Evaluation of Root Canal Morphology of Maxillary First and Second Premolars by Cone-Beam Computed Tomography in Saudi Population

Arwa S Alnoury[1*], Lina O Bahanan[2], Mohanad A Alhedbany[3], Mustafa E Abuzinadah[3], Hanadi M Khalifah[4], Abrar A Tounsi[5]

[1]Department of Restorative Dentistry, Faculty of Dentistry, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[2]Department of Dental Public Health, Faculty of Dentistry, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[3]Faculty of Dentistry, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[4]Oral and Maxillofacial Radiology Division, Faculty of Dentistry, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[5]Department of Periodontics and Community Dentistry, College of Dentistry, King Saud University, Saudi Arabia

ABSTRACT

Objectives: To estimate the prevalence of different root canal morphological variants in maxillary first and second premolars, and to analyze differences across gender and nationality in western Saudi Arabia individuals using cone-beam computed tomography (CBCT) who presented for dental care during February 2021- April 2021.

Methods: Maxillary first and second premolars were analyzed independently to determine the number of roots and canal configuration using Vertucci's classification. The distribution by gender and nationality was analyzed using Fisher's exact test with Monte Carlo simulation. Inter-examiner and intra-examiner reliability were evaluated using Cohen's kappa coefficient (1.0; P<0.001 and 0.9; P<0.001, respectively).

Results: Maxillary first premolars were double-rooted in 57.8% and type IV was the most frequent (63.6%), followed by type II (18.3%). Second premolars were single-rooted in 77.6%, with type I being the most frequent (37.8%) in females (48.2%); while type IV being most frequent in males (33.8%). In both first and second premolars, females had a significant predilection to single root pattern. Differences across nationality were statistically significant with respect to canal configuration of maxillary first premolars.

Conclusion: There is a high heterogeneity in the maxillary premolar root canal configuration among the studied Saudi population, with significant gender disparities supporting fewer roots and canals in females.

Key words: Cone-beam computed tomography, Maxillary, Premolars, Root canal morphology, Saudi Arabia

Corresponding author: Arwa S Alnoury

e-mail✉: aalnoury@kau.edu.sa

INTRODUCTION

Correct identification of the root canal morphology of the tooth is a crucial clinical step for a successful endodontic treatment [1]. Several configurations for tooth hard tissue repository have been identified in normal human dentition. These variations concern the number, shape, and symmetry of the roots and root canals, and are determined using a standardized classification system with several clinical implications [2–4]. However, several factors have been identified to contribute in the development of such variations, such as ethnicity, developmental anomalies, age, and dental conditions such as trauma, caries, and restorative procedures [2].

Various invasive and conservative techniques have been used to analyze the root canal morphology, such as staining and clearing, conventional or digital dental radiographs, micro tomography, and more recently cone-beam computed tomography (CBCT) using three-dimensional images with enhanced quality and accuracy

[5]. Additionally, CBCT is convenient for large sample studies. One of the most frequently used classifications is that elaborated by Vertucci et al., which determined eight morphological types of root canal ranging from single-canal throughout the tooth (type I) to three distinct canals (type VIII). The intermediate types include various anastomoses and bifurcations of the canals at different levels [6,7]. The maxillary first premolars are reported to be principally two-rooted; however, cases of three-rooted configurations are commonly reported among the anatomic variations [8,9]. For maxillary second premolars single-rooted canal was reported to be the most common configuration in different populations including Saudi [10], Spanish [9], and Chinese [11]; however, canal types IV and V were equally common in the Saudi population reported in 23% each, while type I was predominant in the Spanish (47.2%) and Chinese (55.1%) populations.

In this study, the authors used CBCT to estimate the prevalence of different root canal morphological variants in maxillary first and second premolars among consecutive sample of individuals in western Saudi Arabia, and to analyze the differences across gender and nationality. The authors also evaluated symmetry and asymmetry in relation to number of roots and root morphology in both premolars.

MATERIALS AND METHODS

A cross-sectional study was conducted at the oral and maxillofacial radiology department of the faculty of dentistry, King Abdulaziz University, Jeddah, Saudi Arabia, between February 2021 and April 2021. This study is ethically approved by the research ethic committee of King Abdulaziz University faculty of dentistry (Proposal #: 182-12-20).

The study included consecutive CBCT images that were carried out for various dental indications in adult patients. The first CBCT images that fulfilled the inclusion and exclusion criteria were selected in the study.

The CBCT images included in the study were acquired using the i-CAT (Imaging Sciences International, Hatfield, PA, USA). For standardization, all CBCT images were obtained with voxel size of 0.125 µm and a field of view of 8X8 cm. On Demand 3D Imaging Software (Cyber med, Seoul, South Korea) was used to analyze the CBCT images in three planes (axial, sagittal, and coronal).

The inclusion criterion was the presence of at least one or more fully-developed-root maxillary first or second premolar. Previously endodontically treated teeth, teeth with posts, teeth with immature apexes, and unclear or distorted CBCT images were excluded. The patient ID, gender and nationality (Saudi or non-Saudi) were recorded for each CBCT image.

The total sample was analyzed independently by two dentists to determine the following parameters for each included premolar:

Number of roots (one, two, or three) for the maxillary first and second premolars.

Canal configuration for the maxillary first and second premolars, using Vertucci's classification [7], and comprising eight types defined in Box 1.

To ensure the reliability of the results, the inter- and intra-examiner reliability were assessed. Ten randomly selected CBCT images were evaluated by the examiners according to the parameters specified for the study. The same CBCT images were evaluated after 1 week for the intra-examiner reliability.

Vertucci's classification of root canal morphology [7]

Type I: Single canal throughout.

Type II: Two canals merging into one at the canal terminus.

Type III: One canal dividing into two at the mid canal, then reuniting at the canal terminus.

Type IV: Two distinct canals throughout.

Type V: One canal dividing into two canals at the canal terminus.

Type VI: Two distinct canals merging in the body of the root then separating again at the canal terminus.

Type VII: One canal dividing into two, then reuniting then redividing again at the canal terminus.

Type VIII: Three distinct canals throughout.

Statistical methods

Inter-examiner and intra-examiner reliability were evaluated using Cohen's kappa coefficient (1.0; P<0.001 and 0.9; P<0.001, respectively). Descriptive statistics including frequency, percentages and mean and standard deviation (SD) were conducted to summarize the sample variables. Fisher's exact test with Monte Carlo simulation were used to compare the number of roots and root morphology of maxillary first and second premolars across gender and nationality. All statistical analyses were conducted using statistical software SAS, Version 9.4 (Cary, NC: SAS Institute Inc. 2013). The significance level was set at a P-value <0.05.

RESULTS

Participant characteristics

The authors analyzed CBCT images from 269 patients, which included 723 teeth (383 maxillary first and 340 maxillary second premolars). Female patients included 54.6%, and the mean (SD) age was 33.9 (12.7) years. Majority of the participants were Saudi citizens (65.8%). The overall distribution of root canal morphology showed that type IV was the most prevalent type (46.3%), followed by type I (23.0%), and type II (22.4%) (Table 1).

Table 1: Sample characteristics (N=269).

Characteristics	Frequency (%)
Gender*	
Male	122 (45.4)
Female	147 (54.6)
Age (mean ± SD)	33.9 ± 12.7
Nationality*	
Saudi	177 (65.8)
Non-Saudi	92 (34.2)
Maxillary premolars	
First right premolar	198 (27.4)
Second right premolar	176 (24.3)
First left premolar	185 (25.6)
Second left premolar	164 (22.7)
Morphology	
Type I	166 (23.0)
Type II	162 (22.4)
Type III	20 (2.7)
Type IV	335 (46.3)
Type V	17 (2.4)
Type VI	6 (0.8)
Type VII	3 (0.4)
Type VIII	12 (1.7)
Additional types	2 (0.3)

Root numbers in maxillary first and second premolars

Regarding maxillary first premolars, two-rooted and single-rooted variants were generally predominant, representing 57.8% and 40.1% of the total teeth, respectively; while three-rooted represented only 2.1%. In females, single-rooted and two-rooted variants were equally common (50% each), while two-rooted premolars were evidently more frequent in males (65.6%) than single-rooted ones (30.2%). The gender difference was statistically significant (P<0.0001). However, no significant difference was observed across nationality.

Maxillary second premolars were single-rooted in majority of cases (77.6%), followed by two-rooted form (22.1%), while three-rooted were marginal (0.3%). Single-rooted canals were more frequent in females compared to males (86.0% vs. 69.7%, respectively; P=0.0009). There was no significant difference across nationality (Table 2).

Root morphology in maxillary first premolar by gender and nationality

Type IV was the most prevalent in both males and females (68.3% and 58.9%, respectively), followed by type II (16.2% and 20.5%, respectively), and type I (5.7% and 13.2%, respectively). However, type VIII was only observed in males (4.7%). The gender difference was statistically significant (P=0.001). The most common types in Saudi participants were type IV (63.0%), type II (17.5%) and type I (12.6%), while in non-Saudis, the most common types included type IV (63.9%), type II (19.9%), and type III (8.1%). The difference was statistically significant (P=0.0004) (Table 3). Figures 1 and 2 show examples of maxillary first premolar

root canal types detected in axial and coronal section, respectively.

Root morphology in maxillary second premolar by gender and nationality

The most common types in males were type IV (33.8%), type II (28.6%), and type I (28.0%); while in females the most common types were type I (48.2%), type II (25.6%), and type IV (20.1%). The gender difference was statistically significant (P=0.002). No statistically significant difference across nationality was observed (P=0.9) (Table 4). Figures 3 shows examples of maxillary second premolar root canal types detected in axial.

Root morphology in maxillary first premolar by gender and nationality

The number of roots was symmetrical in 75.0% and 74.7% of maxillary first and second premolars pairs, respectively. Root canal morphology was symmetrical in 31.0% and 53.8% of maxillary first and second premolars pairs, respectively. The highest symmetry rate was observed in type IV in both first (65.6%) and second (87.9%) maxillary premolar pairs (Table 5).

DISCUSSION

Summary of findings

This CBCT-based study demonstrated that Vertucci's type IV and type I were the most common root canal morphology of maxillary first and second premolars, respectively. In maxillary first premolars, two-rooted and single-rooted variants were the most frequent, while single-rooted variant was predominant in maxillary second premolars. Root numbers and root canal morphology of maxillary first and second premolars showed significant diffrence across gender. However, root canal morphology of the maxillary first premolar showed significant difference by nation.

Morphology and number of roots in maxillary first premolar

In this study population, two-rooted anatomy was the most frequent, observed in approximately 58% of the participants, and was more frequent in males (65.6%) compared to females (50%). The morphological classification showed type IV to be the most frequent, found in approximately two-thirds of the participants, regardless of gender or nationality. On the other hand, significant differences across gender and nationality were observed in less common types, notably type VIII which was only observed in males. In addition, type III which was the third most common type in non-Saudi participants, instead of type I in Saudis.

Other local studies have reported some variations in the maxillary first premolars. For example, a study by Alqedairi et al. used CBCT to analyze the number of roots and canal configuration of 334 maxillary first premolars. The findings were consistent with those from the present study, showing double-rooted

Table 2: Frequency distribution of root numbers in maxillary first and second premolars by gender and nationality [n (%)].

|	Number of roots			
	One	Two	Three	P-value†
Maxillary first premolar				
Gender				
Male	58 (30.2)	126 (65.6)	8 (4.2)	
Female	95 (50.0)	95 (50.0)	0	<0.0001*
Total	153 (40.1)	221 (57.8)	8 (2.1)	
Nationality				
Saudi	102 (41.5)	138 (56.1)	6 (2.4)	
Non-Saudi	52 (38.2)	82 (60.3)	2 (1.5)	0.7
Total	154 (40.3)	220 (57.6)	8 (2.1)	
Maxillary second premolar				
Gender				
Male	122 (69.7)	52 (29.7)	1 (0.6)	
Female	141 (86.0)	23 (14.0)	0 (0.0)	0.0009*
Total	263 (77.6)	75 (22.1)	1 (0.3)	
Nationality				
Saudi	169 (79.0)	44 (20.5)	1 (0.5)	
Non-Saudi	95 (75.4)	31 (24.6)	0 (0.0)	0.6
Total	264 (77.6)	75 (22.1)	1 (0.3)	
†Fisher's exact test with Monte Carlo simulation				
*Statistically significant				
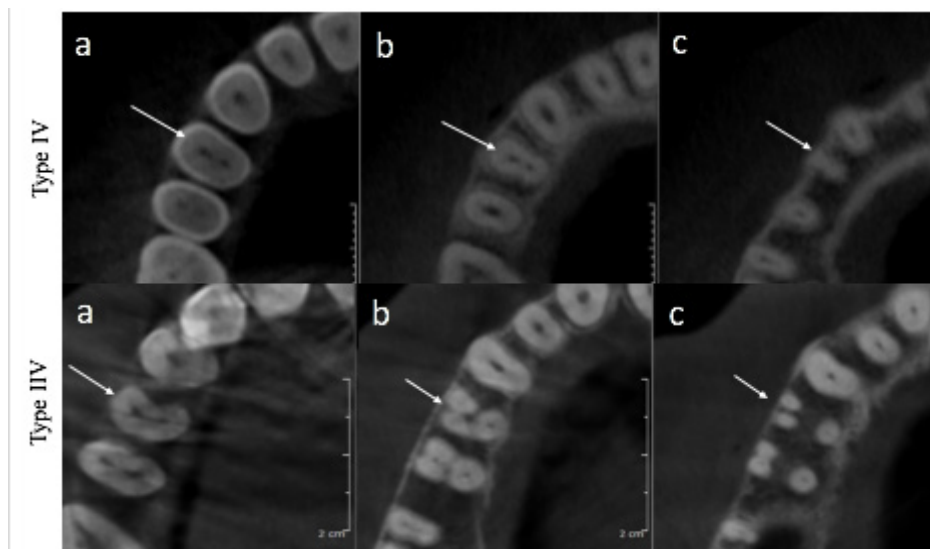
Figure 1: CBCT in the axial plane revealed examples of different root canal morphology of the maxillary first premolars (arrows indicate examined teeth): (a) coronal; (b) middle; and (c) apical thirds.
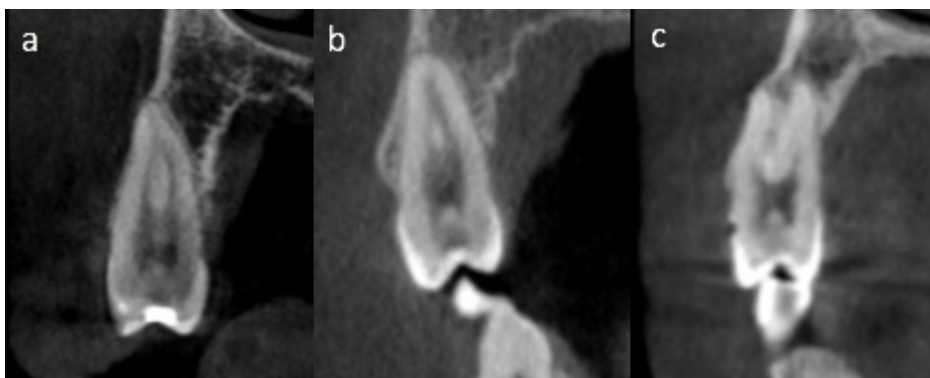

Figure 2: CBCT in the coronal plane revealed examples of different root canal morphology of the maxillary first premolars: (a) Type II (2-1); (b) Type III (1-2-1); and (c) Type IV (2).

Table 3: Frequency distribution of root morphology in maxillary first premolar by gender nationality [n (%)].

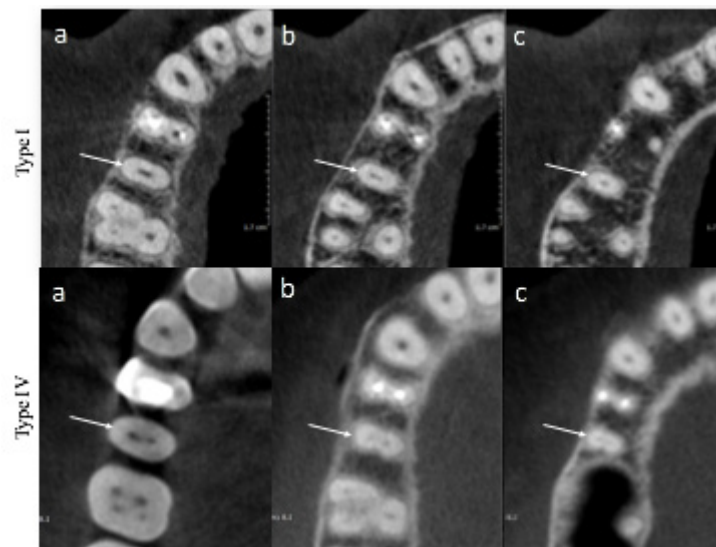|	Types of root morphology									
	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Additional types	P-value†
	Gender									
Male	11 (5.7)	31 (16.2)	6 (3.1)	131 (68.3)	1 (0.5)	2 (1.0)	1 (0.5)	9 (4.7)	0	
Female	25 (13.2)	39 (20.5)	6 (3.2)	112 (58.9)	3 (1.6)	4 (2.1)	1 (0.5)	0	0	0.001*
Total	36 (9.4)	70 (18.3)	12 (3.1)	243 (63.6)	4 (1.1)	6 (1.6)	2 (0.5)	9 (2.4)	0	
	Nationality									
Saudi	31 (12.6)	43 (17.5)	1 (0.4)	155 (63.0)	3 (1.2)	4 (1.6)	2 (0.8)	7 (2.9)	0	
Non-Saudi	6 (4.4)	27 (19.9)	11 (8.1)	87 (63.9)	1 (0.7)	2 (1.5)	0	2 (1.5)	0	0.0004*
Total	37 (9.7)	70 (18.3)	12 (3.1)	242 (63.3)	4 (1.1)	6 (1.6)	2 (0.5)	9 (2.4)	0	
†Fisher's exact test with Monte Carlo simulation										
*Statistically significant										

Figure 3: CBCT in the axial plane revealed examples of different root canal morphology of the maxillary second premolars (arrows indicate examined teeth): (a) coronal; (b) middle; and (c) apical thirds.

Table 4: Frequency distribution of root morphology in maxillary second premolar by gender and nationality [n (%)].

	Types of root morphology									
	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Additional types	P-value†
	Gender									
Male	49 (28.0)	50 (28.6)	3 (1.7)	59 (33.8)	9 (5.1)	0 (0.0)	1 (0.6)	2 (1.1)	2 (1.1)	
Female	79 (48.2)	42 (25.6)	5 (3.1)	33 (20.1)	4 (2.4)	0 (0.0)	0 (0.0)	1 (0.6)	0 (0.0)	0.002*
Total	128 (37.8)	92 (27.1)	8 (2.4)	92 (27.1)	13 (3.8)	0 (0.0)	1 (0.3)	3 (0.9)	2 (0.6)	
	Nationality									
Saudi	80 (37.4)	58 (27.1)	5 (2.3)	56 (26.2)	12 (5.6)	0 (0.0)	0 (0.0)	3 (1.4)	0 (0.0)	
Non-Saudi	49 (38.9)	34 (26.9)	3 (2.4)	36 (28.6)	1 (0.8)	0 (0.0)	1 (0.8)	0 (0.0)	2 (1.6)	0.9
Total	129 (37.9)	92 (27.1)	8 (2.4)	82 (27.1)	13 (3.8)	0 (0.0)	1 (0.3)	3 (0.8)	2 (0.6)	
†Fisher's exact test with Monte Carlo simulation										
*Statistically significant										

Table 5: Symmetry of maxillary first and second premolars [n (%)].

Parameter	Maxillary first premolars			Maxillary second premolars		
	Number of pairs	Symmetry	Asymmetry	Number of pairs	Symmetry	Asymmetry
Number of roots	100 (100.0)	75 (75.0)	25 (25.0)	91 (100.0)	68 (74.7)	23 (25.3)
One	78 (78.0)	53 (67.9)	25 (32.1)	65 (71.4)	43 (66.2)	22 (33.8)
Two	21 (21.0)	21 (100.0)	0	26 (28.6)	25 (96.2)	1 (3.8)
Three	1 (1.0)	1 (100.0)	0	0 (0.0)	0	0
Morphology	100 (100.0)	31 (31.0)	69 (69.0)	91 (100.0)	49 (53.8)	42 (46.2)
Type I	43 (43.0)	7 (16.3)	36 (83.7)	37 (40.7)	11 (29.7)	26 (70.3)
Type II	24 (24.0)	2 (8.3)	22 (91.7)	19 (20.8)	8 (42.1)	11 (57.9)
Type III	0	0	0 (0.0)	1 (1.1)	0 (0.0)	1 (100.0)
Type IV	32 (32.0)	21 (65.6)	11 (34.4)	33 (36.3)	29 (87.9)	4 (12.1)

Type V	0	0	0	1 (1.1)	1 (100.0)	0
Type VI	0	0	0	0	0	0
Type VII	0 (0.0)	0	0	0	0	0
Type VIII	1 (1.0)	1 (100.0)	0	0	0	0
Type VIII	0	0	0	0	0	0

(75.1%), and type IV (70.6%) to be the predominant pattern. Similar to the findings in this study, type I was the second most common (11%), followed by type II (8.4%) [12]. Furthermore, Alqedairi et al. reported 2.3% versus 0% three-rooted teeth in males versus females, respectively, which is consistent with 4.2% versus 0% the findings in this study. However, the authors did not find a significant difference across gender regarding the canal configuration, while the difference was statistically significant in the present study. In another study by Atieh [13], 246 extracted maxillary first premolars were analyzed visually and radiographically. Results showed the predominance of double-rooted teeth accounting for 81% of the sample, while 18% were single-rooted. Although, the author did not use Vertucci's classification, it was found that the most common type (63%) had two separate root canals from the pulp chamber to the apex, corresponding to Vertucci's type IV. The second most prevalent type (27%) had two fused roots, which corresponds to Vertucci's type II. However, type I was observed in only 9%, which is not consistent with the findings in the present study (23%).

International data generally agree for the commonness of double- and single-rooted teeth, with type IV being often the most frequent canal configuration. However, some exceptions have been noted. A study among the Yemeni population, which analyzed 250 maxillary first premolars using staining and digital photography, showed that 55% of the teeth were single-rooted and 44.4% were double-rooted. However, the canal system configuration was consistent with findings in this study, showing type IV to be the most common (56%), followed by type I and III [14]. In a Turkish population, an in vitro study of 653 extracted maxillary first premolars showed 54% double-rooted and 45% single-rooted teeth [15], which is consistent with the pattern observed in this study. Furthermore, although authors did not classify the morphology using Vertucci's classification, they reported that 68.5% had "two separate root canals that remained separate with two apical foramina", which corresponds to Vertucci's type IV. In North India, Gupta et al. analyzed 250 extracted maxillary first premolar teeth and found that 54% were single-rooted, which is inconsistent with the data in this study and with other Saudi studies. However, similar to this study findings, type IV configuration was the most frequent, accounting for 33.2% of the cases, followed by type I (23.2%) [16]. In Europe, similar observations were reported in Spanish and German populations, where double-rooted pattern was the most common in maxillary first premolars, followed by single-rooted, and type IV being the most frequent in both single- and double-rooted teeth [9,17]. Type IV was also the most common (42%) in a North American population, followed by type I (28%) and type II (26%) [18].

Morphology and number of roots in maxillary second premolar

Regarding the maxillary second premolar, approximately 78% were single-rooted, more frequently in females than in males (86.0% vs. 69.7%, respectively), and the most common canal configuration was type I (aproximately, 38%), notably among females (48.2%), while type IV was the most common among males (33.8%). For both genders, type II was the second most common. While all gender differences were statistically significant. However, no significant differences were observed by nation.

In the study by Alqedairi et al., of the 318 maxillary second premolars analyzed, 85.2% were single-rooted with no notable difference across gender (87% in males versus 83% in females). Additionally, the most frequent canal configuration was type I (49%), irrespective of gender, followed by type II (26%) and type IV (12%) [12]. Concordantly, maxillary second premolars were found to be single-rooted in 83% of the Spanish and German populations; however, while Vertucci's type I was predominant in the Spanish population [9], types V (29%) and IV (25%) were most frequent in the German population [17].

Variations across gender and nationality

The authors observed significant differences across gender in the number of roots and canal configuration. In both maxillary premolars, the single-rooted pattern was more frequent among females. Regarding the canal morphology, type VIII was only observed in males in maxillary first premolars. However, in maxillary second premolars, type IV was the most frequent in males, while type I was the most frequent in females. The gender predilection has been previously reported in several studies, such as the previously cited German study [17], showing generally fewer number of roots and root canals in females than in males. In a study by Martins et al., which analyzed 12,325 teeth from 670 Portuguese individuals, the percentage of single-rooted teeth was significantly higher in females including maxillary first and second premolars [19]. Another study from Turkey demonstrated that females exhibited more frequently single-rooted and single canal maxillary first and second premolars than males, and the differences were statistically significant [20]. However, a Saudi study that examined 5,254 maxillary and mandibular permanent teeth, in 100 males and 108 females, showed no significant difference in the number of roots or canals between males and females. By focusing on premolars,

results showed a significantly higher percentage of one canal in females (42.4%), compared to males (34.1%), in the Saudi population. The authors concluded that there were significant gender disparities, with respect to the number of canals, which were only observed in certain groups of teeth [21].

With respect to the nationality, there was no difference in the root numbers in either tooth, whereas a statistically significant difference was observed in the canal configuration of maxillary first premolars. Ethnically wise, the Saudi population comprises a great diversity, notably in the Western region of the country, where this study has been conducted as demonstrated by genetics-based ethnic analysis. The Eastern region also comprises great ethnic diversity, while more limited diversity was observed in the Central and Northern regions of the country [22]. The ethnic group mixture among the Saudi population may explain the absence of significant difference between the Saudi citizens and non-Saudi participants with regards to the morphological types and number of roots in the maxillary premolars.

Number of roots and canal morphology symmetry

Symmetry in root number was equally observed in three-quarters of the maxillary first and second premolars pairs, and a double-rooted premolar was symmetrical in almost all cases (96.2-100%). On the other hand, symmetry in root canal morphology was relatively low, and was more frequent in type IV, probably due to its high prevalence. By comparison, Guneser and Unver observed symmetry in the root and canal morphology among 93% and 98% of mandibular first and second premolar pairs, among a population of Turkish patients [23]. Likewise, Li et al. observed 80.2% and 81.8% symmetry in the number of roots and 72.3% and 73.2% in root morphology, in maxillary first and second premolar pairs respectively. However, Li et al. observed a higher symmetry in type I in maxillary second premolars, as this was the most prevalent root morphology in the studied population [24].

CONCLUSIONS

There is a high heterogeneity in the maxillary premolar root canal configuration among the studied Saudi population. This is more noticeable in the first premolar, where single- and double-rooted patterns compete with each other, while Vertucci's type IV remains the most common canal configuration. In second premolars, single-rooted pattern is predominant. In both first and second premolars, a significant gender disparity is observed in the number of roots as well as in the canal configuration supporting fewer roots and canals in females. On the other hand, differences across nationality were less significant.

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