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Root form and canal morphology of mandibular premolars in a Jordanian population

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Abstract

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Aim To investigate the root canal anatomy of mandibular premolars in a Jordanian population.

Methodology Nine hundred extracted mandibular premolars were examined. After the length of the teeth was measured, the presence of developmental grooves and furcated roots was noted. Following the preparation of access cavities, pulp tissue was removed and the canal systems were stained. The teeth were then rendered clear by demineralization and immersion in methyl salicylate. Cleared teeth were examined and the following features were evaluated: (i) type of root canals; (ii) presence and location of lateral canals; transverse anastomosis; (iii) location of apical foramina; and (iv) frequency of apical deltas.

Results The mean lengths of first and second mandibular premolars were 22.6 mm (18–27.5 mm) and 22.2 mm (16–26.5 mm), respectively. Although the majority of the specimens corresponded to Vertucci's classification scheme, analysis of this large data set revealed four additional root canal morphologies. Variable root canal morphologies were found in the mandibular first premolars; two separate apical foramina were found in 33% of the teeth with two canals, compared to 6.2% with one apical foramen. Teeth with three separate apical foramina were scarce (2.2%). The majority of the mandibular second premolars had a single canal; 72% of teeth possessed type I canal systems, whilst 22.8% of the roots had two canals with two separate apical foramina.

Conclusions The prevalence of multiple canals in the investigated Jordanian mandibular premolars was high, especially for the second mandibular premolar, in comparison with previous studies performed on populations of different racial origin.

Keywords: mandibular premolars, morphology, root canal system.

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Introduction

From the early work of Hess & Zürcher (1925) to the most recent studies demonstrating anatomic complexities of the root canal system, it has been established that a root with a graceful, tapering canal and a single apical foramen is the exception rather than the rule. Rather, investigators have shown that the pulp canal system is complex, and canals may branch, divide and rejoin (Pineda & Kuttler 1972, Vertucci 1984, Kasahara *et al.* 1990). To achieve a healthy response following root canal treatment, the entire root canal system must be adequately debrided and filled. Therefore, clinicians must be familiar with the various root canal configuration and their characteristic features in various racial groups. Such knowledge can aid location and negotiation of canals, as well as their subsequent management.

Although various techniques have been used in studies evaluating canal morphology, it has been reported that the most detailed information can be obtained *ex vivo* by demineralization and staining (Vertucci 1984, Neaverth *et al.* 1987, Sieraski *et al.* 1989).

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Mandibular premolars have gained a reputation for having aberrant anatomy. Different studies (Tables 1 and 2) have looked at the root canal morphology of mandibular premolars over the years and pointed out that the root canal types may vary according to race (Trope *et al.* 1986, Sert & Bayirli 2004, Kim *et al.* 2005, Lu *et al.* 2006) with a high percentage having more than one canal (Amos 1955, England *et al.* 1991, Nallapati 2005).

The incidence of two or more root canals in the mandibular first and second premolars has been reported to vary between 2.7–65% and 0–43%, respectively (Mueller 1933, Amos 1955, Pineda & Kuttler 1972, Green 1973, Vertucci 1978, Baisden *et al.* 1992, Sert & Bayirli 2004). The occurrence of three canals with three separate foramina (type VIII, Vertucci) in mandibular premolars is rare (Zillich & Dowson 1973, Vertucci 2005).

However, these studies were mainly performed on teeth of North American (Vertucci 2005), Far Eastern (Walker 1988, Lu *et al.* 2006) and Turkish populations (Çaliskan *et al.* 1995, Sert & Bayirli 2004). No data seems to be available on root canal morphology of mandibular premolars in Jordan or other Middle Eastern countries. Therefore, the following study was conducted to investigate, in detail, such morphology using a clearing technique.

Materials and methods

For this investigation, 500 extracted mandibular first premolars and 400 mandibular second premolars were obtained from Jordanian patients attending various dental clinics within north Jordan. Teeth included in this study had intact clinical crowns and fully developed apices. The age, sex and reasons for extraction were not recorded. The identification of these teeth as either mandibular first or second premolars was confirmed by two independent observers using accepted criteria (Ash 1985). The mandibular first premolar was identified by the following coronal morphological features: two cusps; long and sharp buccal cusp with prominent buccal ridge, and short, poorly developed lingual cusp that resembled a strongly developed cingulum. A characteristic feature for identification of this tooth was the presence of mesiolingual developmental groove along the lingual surface. The mandibular second premolar is generally larger than the first premolar and it has two major forms; the two-cusp type which has a crescent-shaped central developmental groove and the three-cusp types, which appears more

Table 1 Studies of root canal morphology in mandibular first premolar teeth

Reference	Teeth in study	Type of study	Teeth length (mm)	1 canal (%)	≥2 canals (%)	1 canal at apex (%)	≥2 canals at apex (%)	C-shaped canals (%)	Lateral canals (%)	Intercanal communication (%)	Apical delta (%)	Apical foramen (%) Central	Apical foramen (%) Lateral
Vertucci (1978)	400 (USA)	*ex vivo*; clearing	21.6	70	30	74	26	–	44.3	32.1	5.7	15	85
Walker (1988)	100 (China)	*ex vivo*; radiography	–	64	36	65	35	–	–	–	–	–	–
Baisden *et al.* (1992)	106 (USA)	*ex vivo*; sectioning	–	74	26	76.8	23.2	14	–	–	–	–	–
Çaliskan *et al.* (1995)	100 (Turkey)	*ex vivo*; clearing	21.2	64	36	75	25	–	52.8	16.9	16.9	58.5	41.2
Yoshioka *et al.* (2004)	139 (Japan)	*ex vivo*; radiography and clearing	–	80.6	19.4	80.6	19.4	–	–	–	–	–	–
Sert & Bayirli (2004)	200 (Turkey identified by gender)	*ex vivo*; clearing	–	60.5	39.5	89.5	10.5	–	14	7	15.5	47.5	52.5
Lu *et al.* (2006)	82 (China)	*ex vivo*; radiography and sectioning	–	54	46	60	40	18	–	–	6	–	–
Present study	500 (Jordan)	*ex vivo*; clearing	22.6	58.2	41.8	64.8	35.2	–	25.4	27.4	29.2	49.6	50.4

Table 2 Studies of root canal morphology in mandibular second premolar teeth

Reference	Teeth in study	Type of study	Teeth length	1 canal (%)	≥2 canals (%)	1 canal at apex (%)	≥2 canals at apex (%)	Lateral canals (%)	Intercanal communication (%)	Apical delta (%)	Apical foramen (%) Central	Lateral
Vertucci (1978)	400 (USA)	*ex vivo*; clearing	–	97.5	2.5	97.5	2.5	48.3	30	3.4	16.1	83.9
Çaliskan *et al.* (1995)	100 (Turkey)	*ex vivo*; clearing	21.6	94	6	94	6	38.3	–	21.3	19.2	81
Sert & Bayirli (2004)	200 (Turkey identified by gender)	*ex vivo*; clearing	–	71	29	82	19	16.5	6	25.5	35	65
Present study	400 (Jordan)	*ex vivo*; clearing	22.2	72	28	76.8	23.3	26	10.2	28.8	46.5	53.5

angular and it is characterized occlusally by a deep Y developmental groove.

All teeth were placed in 5.25% sodium hypochlorite (Odex, Bleach; Spartan Co., Amman, Jordan) for 30 min, after which any remaining external tissue or calculus was removed by scaling. Following the measurement of each tooth, the external surface of teeth was examined for developmental groove or bifurcations. Access cavities were prepared with a high-speed handpiece and pulp tissue was dissolved by immersing the teeth in 5.25% sodium hypochlorite for 12 h followed by 20 min immersion in an ultrasonic bath. Teeth were washed under running tap water for 2 h and dried overnight. India ink (Sanford rotring GmbH, Hamburg, Germany) was injected into the pulp chamber with an endodontic irrigating syringe with gauge 27 needle (BU Kwang Medical Inc., Seoul, Korea). The ink was drawn through the canal system by applying negative pressure to the apical end of the tooth with the use of a central suction system. Excess ink was then removed from the surface of the tooth with gauze soaked in alcohol. The stained teeth were air dried and decalcified with 10% nitric acid (Analytical reagents 69–71%; Gainlad Chemical Co., Clwyd, UK) for 3 days followed by 5% nitric acid for 3–5 days. The acid solution was changed daily and the end-point of decalcification determined by periodic radiography. The teeth were washed under running tap water overnight and then air dried. The specimens were then dehydrated in ascending concentrations of ethyl alcohol (70%, 96% and 99%) for 12 h each. Finally, transparent specimens were obtained by immersing the dehydrated teeth in methyl salicylate solution into which teeth were stored until examined.

The specimens were examined using X3 illuminated magnifying glass (Lumagny, Great wall optical product, Hong Kong). The following observations were made: (i) number and type of root canals; (ii) presence and location of lateral canals and intercanal communications; (iii) location of apical foramina (central at root tip or lateral); and (iv) frequency of apical deltas.

The canal configurations were categorized into the first seven types of Vertucci's (1984) classification with additional modifications as follows:

Type I. A single canal present from the pulp chamber to the apex.

Type II. Two separate canals leave the pulp chamber, but join to form one canal to the site of exiting.

Type III. One canal leaves the pulp chamber, divides into two within the root, and then merges to exit in one canal.

Type IV. Two separate and distinct canals are present from the pulp chamber to the apex.

Type V. Single canal leaving the pulp chamber but dividing into two separate canals with two separate apical foramina.

Type VI. Two separate canals leave the pulp chamber, but join at mid-point and divides again into two separate canals with two separate apical foramina.

Type VII. One canal leaves the pulp chamber, divides into two within the root, and then merges at mid-point and divides again into two separate canals with two separate apical foramina.

Additional types

Type (1-2-3) One canal leaves the pulp chamber, divides into two within the root, and then one canal divides further into two separate canals giving a total of three separate apical foramina.

Type (1-3) One canal leaves the pulp chamber, and then divides into three separate canals with three separate apical foramina.

Type (2-1-3) Two separate canals leave the pulp chamber, and then one canal divides further into two separate canals giving a total of three separate canals with three separate apical foramina.

Type (2-1-2-1) Two separate canals leave the pulp chamber, join at mid-point and divide again into two separate canals and then merge to exit in one canal.

Results

The mean values, standard deviations, range and median of the length of the human permanent mandibular premolars are shown in Table 3. Of the 500 mandibular first premolars studied, 3.0% had bifurcated roots and 17.6% had developmental grooves. In 2.4% of cases the groove extended on both the lingual and proximal root sides. In mandibular second premolars, 2.8% of the teeth were bifurcated and 13.5% had evidence of developmental grooves.

In this study, variable root canal configurations were found in both first and second mandibular premolars (Fig. 1a,b) with greater variability observed in the former. The percentages of root canal configurations, of the mandibular first and second premolars examined, are presented in Table 4. Thirteen aberrant roots, with canal configurations that did not fit Vertucci's classification, were distributed between the supplemental canal configurations of Gulabivala *et al.* (2002); type 2-1-2-1 and 2-3, and additional types; 1-2-3 and 1-3 (Table 4 and Fig. 2).

Table 3 Length of permanent mandibular premolars in a Jordanian population

Tooth Type	Mean (SD)	Minimum	Maximum	Median
First premolars *n* = 500	22.6 (1.67)	18	27.5	22
Second premolars *n* = 400	22.2 (1.87)	16	26.5	22

There was an increasing prevalence of lateral canals towards the apical part of the root for both first and second premolars. The highest prevalence of lateral canals was observed in the apical third of mandibular first premolars (17.8%) and the lowest in the coronal part of the mandibular second premolars (Table 5). Intercanal communications were found more commonly in the first premolar (27.7%) than the second premolar (10.8%) and these transverse anastomosis were found mostly in the middle third area (Table 6 and Fig. 3).

The apical foramina were located laterally in more than half of teeth (50.4% and 53.5%, for both first and second mandibular premolars, respectively) as shown in Table 7. Apical deltas were frequently seen in both teeth (Table 7 and Fig. 4).

Discussion

Studies of the internal and external anatomy of teeth have shown that anatomical variations can occur in all groups of teeth with variable prevalence in different ethnic populations. Thus, the clinicians must be fully aware of dental morphology in order to better manage their patients. Tables 1 and 2 compare the results of this population with other populations for mandibular first and second premolars.

This study shows that the mean length for the first mandibular premolars (22.6 mm) was similar to those reported by Ash (1985), but higher than the results of other studies; Çaliskan *et al.* (1995) (21.2 mm), Kim *et al.* (2005) (20.3 mm for Korean and 21.1 mm for Caucasian), Vertucci *et al.* (2006) (21.6 mm). The mean length for the second mandibular premolars (22.2 mm) was similar to that reported by Vertucci *et al.* (2006). In the present study, length measurements were performed on extracted teeth which is considered by many researchers as the most accurate method.

Surprisingly, the mean length value for the second mandibular premolars was less than that for first premolars which is contrary to the findings of other

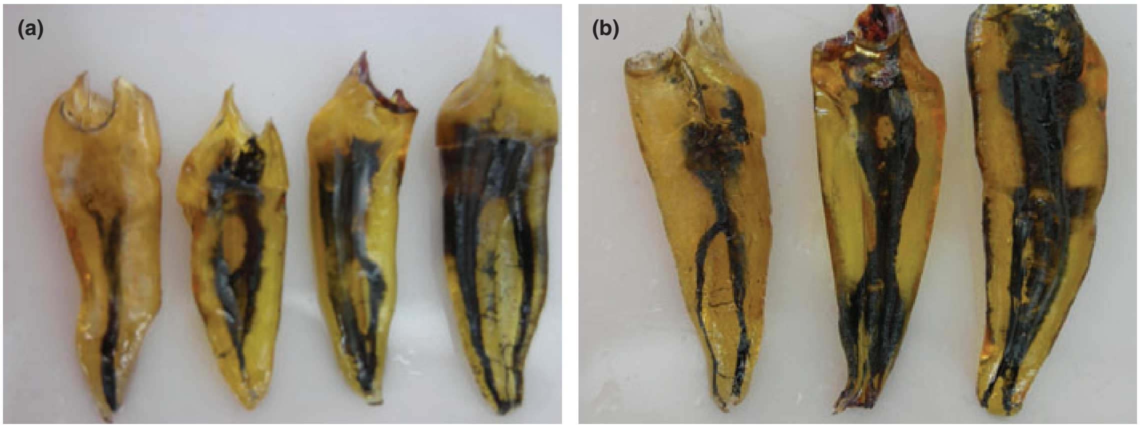

Figure 1 (a) Canal configurations observed in this study. From left to right: type I, II, III and IV. (b) Canal configurations observed in this study. From left to right: type V, VI and VII.

Table 4 Number and percentage of canal system types in mandibular premolars

	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Additional types			
	1	2-1	1-2-1	2	1-2	2-1-2	1-2-1-2	1-3	1-2-3	2-1-3	2-1-2-1
First premolars (*n* = 500)	291 (58.2)	24 (4.8)	7 (1.4)	72 (14.4)	84 (16.8)	4 (0.8)	5 (1.0)	5 (1.0)	2 (0.4)	4 (0.8)	2 (0.4)
Second premolars (*n* = 400)	288 (72.0)	15 (3.8)	4 (1.0)	30 (7.5)	61 (15.3)	0 (0)	0 (0)	2 (0.5)			

Figures in parentheses are percentages.

Figure 2 Additional canal configurations observed in this study. From left to right: type 1-2-3, 1-3, 2-1-3 and 2-1-2-1.

studies (Kim *et al.* 2005, Vertucci *et al.* 2006). The differences could be related to technique of tooth length measurements; direct measurement on extracted teeth, radiographic measurement and electronic measurements using apex locators or to racial divergence.

The presence of developmental grooves (which were deep in some cases) is an occasional finding worth mentioning. Of the 500 mandibular first premolars studied; 3.0% had bifurcated roots and 17.6% had external developmental grooves or deep invaginations. In teeth with developmental groove, 2.4% had developmental grooves on both lingual and proximal root surfaces. For mandibular second premolar, 2.8% of the teeth were bifurcated and 13.5% had developmental grooves. These grooves were mostly associated with type IV and V canal configurations. Such anatomical variation should be kept in mind during cleaning and shaping to avoid weakening of such thin walls and to take additional measures to ensure sufficient cleaning of these irregularities. This deep external invagination along the root surface is similar to what Baisden *et al.* (1992) and Lu *et al.* (2006) described. They correlated such folding grooves with C-shaped canals in mandibular first premolars. Baisden *et al.* (1992) and Lu *et al.* (2006) studied the internal anatomy of mandibular first premolars using a cross-sectioning technique and reported a 14% and 17% incidence of C-shaped canal, respectively. They reported that C-shaped morphology in mandibular premolars was quite different to that in mandibular molars, which are mostly found apically in the former compared with coronally in the later.

Table 5 Number and percentage of roots with lateral canals and distribution of lateral canals along different levels of the root

Type of premolar	Number (%) and position of lateral canals						
	Coronal third	Middle third	Apical third	Coronal & middle	Coronal & apical	Middle & apical	Total
First premolars, *n* = 500 (%)	6 (1.2)	23 (4.6)	69 (13.8)	9 (1.8)	2 (0.4)	18 (3.6)	127 (25.4)
Second premolars, *n* = 400 (%)	6 (1.5)	27 (6.8)	54 (13.5)	3 (0.8)	4 (1.0)	8 (2.0)	102 (25.5)

Table 6 Number and percentage of roots with intercanal communications and distribution of intercanal communications along different levels of the root

Type of premolar	Number (%) and position of intercanal communications							
	Coronal third	Middle third	Apical third	Coronal & middle	Coronal & apical	Middle & apical	Coronal & middle	Total
First premolars, *n* = 500 (%)	6 (1.2)	49 (9.8)	42 (8.4)	10 (2.0)	1 (0.2)	25 (5.0)	4 (0.8)	137 (27.4)
Second premolars, *n* = 400 (%)	4 (1.0)	11 (2.8)	11 (2.8)	5 (1.3)	3 (0.8)	7 (1.8)	2 (0.5)	43 (10.8)

Figure 3 Intercanal communications observed in teeth with multiple root canals.

Figure 4 Examples of apical deltas observed in type I canal.

Table 7 Number and percentage of roots with central and lateral foramina and roots with apical deltas

	Position of apical foramen		Apical deltas
	Central	Lateral	
First premolars, *n* = 500	248 (49.6)	252 (50.4)	146 (29.2)
Second premolars, *n* = 400	186 (46.5)	214 (53.5)	115 (28.8)

Therefore, C-shaped canals would be difficult to detect by clearing techniques in premolars. The clearing technique is an excellent approach for showing the structure and continuity of the root canal system from pulp chamber to root apex (Barker *et al.* 1969), but is not ideal for clearly exposing the complexity of the root canal system and provide clear images of the different types of C-shaped canals, especially in mandibular premolars. C-shaped canals with a single, ribbon-like canal from orifices to apex are simple to detect by the clearing technique but those with distinct canals below the usual C-shaped orifices are not. Unfortunately, C-shaped premolars with a single swath of canal are the exception rather than the rule (Vertucci *et al.* 2006). That is why further study using a combination of computed tomography followed by the clearing method or cross-sectional evaluations to study C-shaped canals in mandibular premolars and to correlate external features with internal morphology is recommended.

The root canal system of the mandibular premolar can be particularly difficult to clean and shape. Ingle & Bakland (1994) stated that the canal anatomy might account for the greater increase in endodontic failure of this tooth. Slowey (1979) reported that mandibular premolars were probably the most difficult teeth to treat endodontically because of wide variations in root canal morphology. Racial differences could contribute greatly to the wide morphological divergence in root canal system that is known to exist.

In a series of studies on extracted teeth Vertucci in the 1970s and 1980s determined canal numbers and configurations by percentages for each of the human permanent teeth (Vertucci 1984) and this can be considered as a baseline point for root canal anatomy comparison.

The frequency of multiple canals of mandibular premolars found in the present study was generally higher than that reported by Vertucci (1984) and Çaliskan *et al.* (1995), but lower than that reported by Lu *et al.* (2006) whereas a comparable distribution pattern was noticed. In the teeth with multiple canals, the type V canal system was the most prevalent followed by type IV configurations. This is in accordance with the findings of other studies performed in different populations (Çaliskan *et al.* 1995, Yoshioka *et al.* 2004). Type V configurations are rather difficult to treat as one canal is bifurcated into two separate root canals. Direct access to the buccal canal is usually possible, whereas the lingual canal may be difficult to locate, as it tends to diverge from the main canal at a sharp angle. In addition, the lingual inclination of the crown tends to direct instruments buccally, making location of a lingual canal orifice more difficult. To counter this situation, the clinician may need to extend the lingual wall of the access cavity more towards the lingual.

The incidence of multiple canal morphology occurring in mandibular first premolars was higher than that in second premolars and in agreement with studies reported previously (Pineda & Kuttler 1972, Green 1973, Zillich & Dowson 1973, Vertucci 1978, Trope *et al.* 1986, Çaliskan *et al.* 1995, Sert & Bayirli 2004). Trope *et al.* (1986) studied root canal morphology of mandibular premolars by radiographs in different race groups. They found that the number of first premolars with more than one canal in black patients was significantly higher than in white patients (32.8% vs. 13.7%). Baisden *et al.* (1992), using the cross-sectioning method, reported a 76% and 24% incidence of one and two canals, respectively, in an United States population. Walker (1988) reported that 34% of the examined Southern Chinese mandibular first premolars had two canals. In another study, in a Turkish population Sert & Bayirli (2004) reported that 62% of mandibular first premolars possessed a single canal. On the other hand, Lu *et al.* (2006) when investigating the root canal morphology of mandibular first premolars in a Chinese population reported that only 54% of the mandibular first premolars had a single canal, 22% contained two canals and the other 24% had either C-shaped or circumferential canals. Therefore, it seems that the frequency of two canals in Jordanian first premolars is higher than that of North American and Turkish but lower than Far Eastern populations.

The incidence of one canal (72%) and two canals (27.5%) in mandibular second premolars reported in this investigation (Table 4) is consistent with the findings of Sert & Bayirli (2004) who found that 71% of mandibular second premolars had a single canal. However, this is much higher than results of most previous studies that reported the occurrence of two canals in mandibular second premolars as ranging from 1.2% to 15% (Pineda & Kuttler 1972, Vertucci 1978, Trope *et al.* 1986, Çaliskan *et al.* 1995, Kerekes & Tronstad 1997).

The occurrence of three canals with three separate foramina (type VIII) in mandibular premolars is rare. The percentage of three canals found in this study was 2.2% and 0.5% for mandibular first and second premolars, respectively, which is comparable to that described by Sert & Bayirli (2004) and Walker (1988). However, Vertucci (1978) and Zillich & Dowson (1973) reported that the occurrence of three canals in mandibular first premolars was 0.5% and 0.4%, respectively. In the second premolars these percentages were 0.0% and 0.4%, respectively. In contrast, the incidence of three canals in the mandibular first premolars of Turkish population was reported to be 5.6% (Çaliskan *et al.* 1995) and that in a Japanese population was 4.3% (Yoshioka *et al.* 2004). In the present study, a wide variation in the anatomy of root canal systems of mandibular premolars with three root canals was found. In mandibular premolars with more than two canals, orifices of the third canal were found either in middle or apical thirds of the root (Fig. 2). Therefore, if mandibular premolar teeth with three canals or more are to be treated predictably, it is necessary to be aware of their clinical and radiographic anatomy. The use of the dental operating microscope and fibreoptic endoscope may allow easier location of such canals. In addition, these canal configurations require special preparation and filling procedures.

In the present study, lateral canals were observed in 25.4% and 25.5% of first and second mandibular premolars, respectively, and were found most frequently in the apical third of the canal. These findings are lower than the results of other studies (Vertucci 1984, Çaliskan *et al.* 1995). Intercanal communications observed in the first and second mandibular premolars (27.4% and 10.8%, respectively) were also lower than that reported by Vertucci (1984) and Çaliskan *et al.* (1995), but with similar pattern of distribution which is mostly in the middle of the root canal. When more than one lateral canal or intercanal communication were detected they were mostly found at the middle and apical levels of the root. Therefore, if evidence of lateral canals appears on radiographs at one position careful inspection of the radiograph is suggested to exclude presence of other branches at other position along the root.

The prevalence of apical deltas was high in the present study; 29.2% in first premolars and 28.8% in second premolars. Vertucci (1984) reported a much lower incidence; 5.7% and 3.4% in first and second mandibular premolars, respectively. On the other hand, Çaliskan *et al.* (1995) reported that the incidence of apical deltas in first and second mandibular premolars was 16.9% and 21.3%, respectively. Such wide variation between studies may be related to racial differences. High incidence of apical delta may be of clinical significance and may account for some cases of persistent post-treatment disease. Cleaning of such apical ramifications is obviously difficult.

The apical foramen was found to coincide with the apical root tip (central) in 49.6% and 46.5% of first and second mandibular premolars, respectively. This is similar to that previously reported by Çaliskan *et al.* (1995) and Sert & Bayirli (2004), but much higher than that reported by Vertucci (2005). This finding is of clinical significance in working length determination using radiography (Al-Qudah & Awawdeh 2006).

Conclusions

The root and canal anatomy of 900 Jordanian mandibular premolars were examined. The findings are, on the whole, comparable with other studies. Mandibular premolars were associated with various types of root canal morphology. The percentage of one canal was 58.2% and 72% for first and second mandibular premolars, respectively, which is lower than results reported in most other populations. In the teeth with two canals, the type V canal system was the most prevalent and type VI was the least prevalent. Clinicians should view mandibular premolars as a complex group of teeth and use all available armamentarium to achieve a successful outcome.

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