ABSTRACT

Aim. To determine the root and canal morphology of permanent maxillary first molars in a Sri Lankan population with special emphasis on the presence of a second canal in the mesiobuccal root.

Materials and Methods. One hundred and fourteen permanent maxillary first molars were examined. The root numbers of the molars were recorded. Root canal morphology was studied using a clearing technique. The examination of root canal systems of the teeth were based on Vertucci’s classification. The location of the second canal in the mesiobuccal root was determined by recording its position along the imaginary line between the main mesiobuccal and palatal orifices.

Result. The commonest canal type in the mesiobuccal root was type IV (42.1%), followed by type II (24.5%) and type I (22.8%). The prevalence of a second canal in the mesiobuccal root was 77.1% and the opening of the second mesiobuccal canal was located in 79% of the cases at the buccal one third of the imaginary line between the main mesiobuccal and palatal orifices. The distobuccal and palatal roots were typically presented with Type I canal configuration. Inter canal communications and lateral canals were more frequently seen in the mesiobuccal root.

Conclusion. The root canal morphology of maxillary first molars is variable in different population groups. Root canal morphology of maxillary first molar of Sri Lankans is consistent with that of people of western Eurasia and far different from people of Sub Saharan Africa.

Key Words: Mesiobuccal root, Permanent maxillary first molars, Population difference, Root canal morphology, Sri Lankan people
maxillary molars. If the prevalence of the MB2 is high in a population, time should be devoted to its location and treatment.\textsuperscript{27} It is also emphasized that when treating M1, the operator should assume that there are two canals present in the MB root and only after a thorough search for a second canal and after it is determined that further preparation would be fruitless or cause a perforation, should the operator accept treating only one canal.\textsuperscript{28} Tuncer et al.\textsuperscript{29} reported in a Turkish sub-population that the presence of second mesiobuccal canal (MB2) is 78.0% and furthermore, it originates disto-palatal to the main mesiobuccal canal (MB1). A study conducted on a Chinese population found that additional canals in the MB root were symmetrically distributed in M1,30. Moreover, it has been reported that the MB root of M1 contains a double root canal system more often than a single canal and highlighted that presence of MB2 is highly variable among different world populations.\textsuperscript{31} For example, in their literature review on the canal morphology of the MB root of M1 using 34 studies of different world populations, Cleghorn et al.\textsuperscript{31} have recorded that the presence MB2 varies from 25.0% to 93.5%. However, most of these previous contributions of root and canal morphology of M1 have been conducted on teeth of European, North American and Far Eastern populations. Prevalence of such morphological variations for South Asian people has rarely been reported. Chopra and Bal\textsuperscript{32} who investigated the canal morphology of M1 radiographically, have shown a high prevalence of MB2 (81.3%) in an Indian population. Meanwhile, Peiris\textsuperscript{33} who discussed the root and canal morphology of human permanent teeth in a Sri Lankan and Japanese population reported that the occurrence of MB2 in Sri Lankans and Japanese is nearly identical (73.2% and 74.1%, respectively). Nevertheless, a detailed discussion on root canal morphology of the MB root of M1 is yet to be done on Sri Lankans. Moreover, the information concerning the frequency of occurrence of root canal variants in human M1 of especially South Asian populations is insufficient from anthropological and clinical perspectives.

Therefore, we conducted this study to determine the root and canal morphology of Sri Lankan permanent maxillary first molar with special concern to the presence of a second canal in the mesiobuccal root.

**MATERIALS AND METHODS**

One hundred and fourteen Sri Lankan permanent maxillary first molars were used in this study. Teeth were collected from patients who came for extractions due to several reasons such as caries, before prosthodontic treatments, etc. at the Department of Oral Surgery, Faculty of Dental Sciences, University of Peradeniya, General Hospital, Polonnaruwa and a Private Dental practice in Matale. All the subjects enrolled in this research responded to an informed-consent protocol, which has been approved by the Faculty Research Committee of the Faculty of Dental Sciences, University of Peradeniya and it conforms to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh 2000). Only teeth, which could be verified as maxillary permanent first molar teeth by crown morphology, were included.

Teeth were washed immediately after extraction and stored in 10% formalin until the collection was completed. They were boiled in 5% NaOH for 5 minutes and then cleaned with 10% NaOCl to remove organic debris on the surface. Any further deposits such as calculus and bone fragments were removed by scaling and polishing and each specimen was examined visually beneath a quartz-halogen light with the aid of a hand lens. The root number of the molars was recorded following Turner’s classification;\textsuperscript{33} a root is not considered separate and distinct unless it is independent of other roots for at least one fourth to one third of the total root length.

After recording the external root morphology of the teeth, vacuum injection protocol described by Yoshiuchi et al.\textsuperscript{34} was used to inject the ink into the root canal system and make the tooth transparent in order to visualize the canal system. Initially, a rhomboid access cavity was prepared in all teeth to expose the canal orifices and allow proper infiltration of the ink into the canal system. China ink was injected into the pulp cavity under high pressure, two to three times. Teeth were then thoroughly cleaned with water to remove any stains on the surface and demineralized for five days in 5% Nitric acid at room temperature (25°C). The Nitric acid solution was changed everyday. To test the reliability of the demineralization procedure, teeth were tested for softness by inserting a needle in the
coronal region. After demineralization, the teeth were rinsed in running water for 24 hours and then dehydrated using ascending concentrations of ethanol (70%, 80%, 90%, 95%, and 100%) for 5 days. Finally, the teeth were rendered transparent by immersing in a solution containing benzoic acid mixed with Benzene and Methylsalicylate for 2-3 days. At the end of this procedure, all the samples were transparent.

The cleared specimens were examined under a dissecting microscope at ×10 magnification and the number and type of root canals, the number and position of lateral canals and inter canal communications were recorded. During the evaluation of the samples, Vertucci’s classification was taken as the main reference. Vertucci classified root canal configuration of human permanent teeth into eight types (Figure 1 & 2) type I (1) – A single canal extends from the pulp chamber to the apex. type II (2-1) – two separate canals leave the pulp chamber and join short of the apex to form one canal. type III (1-2-1) – One canal leaves the pulp chamber, divides into two within the root, and then merges to exit as one canal. type IV (2) – Two separate and distinct canals extend from the pulp chamber to the apex. type V (1-2) – One canal leaves the pulp chamber and divides short of the apex into two separate and distinct canals with separate apical foramina. type VI (2-1-2) – Two separate canals leave the pulp chamber, merge within the body of the root, and re-divide short of the apex to exit as two distinct canals. type VII (1-2-1-2) – One canal leaves the pulp chamber, divides and then rejoins within the body of the root, and finally re-divides into two distinct canals short of the apex. type VIII (3) – Three separate canals extend from the pulp chamber to the apex. Furthermore, location of the MB2 was determined by recording its position along the imaginary line between the MB1 and palatal orifices (MB1-P line). We divided the MB1-P line into three segments namely buccal, middle and palatal one third for this purpose.

A test of the consistency of the observer in assessing root canal types was done by re-examining the MB root of 50 randomly selected molars and then comparing this test to the original canal assessment. Concordance rate was 96% for canal types, indicating that using the present classifications, canal morphology could be scored with high reliability. The MB root was selected because it showed the most variable and complicated canal morphology. We combined male and female for the analysis because no statistically significant difference was observed in either root or canal morphologies. Prevalence of root canal types in the mesiobuccal, distobuccal and palatal root was calculated. Prevalence of MB2 was also calculated. SPSS (Version 18) software was used for the statistical analysis.
Table 1. Root canal morphology of the permanent maxillary first molar in a Sri Lankan population (%)

<table>
<thead>
<tr>
<th>Canal Configuration</th>
<th>Canal Type</th>
<th>Mb (n=114)</th>
<th>Db (n=114)</th>
<th>P (n=114)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I</td>
<td>22.8</td>
<td>96.5</td>
<td>99.1</td>
</tr>
<tr>
<td>2-1</td>
<td>II</td>
<td>24.5</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>1-2-1</td>
<td>III</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>IV</td>
<td>42.1</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>1-2</td>
<td>V</td>
<td>4.4</td>
<td>1.7</td>
<td>0.9</td>
</tr>
<tr>
<td>2-1-2</td>
<td>VI</td>
<td>4.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1-2-1-2</td>
<td>VII</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>VII</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Prevalence of MB2 in maxillary first molars in different population groups (%)

<table>
<thead>
<tr>
<th>Population group</th>
<th>Prevalence of MB2</th>
<th>Population group</th>
<th>Prevalence of MB2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Eurasia</td>
<td></td>
<td>Sino Americans</td>
<td></td>
</tr>
<tr>
<td>New Zealand</td>
<td>77.0</td>
<td>Chinese</td>
<td>52.2</td>
</tr>
<tr>
<td>Italian</td>
<td>90.0</td>
<td>Japanese</td>
<td>55.6</td>
</tr>
<tr>
<td>American whites</td>
<td>79.8</td>
<td>Korean</td>
<td>71.8</td>
</tr>
<tr>
<td>Turkish</td>
<td>78.0</td>
<td>Sundan Pacific</td>
<td></td>
</tr>
<tr>
<td>Serbian</td>
<td>86.5</td>
<td>Indonesian</td>
<td>68.5</td>
</tr>
<tr>
<td>Indian</td>
<td>81.3</td>
<td>Thai</td>
<td>65.0</td>
</tr>
<tr>
<td>German</td>
<td>78.0</td>
<td>Burmese</td>
<td>66.7</td>
</tr>
<tr>
<td>Irish</td>
<td>78.0</td>
<td>Sub Saharan Africa</td>
<td>22.0</td>
</tr>
<tr>
<td>Jordanian</td>
<td>77.3</td>
<td>Nigerian</td>
<td>25.0</td>
</tr>
<tr>
<td>Sri Lankan</td>
<td>77.0</td>
<td>Ugandan</td>
<td></td>
</tr>
</tbody>
</table>

aPresent study

RESULTS

The data for root canal morphology are presented in Table 1 and 2. All 114 maxillary first molars observed had three roots with two buccal (mesiobuccal, distobuccal) and one palatal. The MB roots of M1 presented with two canals in 77.1% of the cases with type II (24.5%), III (1.7%), IV (42.1%), V (4.4%), and VI (4.4%). The prevalence of two canals and two apical foramina with type IV, V, VI canal configurations in the MB root was 50.9% (Table 1). Furthermore, MB root showed two separate canal openings at the floor of the pulp chamber in 71% of the cases with type II, IV and VI canal configurations (Table 1). In these cases, opening of the MB2 was located in 79% of the cases at the buccal one third of the MB1-P line. Meanwhile, the location of MB2 in the middle and palatal one third was seen in 20.9% and 0% of teeth observed. The distobuccal and palatal roots of M1 were typically presented with type I canal configuration (96.4% and 99.1%, respectively) (Table 1).

The percentages of number and location of the lateral canals and inter canal communications are presented in Table 2. Inter canal communications were more common in the MB root of M1 (47.3%). They were seen less frequently in the distobuccal and palatal roots (6.1% and 0.9%, respectively). Inter canal communications were found mostly in the middle one third and less frequently in the cervical and apical one third of the root, respectively. In few cases, they were observed in all positions simultaneously. In addition, variable number of communications was found at each position. For example, number of inter canal communications at the middle one third varied from 1-5 canals. Lateral canals were more frequently seen in the MB root (45.6%). When present they were commonly found at the cervical (23.8%) and apical (15.8%) one third while middle one third showed a lower prevalence (1.7%).

DISCUSSION

According to Carlsen,35 the primary elements of the root complex are root cones and supernumerary
radicular structures. For consistency with other publications, we used the term ‘radical’ rather than ‘cone’ to refer to unseparated root like divisions. When a root has two or more radicals, the individual root elements may be completely or incompletely divided. In completely separated root, radicals are completely divided by inter-radicular processes at some point along the total length of a root and the result is two or more separated roots.

Table 3. Number and position of lateral canals and inter canal communications in maxillary first molars of Sri Lankan people (%)

<table>
<thead>
<tr>
<th>N</th>
<th>Lateral canals</th>
<th>Position of lateral canals</th>
<th>Inter canal communications</th>
<th>Position of inter canal communications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>114</td>
<td></td>
<td>45.6</td>
<td>23</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>114</td>
<td></td>
<td>5.2</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

C – cervical 1/3 of the root, M – middle 1/3 of the root, A – apical 1/3 of the root

In M1, three root components always occur, a mesiobuccal, distobuccal and a palatal component. The three root components are often separated by inter radicular processes. Each root component of M1 is usually composed of two root radicals, and they are usually nonseparated throughout the cervicoapical extension. For example, MB and distobuccal roots have a buccal and palatal radical each. The palatal root has a mesial and distal radical. In the MB root the two root radicals may be separated apically and presented with a bifid apex. Few investigations have recorded unusual root morphology in the M1 with two palatal roots. This rare situation can be explained as complete separation of the mesial and distal radical of the palatal root. Moreover, in the present study, we observed a single incidence of Type V (1 2) canal morphology in the palatal root showing a situation where the two radicals are incompletely divided due to only minimal penetration of the inter-radicular process and therefore, the root is not divided externally but the root canal system is divided internally. However, complete division of radicals is not reported yet in the literature for the MB and distobuccal root of M1. Meanwhile, as evident in the present study and all the other investigations regarding the root canal morphology of M1, incomplete division of radicals having one root and two root canals is seen most frequently in the MB and less frequently in the distobuccal root.

Verma and Love found a high incidence of MB2 (90%) in M1 in a New Zealand population. They further reported a single apical foramen in 15%, two foramina in 20% and three or more foramina in 65% of the teeth observed. Degerness and Bowles recorded incidence of MB2 in an American population as 79.8%. Furthermore, Somma et al. also reported a high incidence (80%) of MB2 in M1 in an Italian population and when present, the MB2 canal merged with the MB1 in 58% of the cases. Chopra and Bal and Beljić-Ivanović and Teodorović have investigated the prevalence of MB2 in Indian and Serbian populations and recorded its presence as 81.3% and 86.5%, respectively. In a similar study on a Turkish, German and Irish populations Alaçam et al., Schwarze et al., and Al Shalabi et al., respectively claimed the
occurrence of MB2 in M1 as 78% each. Meanwhile, 77.3% of Jordanian has shown MB2 in a study of Smadi and Khraisat. Moreover, in a Chinese population Zheng et al. stated the incidence of additional canals in MB root as 52.2%. In addition, they highlighted that patients aged 20 to 30 years showed a higher prevalence of additional MB root canals. MB2 was seen in 55.6% and 71.8% of the cases in Japanese and Korean populations, respectively. Furthermore, Abiodun-Solanke et al. encountered a low prevalence (22%) of MB2 in a Nigerian population. Rwenyonyi et al. investigated the root canal morphology of maxillary molars in an Ugandan population and reported type I canal configuration was the most frequent (>75%) in all the roots of the first molars investigated. Meanwhile, Peeters et al. recorded the incidence of MB2 in M1 as 68.5% in an Indonesian population. Similar findings were observed in Thai and Burmese populations as 65.0% and 66.7%, respectively.

In the present investigation, we observed a wide variation of canal morphology in the MB root. Two canals were found in 77.1% of the cases and two canals and two apical foramina were observed in 50.8% of the cases. In the meantime, two separate canal openings at the floor of the pulp chamber were seen in 71% of the cases investigated. Therefore, our result has close affinities with those of populations of western Eurasia such as New Zealand, American, Turkish, Italian, etc. which have showed high prevalence of MB2. Furthermore, the presence of MB2 in Sri Lankans is different from that of the people of Sub Saharan Africa which have shown low prevalence and Sino American and Sahul pacific populations which have shown moderately high prevalence (Table 3).

The prevalence and factors affecting the negotiability of the MB2 in maxillary molars have been discussed in several occasions in the literature. However, there is little being reported about the location of MB2. The openings of MB2 are localized on an imaginary line between the MB1 and palatal orifices (MB1-P line). Peeters et al. reported that the distance between the orifices of MB1 and MB2 varied from 0.3 mm to 3.8 mm (Mean - 1.55 mm). Kulild and Peters and Gilles and Reader described the MB2 canal according to the MB1 and found the mean distance of MB2 from the MB1 as 2.31 mm and 1.82 mm, respectively.

Görduysus et al. and Zhang et al. remarked that the location of the MB2 canal varied not only in relation to the MB1 but also to MB1-P line. Zhang et al. reported that the MB2 was located less than 1mm mesial to the MB1-P line and 2mm palatal from the MB1. Görduysus et al. determined that the location of the MB2 in 45 extracted maxillary molars and found that MB2 is 0.69 mm mesial to the MB1-P line and 1.65 mm palatal from the MB1. Furthermore, in a microcomputed tomographic analysis of mesiobuccal orifices in M1, Spagnuolo et al. recorded that the mean vertical distance between MB1 and MB2 planes was 1.68 mm and the mean horizontal interorificial distance between MB1 and MB2 orifices was 1.21 mm. In our study, it was observed that majority of MB2 (79%) was located at the buccal one third of the MB1-P line. Therefore, our findings are in accord with those of other investigations. Interestingly, we observed that in a moderate number of cases (20.9%) the location of MB2 canal was in the middle one third of the MB1-P line. A good knowledge and understanding of these variations in the location of MB2 is important for access cavity design. Weller and Hartwell suggested that if the initial access is changed from a classical triangular shape to a more rhomboidal shape, the probability of finding the MB2 canal increases.

The present investigation showed that the root canal morphology of the MB root of the M1 is highly variable and frequently has more than one canal. We found that the prevalence of MB2 in M1 was 77.1% in a Sri Lankan population. Root canal morphology of M1 of Sri Lankans is consistent with that of people of western Eurasian population groups and far different from the people of Sub Saharan African populations. In addition, we observed that majority of MB2 is located at the buccal one third of the MB1-P line. The present study further reinforces the idea that the root canal morphology is variable in different population groups. It is therefore important to be familiar with these variations because they ultimately may have both clinical and anthropological significance. Such knowledge can aid in the location and negotiation of canals as well as their subsequent management in clinical practice and even tracing the origins of world populations.

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