Analysis of Mandibular Premolars Root Canal Morphology Using Radiographic and Cross-Sectional Techniques in Malaysian Population

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Abstract

Introduction: Aberrant root canal morphology of mandibular premolars has always been associated with high endodontic treatment failures. This study was conducted to assess the canal morphology of the mandibular premolars in the Malaysian population using periapical radiographs and cross-sections of the premolar teeth. Materials and Methods: One hundred extracted permanent mandibular premolars with intact apex were randomly collected from various clinics across Malaysia. Radiographs were taken both in mesiodistal (MD) and buccolingual (BL) views to examine the presence of a second canal and to evaluate the type of canal configuration. The roots were then stained and perpendicularly resected to the long axis at three levels (cervical, middle, and apical one third). Digital photographs were taken for each of the cross-section sample and analyzed according to the number and shape of canals. Results: It was found that 78% of the mandibular premolars had single canal in BL radiographic view and 65% in MD view. Seventy-one percent of the single-canal premolars were observed in all three cross-sectional views (1-1-1 configuration). Furthermore, 37% showed oval-shaped canals and 34% showed irregular-shaped canals mainly found at cervical one third; 20% of the teeth showed the canals to be rounded in shape, most prevalent at the apical one third. Two canals with isthmus were observed in 5% of the all cross-sectional views. Conclusion: The majority of mandibular premolars in Malaysian population have a single canal, and there are a few possibilities of two or more canals in these teeth.

Keywords: Endodontics, mandibular premolars, radiography, root canal, tooth morphology

INTRODUCTION

Root canal treatment (RCT), also known as endodontic therapy, is a crucial, comprehensive practice in dental restorative care.[1] However, the lack of thorough knowledge about root canal anatomy, in terms of configuration of the pulp and possible variations, is one of the main reasons for treatment failure (e.g., coronal leakage) in endodontics. Thus, it is essential for a clinician to picture the pulp in cross-section from the coronal aspect to the apical foramen, so as to reach maximum canal area while chemomechanical preparation. In fact, different methods have been used to study the root canal morphology. These include the use of radiography,[2] by placing files in the canals to determine canal configuration,[3] cross-sectioning the teeth at different levels,[4] polyester resin cast replicas of the pulp spaces,[5] injection of dye and clearing,[6] and computed tomography (CT).[7] Instruments must access the corners and hidden regions to avoid or minimize treatment failures.[8,9]

Endodontically, the mandibular premolars present the most difficult teeth to treat with the highest failure rate (up to 11.45%) reported during RCT.[10] As per the ideal root anatomy, mandibular premolar is expected to have single canal exiting in a single apical foramen. However, in clinical scenario, they may have the most complex anatomical configuration with high prevalence of curvatures, fins, and isthmuses, and may branch, divide, and rejoin taking various
A plethora of studies were conducted on root canal anatomy, from the early work of Hess and Zurcher, back in 1925 to the more recent, demonstrating anatomic complexities of the root canal systems; these all have emphasized on the fact that a root with tapering canal and a single foramen is an exception rather than a rule. Weine et al. had categorized the root canal system into four basic types. Meanwhile, Vertucci had later reported numerous complex canal systems and identified eight pulp canal configurations.

Interestingly, there is a wide variation in coronal shape, external root form, and internal canal space morphology in the Asian population. The incidence of two or more canals in mandibular premolar was found to be varying between 1.2% and 34%. Based on a systematic review conducted by Kottoor et al., a significant variation in the number of roots, apical foramen, and root canals configuration was observed between different ethnicities, which includes Caucasian, Indian, Mongoloid, and Middle Eastern populations, involving a total of 12,752 and 6646 first and second mandibular premolars, respectively. By means of traditional decalcifying and stereomicroscopy techniques, Jain and Bahuguna studied 138 mandibular premolars and stated that 97.1% of them are single-rooted and only four teeth (2.89%) had two roots. Meanwhile, earlier studies performed by Miyoshi et al., using radiographic technique, reported that about 13.8% of Japanese population had two canals, whereas Walker had later reported numerous complex canal systems; these all have emphasized on the fact that a root with tapering canal and a single foramen is an exception rather than a rule. Weine et al. had categorized the root canal system into four basic types. Meanwhile, Vertucci had later reported numerous complex canal systems and identified eight pulp canal configurations.

Little information was known regarding the root canal anatomy and morphology of the mandibular premolars in the Malaysian population. Therefore, the purpose of this study was to investigate the root canal morphology of mandibular premolars in a Malaysian population using both radiographic and cross-sectioning method.

Materials and Methods

Ethical approval was obtained from the Institutional Review Board, Research Management Centre (RMC), MAHSA University, Saujana Putra Campus, Selangor, Malaysia (approval no. RMC/EC24/2017). A total of 100 extracted human mandibular premolars with intact apex were randomly collected from several clinics situated in different states in Malaysia. Written consent to publish was taken from the included patient regarding incorporating his radiographic and cross-sectional tooth images in this study. Mandibular premolars were differentiated from maxillary premolars based on wider occlusal surface mesiodistally, circular/ square-shaped occlusal surface, and cusps are beyond the confines of the root trunk. The inclusion criteria were intact clinical crown and fully developed roots and no caries involving or extending to the root. The exclusion criteria were carious teeth, fractured teeth, teeth with aberrant shapes, teeth with full-coverage restoration, and root-canal-treated teeth. The teeth were cleaned using ultrasonic scaler (Piezon Master 400; Boise, Idaho, Switzerland), washed with tap water, and then placed in 5.25% sodium hypochlorite (Clorox; Clorox Co., Oakland, California, USA) for 24 h to remove organic substance.

Teeth were arranged over intraoral periapical dental radiographic film (size no. 2, Kodak Insight Dental film in SureSoft packet IP21-S; Eastman Kodak Company, Rochester, New York, USA), and radiographs were taken in teeth placed in both mesiodistal (MD) and buccolingual (BL) direction using paralleling technique. For research purposes, MD direction is used to provide radiographic view from another angulation. Teeth were placed directly on the film in a MD view as stabilization was not needed. The X-ray cone was directed perpendicularly on the table where the films were placed flat. As for BL radiographic view, the teeth were directly placed on the X-ray film, stabilized with a small piece of sticky wax at the crowns. To minimize variations, target film distance was kept at 5 cm. The X-rays were developed according to the manufacturer instructions. The resultant images were systematically examined by two independent observers in a dark room using an illuminated viewer box (Star X-ray Illuminator; Star X-ray, Amityville, New York, USA) under 2.5x magnification for the presence of a single root canal or variations. The configurations of each canal at both views for each tooth were recorded and tabulated.

The root length from cementoenamel junction (CEJ) to the apex of each tooth was measured using a digital Vernier caliper. Access cavity was prepared using No. 2 round diamond bur (Mani, Takenzawa, Japan), with a high-speed handpiece (NSK Standard; NSK, Osaka, Japan) and air–water spray. To ensure smooth flow of the injected dye, a No. 2 endo access bur was used to prepare the access cavity. Using a 2-ml syringe and disposable 21G×1/2” needle (Terumo Co., Tokyo, Japan), carbol fuchsin solution (Merck, Brussels, Belgium) was injected into the root canal till the dye exited from the apex, which confirms that the whole root canal system was colored with the dye. Then, the root was resected perpendicular to the long axis starting from CEJ, at coronal one third (1 mm below CEJ), middle one third, and apical one third using a fine-cutting diamond disc. In this study, a sectional view of 1 mm below CEJ is obtained regardless of the tooth length, as it is more applicable in clinics, whereas gutta-percha is recommended to be sheared off 1 mm below CEJ level. Hence, a sectional view of 1 mm below CEJ is crucial as it provides a vision of the shape of the canals before cleaning and shaping was performed. Digital photographs of each section were taken at 24x magnification using digital camera (EOS 500D; Canon,
Tokyo, Japan), macrolens (EF 100-mm F2.8L; Canon), and flash system (MR-14EX II Macro Ring Lite; Canon) with fixed distance of 25 cm after mounting the cross-sections.

All the cross-sectional images of the mandibular premolar roots were examined on a computer screen by two examiners. The images of each tooth were evaluated from the most coronal section to the most apical section. The number of canals and morphologic configuration of the root canal system were determined and recorded. The presence of more than one canal in any cross-section of the root was categorized as variations. The shapes of each canal observed from each cross-section were also recorded and tabulated. Root canal systems were identified according to Vertucci’s classification and roots exhibiting two canals with isthmus were noted as additional findings.

**RESULTS**

All the samples (first and second premolars) had only a single root with average root length of 13.2 mm. Two cusps were found in all 100 premolars.

**Radiographic observations**

The radiographic results are summarized in Table 1. Of the 100 teeth studied, 78% displayed a single canal, uniform radiolucency from CEJ to apex in a BL radiographic view. Twenty-two percent of the samples showed variations where canals disappeared or narrowed, which probably infers presence of two canals. As for the MD radiographic views, 65% of the root canals were observed to have single canal and 35% showed variations. Figure 1 shows samples of radiographs representing the BL and MD radiographic views.

**Observations from cross-sectional view**

The results from cross-sectional view were also summarized in Table 1. About 71% of the mandibular premolars showed one canal in all three cross-sections giving 1-1-1 configuration, hence categorized as single canal. As for the other 29% of teeth, variations were noted where one or more of the three cross-sections showed more than one canals. Interestingly, there are strong correlation between findings using radiographic techniques and the cross-sectional views indicating the suitability of latter techniques in determination

### Table 1: Canal configuration of mandibular premolars based on buccolingual and mesiodistal views from X-ray findings and cross sectional views

| Canal number and configuration | Percentage of total |
|--------------------------------|---------------------|
| **A) Radiographic findings**   |                     |
| Bucco-Lingual (BL) views       |                     |
| Single root canal              | 78%                 |
| Complicated root canal (Variations) | 22%         |
| Mesio-Distal (MD) views        |                     |
| Single root canal              | 65%                 |
| Complicated root canal (Variations) | 35%         |
| **Canal type based on Mesio-Distal (MD) views** | Configurations | Percentage of total |
| Type I                         | (1-1)               | 65%                 |
| Type II                        | (2-1)               | 2%                  |
| Type III                       | (1-2-1)             | 5%                  |
| Type IV                        | (2-2)               | 1%                  |
| Type V                         | (1-2)               | 23%                 |
| Type VI                        | (2-1-2)             | 0%                  |
| Type VII                       | (1-2-1-2)           | 3%                  |
| Type VIII                      | (3-3)               | 1%                  |
| **B) Cross sectional views**  |                     |
| Cross sectional views          |                     |
| Single root canal              | 71%                 |
| Complicated root canal (Variations) | 29%         |
| **Canal type based on cross-sectional views** | Configurations | Percentage of total |
| Type I                         | (1-1-1)             | 71%                 |
| Type II                        | (2-1-1)             | 0%                  |
| Type III                       | (1-2-1)             | 2%                  |
| Type IV                        | (2-2-2)             | 0%                  |
| Type V                         | (1-2-2) or (1-1-2)  | 23%                 |
| Type VI                        | (2-1-2)             | 0%                  |
| Type VII                       | (1-2-1-2)           | 3%                  |
| Type VIII                      | (1-3-3)             | 1%                  |
of root canal morphology. The number of canals found in each cross-section and the shapes of each canal observed were shown in Table 2. The shapes were categorized into oval, round and irregular tear, flat, C-shaped, and others. Two canals with isthmus were recorded as an additional finding. The majority of the coronal and middle one-third cross-sectional views showed oval-shaped canals and apical third showed mainly round-shaped canals [Figure 2]. However, a large percentage of the canals observed (34% of all cross-sections) had an irregular shape. Two canals with isthmus (5%) were slightly more frequent as compared to two separate canals without isthmus (4%).

**DISCUSSION**

Several studies have reported the root and canal morphologies of the mandibular premolars because these teeth can present with complex morphologies and anatomical variations,[7,9,10,16] and hence have possessed a high frequency of endodontic flare-ups and failures.[25] Although it is unlikely to record the complexities of the root canal system such as lateral canals and eccentrically located apical foramina in periapical radiographs, it may demonstrate the main anatomical features.[26] Radiographs could be the only non-invasive means to provide clues about the morphology of the root canal system. This technique proved to be simple, fast, and needs little equipment.[27] In this study, periapical (PA) taken both in MD and BL views are compared and studied. MD view enables to clearly demarcate the presence of second roots canal if present. BL view is also included in this study, as it is routinely taken preoperatively, as a protocol of treatment before starting any RCT and therefore serves for comparison and validation of the findings.

Nattress and Martin[28] evaluated the incidence of twin canals in mandibular incisors and premolars and were able to detect many variations using the guideline of ‘Disappearance or narrowing infers division’ from PA radiograph. With similar concept, 78% of BL views were observed to have one canal compared to 65% from the MD views. This observation signifies that canal configuration should be studied with two different angulation radiographic views and not solely depending on one BL view.

Table 2: Shapes and additional findings of each canal

| Shapes        | Coronal 1/3 | Middle 1/3 | Apical 1/3 | Percentage |
|---------------|-------------|------------|------------|------------|
| Oval          | 52          | 36         | 22         | 37%        |
| Round         | 1           | 21         | 37         | 20%        |
| Irregular     | 47          | 30         | 25         | 34%        |
| Two canals    | With isthmus| 0          | 7          | 8          | 5%         |
|               | Without isthmus | 0 | 6 | 8 | 4% |

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Figure 1: Representative radiographical images of (A) the mandibular premolars showing (i) single canal and (ii) disappearance of canals, narrowed or divided into two (variations) from BL view. Representative radiographical images of (B) the mandibular premolars showing (i) single canal and (ii) different canals configurations term as variations from MD view.
Although radiographic method is noninvasive, it presents a two-dimensional image of a three-dimensional object and does not reveal the complexity present in the root canal system due to superimposition. The cross-section method combined with the magnification used in this study clearly exposed the complexity of root canal system and provided impressive images of the number and shapes of canals. In a study conducted by Sandhya et al.,[29] spiral CT has been used to investigate the different configurations of mandibular first premolars in Indian population and may be a technique for future studies involving mandibular premolars in Malaysia. A combination of CT followed by the transparent method or cross-sectional evaluations would possibly give more precise results.

The incidence of single canal (71%) reported in this investigation [Table 1] is in agreement with the results shown in the previous studies.[16-18] Ahmad et al.’s[16] study on Kashmiri population with a total of 100 extracted intact permanent mandibular premolars (50 each mandibular first premolar and mandibular second premolar) presented an incidence of type 1 single-canal teeth of 50% and 71%, respectively. Karunakaran et al.’s[17] findings on single root canal configuration of human permanent mandibular first molars of an Indo-Dravidian population based in southern India, on the other hand, revealed an incidence of 62.7%. Jain and Bahuguna[18] found that 67.39% of the 138 extracted mandibular first premolar teeth collected from a Gujarati population are type 1 single root canal system. In addition, predominant oval shape of the root canal at CEJ that tapers to a round canal shape in the apical segment is comparable to that described by Ingle and Beveridge.[30] A comparison was done between radiographic findings and cross-sectional observations. Actual canal configuration of 1-1-1 from cross-sectional observations was reported as 71% as compared to 78% in BL and 65% in MD views. This difference further proves that mere radiographic assessment may not be sufficient to understand the configuration and morphology of a root canal system. Shapes of the root canals are broadly categorized into three groups. Oval represents the general outline of the cavity access of mandibular premolars where the BL distance is more than the MD. Round shape is considered to be common. Irregular shaped are those that cannot be categorized in either oval or round such as C-shaped, dumbbell, tear, or flat. In the present study, the majority of the cross-sections showed oval-shaped canals. A large number of canals were found to be irregular. Therefore, endodontic instrumentation causing canals to be forcefully shaped into round should be reassessed. Possible removal of unnecessary dentinal wall can cause thinning of the root, which may result in perforation or root fracture.

An interesting finding was the presence of root canal isthmus in 5% of samples [shown in Table 2], which is a narrow ribbon-shaped communication from either one or two main root canals and can be considered as a lateral connection between canals within the same root.[31] Two canals with isthmus may complicate debridement of the root canal system. Instrumentation and debridement of the isthmus become more difficult, leaving it uninstrumented when present further apically. Inadequate debridement may leave bacteria and irritants within the canal system and compromised the healing of the periapical tissues. Complex anatomy, as such, could account for countless failures when treating mandibular premolars root.

**CONCLUSION**

The findings of the study emphasize the fact that root canal morphology has racial disparities. The majority of the
mandibular premolars in Malaysian population have a single canal, but the presence of two or more canals is not unusual; therefore, when performing endodontic therapy in mandibular premolars, clinicians should always predict a possibility of two or more canals in these teeth. Radiography combined with cross-sectioning is an efficient and reliable method of studying the complexity of root canal system.

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Conflicts of interest
There are no conflicts of interest.

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