar</td>
<td>(n = 298)</td>
</tr>
<tr>
<td></td>
<td>145 (48.7)*</td>
</tr>
</tbody>
</table>

*Statistically significant (P < .05).
should keep trying techniques and devices necessary to locate, debride, and fill both canals and the entire root canal system to produce a more predictable and favorable prognosis.\textsuperscript{33} This is the reason why a better understanding of internal morphology of root canal system is essential for successful outcome of endodontic therapy.

Regarding the incidence of MB2 canals in maxillary first molars, previous in vivo and in vitro studies have shown the incidence to range from 56.9\% to 96.0\%.\textsuperscript{4-7,10-13,18,19,21,23,24,30,34,35} The present CBCT result (71.8\%) was within the range reported in those studies, which means that CBCT may be useful for finding or confirming additional canals.\textsuperscript{29}

Considering that ethnicity might result in differences in tooth morphology,\textsuperscript{7} 2 ex vivo morphology studies of Korean populations were compared.\textsuperscript{18,35} Both studies examined the incidence of an MB2 canal in extracted maxillary first molars by using MCT\textsuperscript{18} and a sectioning method after instrumentation and obturation.\textsuperscript{35} The incidences were reported to be 71.7\% and 80.8\%, respectively, and the present CBCT result was within that range. Furthermore, the most common canal configuration in those 2 studies was the same (type III) as in the present study.

For the MB roots of maxillary second molars in the present study, the incidence of an MB2 canal (42.2\%) was similar to the results of some studies\textsuperscript{10,11,31,32} but higher than reported by others.\textsuperscript{1,6,9,36} This variation in the incidence of an MB2 canal can be attributed to multiple factors, such as the study design (clinical/ laboratory), method of analysis, population studied, and age of the sample (tooth).\textsuperscript{7,9,36}

In the present study, a significant correlation with the tooth position was not found in either molar, but a significant gender difference was found regarding the incidence of an MB2 canal in the maxillary second molars. These results concur with those reported by Fogel et al.\textsuperscript{34} However, Zheng et al.\textsuperscript{8} and Neaverth et al.\textsuperscript{23} reported that gender or tooth position had little impact on the incidence of an MB2 canal.

Although tooth position had no influence on the incidence of an MB2 canal in the present study, both the first and second molars showed a high tendency for the bilateral occurrence of an MB2 canal (73.4\% for first molars vs. 52.0\% for second molars). This means that if an MB2 canal exists on 1 side, clinicians must consider the possibility of 2 canals in the contralateral MB root and search for them when treating the contralateral maxillary molars.

Recently, MCT has been used as a precise noninvasive technique in experimental endodontology.\textsuperscript{20} However, the technique is time consuming and suitable only for laboratory use on a limited number of teeth.\textsuperscript{19} In contrast, CBCT technology provides the clinician with an imaging modality that is capable of providing a 3D representation of the maxillofacial region and teeth with minimal distortion. Blatter et al.\textsuperscript{30} evaluated the ability of CBCT to detect an MB2 canal accurately in extracted maxillary first and second molars. They demonstrated that CBCT scanning accurately identified the presence or absence of an MB2 canal in 78.9\% of samples and was a reliable method for detecting an MB2 canal compared with sectioning of the specimens. Matherne et al.\textsuperscript{37} compared the ability of CBCT to identify root canal systems with images obtained by charge-coupled device and photostimulable phosphor plate digital radiography in vitro, concluding that CBCT images always identified a larger number of root canals than did digital images. They concluded from their results that CBCT is an accurate and effective tool for examining the morphology of the root canal.

The present study clearly showed that age had some influence on the incidence of an MB2 canal in maxillary MB roots. The maxillary first molars in subjects 30-40 years old and the maxillary second molars in subjects 10-20 years old showed the highest frequency of an MB2 canal. Furthermore, an inverse correlation was found between age and frequency of an MB2 canal in both maxillary molars. With age, the time the tooth had been exposed to outside irritation, such as caries, trauma, and canal calcification caused by restorative procedures, also increased, and the probability of locating an MB2 canal decreased. This was also confirmed by the results of Neaverth et al.\textsuperscript{23} and Thomas et al.\textsuperscript{13} We therefore suggest that more attention be directed toward searching for and locating MB2 canals in the MB roots of maxillary molars, especially in those patients <40 years old. In this regard, the incidence of an MB2 canal may have been underestimated in the present study. Because older subjects have more calcified canals and the diameter(s) of the additional canal(s) are smaller than the diameter of the MB1 canal,\textsuperscript{38} it would be too difficult to detect the additional canal(s) clearly in the CBCT images.

Although many earlier studies, as well as the present study, clearly demonstrated that CBCT systems might be a valuable tool for morphologic analysis of the root canal system,\textsuperscript{8,9,28-30,37,39,40} CBCT cannot be routinely used in all cases of nonsurgical endodontic treatment. It is worth remembering that CBCT still uses ionizing radiation and is not without risk. It is essential that the patient’s radiation exposure be kept as low as reasonably achievable\textsuperscript{41} and that evidence-based selection criteria for CBCT be developed. Therefore, endodontic cases should be judged individually, and until further
evidence is available, CBCT should be considered only when it has been determined that conventional radiographic view(s) are yielding limited information and that further radiographic details are required for diagnosis and treatment planning. 26-29,42,43

In conclusion, the present retrospective study showed that the Korean population has a higher prevalence of type III and II canal configurations in 2-canaled MB roots of maxillary molars and that the incidence of 2 canals in MB roots was higher in first molars than in second molars. These anatomic variations of MB roots may exist in ethnically different populations and should be considered during surgical or nonsurgical endodontic procedures of the permanent maxillary molars.

REFERENCES

34. Fogel HM, Peikoff MD, Christie WH. Canal configuration in the


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