

Root canal anatomy of mandibular first premolars in an Emirati subpopulation: A laboratory study

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ABSTRACT

Objective: The purpose of this study was to determine the root canal anatomy of mandibular first premolar teeth in an Emirati subpopulation using a decalcification and clearing method. **Materials and Methods:** One hundred permanent mandibular first premolar teeth extracted for orthodontic purposes from an Emirati subpopulation from the United Arab Emirates were used for this study. They were subjected to decalcification and clearing. The tooth length, the canal orifice shape, mesial invagination, canal pattern, the location of apex, presence of lateral canals, and intercanal communications were determined. **Results:** The most common canal pattern was the Vertucci Type I (65%) followed by Type V (14%) and Type IV (13%). The most common type of canal orifice seen was the oval shape (36%) followed by the round shape (25%). Mesial invaginations were seen in 44% of the teeth. The mean tooth length was 19.9 mm, and apical deltas were seen in 24% of teeth. **Conclusion:** The Vertucci Type I canal pattern was the most prevalent in the mandibular first premolars while the occurrence of multiple canals was noted in 35% of this population.

Key words: Canal morphology, Emirati population, premolar

INTRODUCTION

Successful root canal therapy requires a comprehensive knowledge of the root and the root canal morphology. There have been numerous studies assessing the root canal morphology over the years; from the early work of Hess and Zurcher^[1] to the most recent technologically advanced studies demonstrating complexities of the root canal system, and all these have concluded that a single root canal ending in a single foramen is rare. Deviations in the anatomy of the root canal systems occur often and are not considered abnormal.^[2] Unfilled canals may continue to harbor bacteria and can lead to posttreatment infection. Therefore, knowledge of the various root canal configurations aid the clinician to negotiate and debride the canals efficiently and thus provide a successful endodontic outcome.

A study by Brescia in 1961^[3] on human teeth reported that the mandibular first premolar displayed the most variable canal morphology. The Washington study also reported the mandibular first premolar had the highest rate of failure owing to the differences in the root canal morphology and inaccessibility of extra canals.^[4] The occurrence of two or more root canals in the mandibular first and second premolars have

been found to vary between 2.7% and 65% and 0–43% respectively.^[5-10]

It has been established that root canal systems vary among genders^[11] and races.^[12,13] Most studies assessing the root canal morphology of mandibular first premolars were performed on individuals from the American,^[13] Far-Eastern,^[14] Iranian,^[15] Indian,^[16] and Turkish population.^[17] A study of the Jordanian population in 2008^[18] reported the high prevalence of multiple canals in the mandibular premolars in comparison to studies performed in populations of different origins. A review of the literature by Cleghorn *et al.*^[19] on the permanent mandibular first premolar have revealed that this tooth has both a complex root morphology as well as a complex internal canal morphology.

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Various techniques have been employed to evaluate canal morphology such as conventional^[20] and digital radiographic techniques,^[21] using cross-sections,^[22] cone-beam computed tomography (CT),^[23] and peripheral quantitative computed tomographic imaging.^[24] More recently, micro-CT has been utilized in canal morphology studies. It has been shown that detailed information can be obtained *ex vivo* by demineralization and staining.^[13,24,25] This clearing technique allows the form of the canal and all minute structures to be clearly visible, enabling the tooth to be preserved for a considerable amount of time with the use of readily available and inexpensive chemicals.^[26]

The purpose of this study was to investigate the root canal morphology of mandibular first premolars in an Emirati subpopulation using decalcification and clearing method.

MATERIALS AND METHODS

One hundred extracted permanent mandibular first premolar teeth were collected in the United Arab Emirates (UAE) from an Emirati subpopulation. These teeth were acquired from the tooth bank of the Oral Surgery Department of Al Tawam Hospital, Al Ain, and UAE from Emirati patients who had undergone orthodontic treatment at the hospital. The extracted permanent mandibular first premolars were collected in a separate container to avoid mixing with the second mandibular premolars. A written consent for usage of patients' extracted teeth for research purposes was obtained. The patients' ages ranged between 16 and 24 years while gender was not specified. Teeth with large carious lesions, large metal restorations, teeth with fractures, and teeth with immature apices and those which were endodontically filled were discarded. Ethical approval for this study was obtained from the Research and Ethics Committee, University of Sharjah (No. 110077), in accordance with The World Medical Association Declaration of Helsinki.

The teeth samples were stored in 10% formalin. All the soft tissue and calculus attached on the tooth surface was removed using an ultrasonic scaler. The tooth length was measured using vernier calipers from the tip of the crown to the apex of the root. The presence or absence of mesial invagination was observed on the root surface. The teeth were then subject to the process of decalcification and clearing following the method explained by Robertson *et al.*^[27]

Access cavities were prepared on all teeth using a no. 2 round bur (Cavity Access Z Set, Dentsply,

Maillefer, USA), the root canal orifice was located, seen with the naked eye, and was photographed using the microscope at $\times 12.8$ (Zeiss, OPMI PROergo, Germany). Following this, the teeth samples were kept in 3% sodium hypochlorite for 48 h and agitated manually to remove the pulp tissue. The samples were rinsed in running tap water for 2 h and dried overnight. India ink (Sanford Rotring GmbH, Hamburg, Germany) was injected into the pulp chamber using an endodontic irrigating syringe with a 27-gauge needle. Simultaneously, a suction tip was placed at the root apex to draw the ink through the root canal system. Excess ink was removed from the surface with gauze soaked in alcohol.

The teeth samples were then placed in 5% nitric acid for 72 h. The acid in which the samples were soaked was changed every 24 h and was stirred once every 8 h. The decalcification was considered complete after verifying by periodic radiography. The teeth were then washed in running water and dehydrated by immersing the samples in increasing concentrations of isopropyl alcohol (70%, 80%, 90% and 100%) for 12 h consecutively. The samples were then immersed in methyl salicylate (99% methyl salicylate, Al Nawras Medilab, Dubai, UAE) to make them transparent and were stored in this solution until examination.

The samples were observed with a $\times 3$ magnifying glass, and the canal configurations were categorized into the eight types according to Vertucci's classification.^[13] Location of the apex whether central or lateral and apical deltas, if the present was documented. Lateral canals (LCs), which are branches of the main canal which arise along its length at right angles or obtuse angles to open onto the side of the root, were identified in reference to the coronal, middle or apical third of the root. Intercanal communications (ICCs), defined as complex canal ramifications that join the main canal but do not open onto the root surface, were also identified in reference to the coronal, middle or apical third of the root.

RESULTS

In the one hundred lower first premolar teeth collected, the average length was 19.93 mm (standard deviation 2.084). All the teeth were single rooted, and 44% had mesial invaginations on the root surface. Various canal patterns seen in the present samples are shown in Table 1 and Figure 1. There were no teeth which displayed Vertucci Type VI, VII, and VIII canal morphology. We observed two canal morphology which did not match Vertucci's classification.

Table 1: Percentage of canal system types		
Type of canal	Canal pattern	Percentage (n=100)
Type I	1	65
Type II	2-1	2
Type III	1-2-1	3
Type IV	2	13
Type V	1-2	14
Type VI	2-1-2	0
Type VII	1-2-1-2	0
Type VIII	3	0
Modification 1	2-3	1
Modification 2	1-4	2

They have been described as Modification 1 and modification 2 [Figure 2a and b]. Modification 1 is where two canals arise from the pulp chamber in the coronal third and one of these canals further divide into two in the middle third of the root. Modification 2 is where the main trunk of the root canal divides into four canals in the apical third of the root.

Forty-four percent of the teeth displayed mesial invaginations, of which the canal patterns were Type IV (11%), Type V (10%), 1% modification 1 and 2% modification 2, and Type I (20%). LCs, when present, were seen typically in the coronal and middle third of the teeth [Figure 3].

ICCs, if present, were observed in the middle and apical third of the teeth [Figure 4]. Apical deltas are shown in Figure 5. The shapes of the orifices

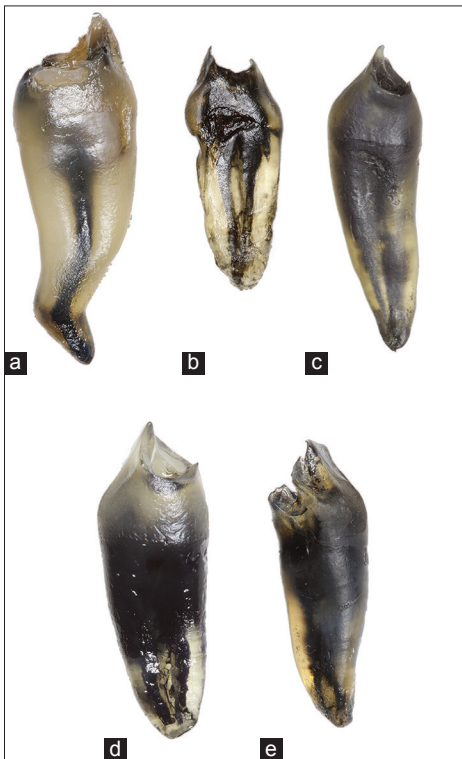


Figure 1: The canal patterns (a) Type I, (b) Type II, (c) Type III, (d) Type IV, and (e) Type V



Figure 2: Alterations in canal morphology (a) Modification 1, (b) modification 2



Figure 3: Lateral canals



Figure 4: Intercanal communication

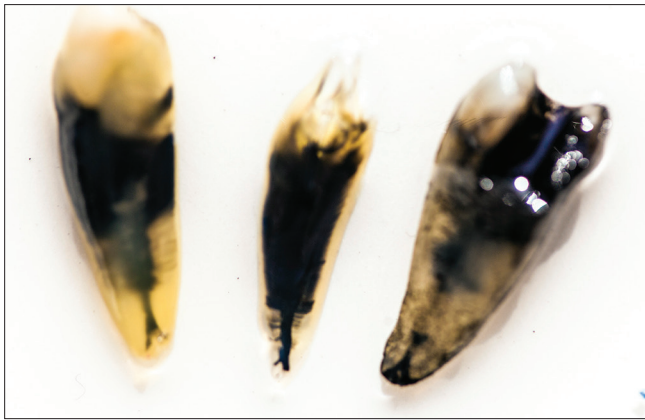


Figure 5: Apical delta

photographed using the microscope are shown in Figure 6 a-d, and detailed percentages of various orifices observed in the present sample are given in Table 2.

DISCUSSION

Complexities in root canal anatomy differ in ethnic populations. Evaluation of root canal morphology of first mandibular premolar teeth in an Emirati subpopulation will unveil canal characters in this ethnic group. The mean length of the first mandibular premolar teeth was 19.9 mm which is comparable to previous studies.^[17,28,29] In this study, although all teeth were single rooted, there were mesial invaginations in 44% of the teeth. Twenty-four percent of these teeth with invaginations displayed multiple canal morphologies. The presence of mesial invaginations should lead the clinician to suspect a possibility of multiple canals as observed in the present study.^[16] Lu *et al.*^[22] in their study on permanent mandibular first premolars showed that all permanent mandibular premolars that had an external concavity on the root surface showed a C-shaped configuration. The groove did not always extend upto the root apex. The C-shaped morphology was found in the apical 3 mm and or 6 mm cross sections with their coronal sections demonstrating a single oval or two canals in an oval-shaped root. All the samples in the present study were single rooted yet 44% of them had mesial invaginations present. Furthermore, the samples in the present study were only viewed coronally, and the majority of the orifices were either oval-shaped (36%) or round (25%). There were only two samples that showed a C-shaped orifice coronally. Baisden *et al.*^[9] using cross-sectional method also reported a 14% incidence of C-shaped canals in 106 permanent mandibular premolars in the United States population.

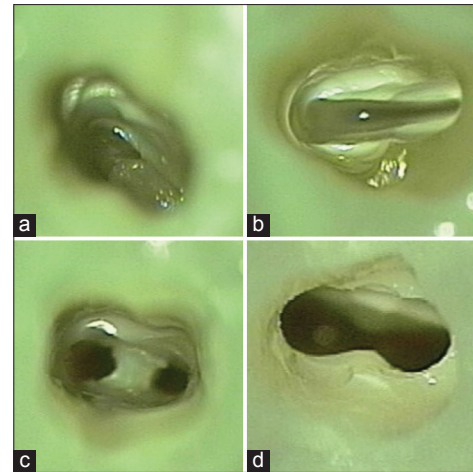


Figure 6: Canal orifices (a) C-shaped, (b) ribbon-shaped, (c) two orifices, and (d) dumbbell-shaped

Table 2: Root canal anatomy in mandibular 1st premolar teeth

Canal anatomy	Percentage (n=100)
Apical foramen	
Central	77
Lateral	23
Apical delta	24
LC	40
Location of LC	
Coronal	13
Middle	14
Apical	6
Coronal and middle	5
Middle and apical	2
ICC	17
Location of ICC	
Coronal	3
Middle	11
Apical	6
Shape of orifice	
Oval	36
Tear shaped	11
C-shaped	2
Round	25
Dumbbell	4
Rounded triangle	6
Two orifices	2
Ribbon	14

LC: Lateral canal, ICC: Intercanal communication

They noted that the C-shaped canals were associated predominantly with Type IV canals. Therefore, it may be possible that many of the root canals could have a more complex configuration further deeper into the canal. The presence of multiple canals in the apical 3 mm, as in the case of circumferential canal configurations, make complete debridement

in this region difficult.^[22] As a consequence, when treating failed cases surgically, apicoectomies of more than 3 mm should be considered as an option and the resected end should be further examined using microscopes for viewing circumferential openings so that they can be sealed adequately.

The shape of the root canal orifices most commonly seen were the oval and round orifices. Ribbon-shaped canal orifices were seen in 14% of the teeth [Figure 6 b]. The teeth with this type of orifice generally had a Type I canal pattern, but the shape of the orifice should encourage the clinician to clear the canal of all residual pulp tissue and necrotic debris with thorough irrigation and adequate instrumentation. Love and Jenkinson, in their study, showed that when bacteria are left behind in the dentinal tubules, they may cause infections following root canal therapy.^[30] The thorough cleansing and shaping of canal irregularities is the most important factor considered when discussing endodontic treatment success.

The majority of teeth (65%) displayed Type I category of Vertucci root canal pattern with a single canal from the orifice to the apex. This is comparable with studies pertaining to mandibular first premolars reported among different populations, 69.3% American,^[7] 64% Chinese,^[14] 72% Jordanian,^[18] and 76% Indian.^[31] The frequency of multiple canals in the mandibular first premolars was 35% in the present study. Previous studies in the frequency of multiple canals in the mandibular first premolars have reported different percentage value among different populations. The values observed 23% Jordanian,^[18] and 28% Indian,^[16] 29% Iranian,^[15] and a range of 14–30% among Americans.^[7,8,11,13]

In the present sample, Type V canals were observed in 14% of the samples and Type IV in 13% of the samples. Similar findings were observed in Turkish^[17] and Japanese populations.^[32] The finding is of clinical importance as one canal bifurcates in the lower two-thirds of the root. Significantly, two modifications in the canal system types were observed in this study. Although the percentage of teeth with this modification was low, its presence in the Emirati subpopulation is of clinical relevance. It is very difficult to define the exact configuration of the middle and apical third of the canal by just assessing the coronal orifice morphology. It would be easy to access the buccal canal, but the lingual canal can be negotiated only if the access cavity preparation is extended more lingually.^[32] Adequate access cavities to view the

canals and locate individual canals that can be traced to the apex are of immense importance. Operating microscopes may aid in visualizing canal system branching off from the main canal in the middle third of the root. Fan *et al.*^[33] using micro-CT did detailed studies on the C-shaped canal systems and have shown that some of the isthmuses could be found dangerously close to the developmental groove on the root surface. England *et al.*^[34] reported that in Type IV canals, the majority of the secondary canals originate on buccal or lingual walls and exit the major canal at a sharp angle. An experienced practitioner would be able to detect accessory canal systems with the help of a fine curved stainless steel file using his tactile sense.^[34] The practitioner has to consider this tooth group as a complex one and rely on available diagnostic tools and technology and to ensure a successful outcome. While taking radiographs, varying the horizontal angle of the X-ray projection could enhance the visualization of the superimposed canals. However, the radiographs have their limitation in complex morphologies and more advanced techniques such as the cone-beam CT and spiral CT are presently being employed. Endodontic microscopes and apex locators should be routinely used during treatment.

The apical foramen was located centrally in 77% of the teeth in the present sample, which is relatively higher when compared to the study conducted by Sert and Bayirli,^[10] while that of Awawdeh and Al-Qudah^[18] was reported as 44–51% and 49.6%, respectively. However, the present finding is comparable to a study done in the Indian population by Velmurugan and Sandhya^[16] on mandibular premolar teeth reporting a percentage of the centrally located foramen to be 83%. The position of the apical foramen is of clinical significance in the working length determination while using radiographs. When the foramen opens laterally, the working length may appear to be short on the radiograph.

LCs were seen in 40% of the teeth with the majority of these canals located in the coronal and middle third of the teeth. The findings of the present study are comparable with that of Vertucci in which he found 44.3% of LCs.^[13] Awawdeh and Al-Qudah^[18] identified 25.4% of LCs in the apical third of the root in the Jordanian population. In comparison, Sert and Bayirli^[10] observed LCs in the middle and apical third in 22% of the samples. The percentages in both these reports were lower than that observed in the present study. The presence of LCs makes complete debridement of microorganisms from the canals

almost impossible. Hence biomechanical preparation, including the use of irrigating systems and intracanal medications should be considered in order to achieve a sterile field prior to obturation.

ICCs were seen in 17% of the teeth, and the majority were found in the middle and apical one-third of the canals. This percentage stands lower than previous reports at 27.4%^[18] and 32%.^[13] Caliskan *et al.*^[17] reported an incidence of 16% which compares with the present study. Apical deltas were seen in 24% of the teeth. Results obtained from studies among American 5.7%,^[13] Turkish 16.9%,^[17] and Jordanian 29.2%^[18] population are comparable to those of this present study. This varied range could be based on ethnic differences. Cleaning of the apical ramification is not easily achievable hence it remains a source of infection.

The samples in the present study showed diffusion of dye into the dentinal tubules which might have resulted in a smudged appearance of the samples. This could be attributed to a limitation of the study method. Henceforth using micro-CT in these types of studies could enhance the identification of detailed anatomic structures.

CONCLUSION

In one hundred mandibular first premolars examined the most common type of canal pattern detected was Type I (65%). While 35% of the samples were those with multiple canals (Type II, III, IV, V, and modification 1 and 2). Teeth with mesial invaginations had multiple canal morphologies. The present findings are characteristic of the Emirati subpopulation living in UAE.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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