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CONE-BEAM COMPUTED TOMOGRAPHIC ANALYSIS OF ROOT AND ROOT CANAL MORPHOLOGY OF MANDIBULAR PREMOLARS IN EGYPTIAN POPULATION

Shaimaa Ismail Gawdat [*], Ahmed Mohamed Abd Alsamad [**] *and* Hany Samy Sadek [***]

ABSTRACT

The goal of this retrospective research was to assess the root and root canal morphology of mandibular premolars in the Egyptian population using cone-beam computed tomography. 300 CBCT scans were surveyed and the anatomy of 306 mandibular first and 288 second premolars was evaluated. The prevalence of the number of roots, root canals, canal morphologies according to the Vertucci classification and C-shaped canals was calculated and statistically assessed. Regarding the first and second mandibular premolars, the majority showed 1 root (95.4% and 98.6%, respectively) with 1 canal (84.6% and 97.9%). Most of the mandibular first (62.4%) and second premolars (96.2%) showed (type I) root canal morphology, followed by type V (27.1% and 2.1%) in the first and second premolars, respectively. A C-shaped root canal configuration was only detected in one mandibular second premolar (0.3%). Additional root canals and variations in root canal morphology should be considered when treating mandibular premolars to avoid failures.

KEY WORDS: Cone beam computed tomography, C-shaped canals, Mandibular premolars, Root canal anatomy, Vertucci.

INTRODUCTION

Root canal anatomy of mandibular premolars is complicated, making it one of the hardest teeth to treat and one with the greatest like-hood of failure at a rate of 11.45% [(1)]. The existence of multiple root canals, as well as a wide range of root canal morphology, apical ramifications, and double canals with a lingually placed second canal that mostly has a sharp entry angle placed in the middle or apical thirds, contributes to its being overlooked clinically [(2)]. Another anatomical variation that was documented in Chinese populations is the C-shaped canals, which are usually accompanied by a groove on the outer root surface [(3)].

* Associate Professor of Endodontics, Endodontic Department, Faculty of Dentistry, Cairo University, Egypt.
** Associate Professor of Oral and Maxillofacial Radiology, Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Egypt.
*** Associate Professor of Endodontics, Endodontic Department, Faculty of Dentistry, Cairo University, Egypt.

Post-treatment flare-ups with a reported high prevalence of apical lesions in teeth with missed canals have been reported, confirming the presence of too much variation in their morphology [4]. Proper knowledge and comprehension of the internal complex 3-dimensional anatomy of teeth, as well as anticipation of unusual root canal anatomy, are essential for avoiding treatment failures and achieving success [5].

Single-rooted first mandibular premolars account for the vast majority (98%), followed by two-rooted premolars (1.8%), and three-rooted premolars (0.1%). In terms of internal canal morphology, approximately 75.8% have a single canal, whereas 24.4% have two or more canals [6]. Typically, the second mandibular premolar has one root (99.6%) [7]. Although the single canal system is the most frequently observed morphology in mandibular premolars, the presence of multiple canals is frequently described in many ethnic groups [3,8-10].

Several attempts have been made to study the anatomical variations of roots and root canals, with Vertucci et al. being one of the most commonly used classifications[11]. Canal staining and tooth clearing techniques [12], contrast medium–enhanced radiography [13], and micro–computed tomographic imaging, which provides higher resolution and detailed images of accessory root canal isthmic structures [14], have all been used to investigate root canal morphology in vitro. However, since these approaches are performed ex vivo and can only be employed with extracted teeth, their clinical utility is restricted. In vivo methods include conventional intraoral periapical radiographs, but they produce only two-dimensional images of three-dimensional objects, distorting and superimposing structures and omitting the pivotal third dimension, which may result in missing canals and buccolingual curves of root canals. CBCT scans have recently become a great tool, offering an improved understanding of root canal anatomy in three dimensions. Patients' sex, age, and ethnicity are normally listed in their medical histories so ethnic variability can be properly considered [15-19].

Root canal morphology of the mandibular first premolars has been studied in various populations [3,8-10,15-19]. Previous research has been published on the root canal anatomy of mandibular premolars in Egyptians. However, they used clearing techniques [20] or digital periapical radiographs [21] but, to our knowledge, no study has utilized the use of CBCT to assess the prevalence of different root canal anatomies of mandibular premolars in the Egyptian population. The current retrospective study was conducted to determine the incidence of Vertucci root canal configurations, number of roots, root canals, and C-shaped root canals in mandibular premolars. This knowledge can assist dentists in identifying and treating complicated root canal anatomies.

MATERIALS AND METHODS

The prevalence of mandibular first premolars with a single canal was found to be 75.8% [6]. With a 95% confidence limit and 5% precision, the minimum sample size for measuring the prevalence of single canals in mandibular 1st premolars of the Egyptian population was calculated and found to be 282 mandibular first premolars. About 300 CBCT scans were surveyed to reach the target sample size required.

CBCT scans of Egyptian patients were gathered in this cross-sectional analysis after the approval of the Research Ethics Committee, Faculty of Dentistry, Cairo University (Ethics committee approval number 8421). CBCT scans were obtained from the database available at the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Cairo University. CBCT scans were taken in the course of their dental checkup, diagnosis, or planning of treatment during the period from 2018–2020. Retrospective data collection was done to avoid exposing the patients to unneeded radiation doses for research purposes.

At the time of radiation exposure, only the patients' sex, age, as well as origin were known, ensuring that all patients were Egyptian, other data was kept confidential. High quality CBCT images with a full view of the mandibular first or second premolar were included. The following exclusion criteria were used: The CBCT image quality was inadequate for analysis. Sex was not recorded. In the CBCT scan, the mandibular premolar had the following features: previous endodontic treatment, a radiopaque filling obscuring the pulp chamber or root canal, resorbed roots, incompletely formed roots or root canal calcifications, and evidence of tumors or cysts that can make identifying anatomical features more difficult.

CBCT scans were performed using Planmeca ProMax® 3D Mid (Planmeca OY, Helsinki, Finland). All CBCT images were acquired in a digital DICOM format. The images were then imported to Planmeca Romexis® Viewer (Romexis version 4.6.2.R; Planmeca OY, Helsinki, Finland). The scans enrolled in the study were imaged using 90 kVp, 6-8 mA, a voxel size of 200 µm, 12–13.6 sec scanning time, and various fields of view, ranging from larger scans of 16 × 10 cm to smaller ones of 4 × 5 cm.

Scans were analysed in three orthogonal planes: axial, coronal, and sagittal. The three orthogonal planes were adjusted and corrected for each tooth independently according to its own alignment, where several outcomes have been assessed. The image contrast, brightness, and magnification were adjusted in the examined scans whenever needed, using the software image processing tools. On the axial image, the coronal plane was rotated to be perpendicular to the buccal tooth surface in the middle of the tooth. Then, on the coronal and sagittal images, the sagittal and coronal reference lines were oriented parallel to the long axis of the root.

The axial images with a thickness of 0.2 mm were thoroughly scrolled starting from the cemento-enamel junction (CEJ), ending at the root apex for detection of the number of roots, number of root canals, root canal configuration according to Vertucci classification, and C-shaped root canal. Using the coronal images with a thickness of 0.2 mm, tooth length was measured, as well as the distance of canal bifurcation from the cementoenamel junction (CEJ). The direction of root curvature was determined, whether mesial, distal, buccal or lingual on both the coronal and sagittal images.

CBCT images were interpreted by one oral and maxillofacial radiologist and two endodontists who have experience in interpreting CBCT images independently; any disagreements in the observation were discussed and, if needed, analysis by another blinded endodontist was done until the authors reached a final ***consensus***.

Criteria to be evaluated were: sex of the patient, tooth number, length of the tooth, number of roots, number of root canals, root canal configuration according to Vertucci classification, which is as follows: type I (1), type II (2-1), type III (1-2-1), type IV (2), type V (1-2), type VI (2-1-2), type VII (1-2-1-2), and type VIII (3), C-shaped root canal, direction of canal curvature, distance to canal bifurcation, and association of gender with number of roots, root canals and configuration.

Statistical analysis

SPSS (Version 20.0; SPSS Inc, Chicago, IL) software was used for statistical analysis. The predominance of root canal configuration according to Vertucci classification, number of roots and root canals, C-shaped root canals, and canal curvature direction were all recorded using descriptive statistics as frequencies (N) and percentages. Continuous data as tooth length , distance to canal furcation were shown as mean, and standard deviation (SD). The correlation between gender and the number of roots and root canals was investigated using the Chi-square test and Fisher's exact test.

RESULTS

The study comprised 300 CBCT scans containing 306 mandibular first premolars from 124 males (40.5%) and 182 females (59.5%) and 288 mandibular second premolars from 115 males (39.9%) and 173 females (60.1%). On assessing root number, the mandibular 1st and 2nd premolars had 1 root (95.4% and 98.6%, respectively). As for the 2 roots configuration, they were present in 4.6% and 1.4% of the mandibular 1st and 2nd premolars, respectively (Figure 1). Three rooted mandibular premolars were not detected in our research (Table 1).

Vertucci type I was presented in 62.4% and 96.2% of the mandibular 1st and 2nd premolars, respectively, to be the most prevalent root canal configuration. Vertucci type V (canal bifurcation) came second with a prevalence of 27.1 % and 2.1 % in the mandibular 1st and 2nd premolars, respectively. The incidence of alternative root canal morphologies according to the Vertucci classification is shown in (Table 1). There was a statistically significant difference between 1st and 2nd premolars regarding the number of roots ($p = 0.03$), the number of canals ($p < 0.001$), and canal types according to Vertucci ($p < 0.001$) (Table 1).

TABLE (1): Frequencies (N) and percentages (%) of gender distribution, roots number, canals number, canals type by Vertucci classification, canals curvatures, C – shaped canals in mandibular 1st and 2nd premolars and the results of Chi square test and Fisher's exact test for comparison between them:

		Lower 1st premolar		**lower 2nd premolar**		***P* – Value**
	Left	**N**	**%**	**N**	**%**	
Gender	**Male**	124	40.5%	115	39.9%	0.933
	Female	182	59.5%	173	60.1%	
Number Of roots	**1 root**	292	95.4%	284	98.6%	0.03*
	2 roots	14	4.6%	4	1.4%	
Number of canals	**1 Canal**	259	84.6%	282	97.9%	<0.001*
	2 Canals	47	15.4%	6	2.1%	
Canal Type by Vertucci	**Type I**	191	62.4%	277	96.2%	
	Type II	2	0.7%	0	0.0%	
	Type III	28	9.2%	5	1.7%	
	Type IV	0	0.0%	0	0.0%	
	Type V	83	27.1%	6	2.1%	<0.001*(f)
	Type VI	1	0.3%	0	0.0%	
	Type VII	1	0.3%	0	0.0%	
	Type VIII	0	0.0%	0	0.0%	
Canal Curvature	**Straight**	217	70.9%	228	79.2%	
	Buccal	1	0.3%	3	1.0%	
	Lingual	5	1.6%	3	1.0%	
	Mesial	7	2.3%	2	0.7%	0.054
	Distal	73	23.9%	52	18.1%	
	Dilacerated	3	1.0%	0	0.0%	
C-shaped Canals	**Present**	0	0.0%	1	0.3%	0.485
	Absent	306	100.0%	287	99.7%	

Significant at p<0.05

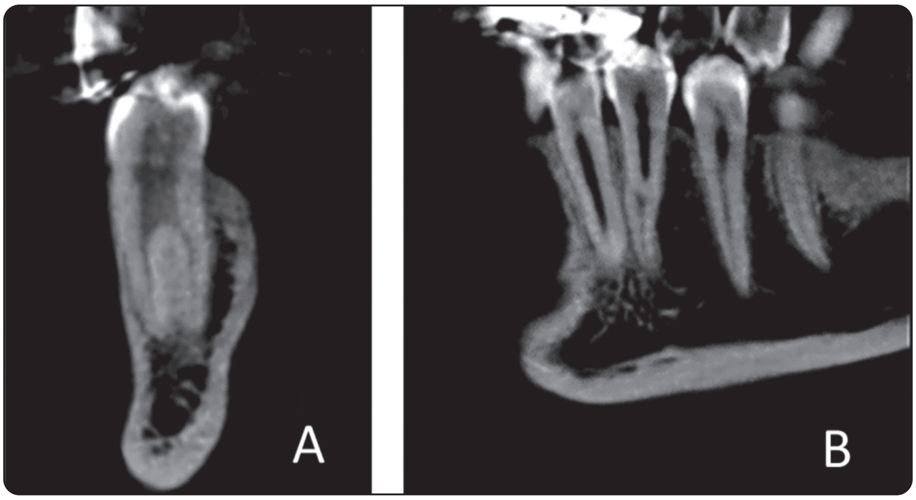

Fig. (1): CBCT images of 2 rooted mandibular right first premolar. A Coronal view showing buccal and lingual roots . B Sagittal view showing fading of the root canal in middle third (fast break).

There was no C-shaped root canal configuration in mandibular first premolars, and only one mandibular second premolar (0.3%) had C-shaped canal morphology type C4 according to Fan's classification (22) (Figure 2) (Table 1). 217 (70.9%) mandibular first premolars and 228 (79.2%) mandibular second premolars showed straight roots, percentage of various directions of root canal curvature is shown in (Table 1) (Figure 3) .There was no statistically significant difference between 1st and 2nd premolars regarding the direction of canal curvatures (p = 0.054) and the incidence of C-shaped canals (p = 0.485).

The mean values of the tooth length of the mandibular first and second premolars were 22.2 (1.8) mm and 22.1 (1.8) mm, respectively. (Table 2) highlights descriptive statistics of tooth length of 1st and 2nd premolars in both genders. In double-canalled mandibular 1st premolars, the mean values of the length from CEJ to the furcation area were 5.7 mm (2.7), and 6.6 (3.4) mm for mandibular second premolars, with no statistically significant difference between first and second mandibular premolars (Figure 4) (Table 3).

There was no correlation between gender and the number of roots of mandibular 1st premolars (p = 0.265) or mandibular second premolars (p = 1.0). Also, no association was found between gender and the number of root canals of mandibular 1st premolars (p = 1.0) or mandibular second premolars (p = 0221) (Table 4).

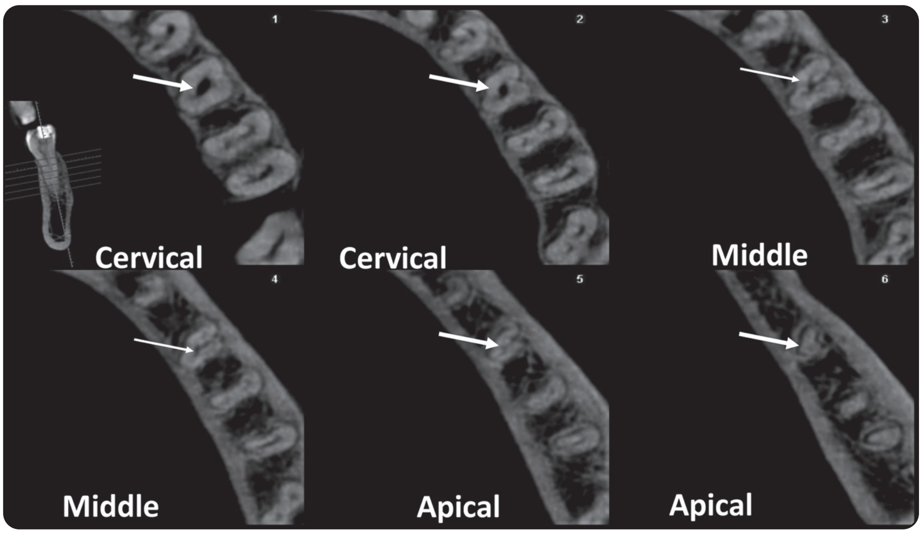

Fig. (2): CBCT image of Lower left second premolar with serial axial cuts showing cross sections of C-shaped canal type C4 according to Fan's classification in cervical, middle and apical parts of root.

Fig. (3): CBCT scan of a Lower left second premolar showing A) mesial root curvature and B) lingual root curvature. C) CBCT scan of a Lower right first premolar showing distal root curvature.

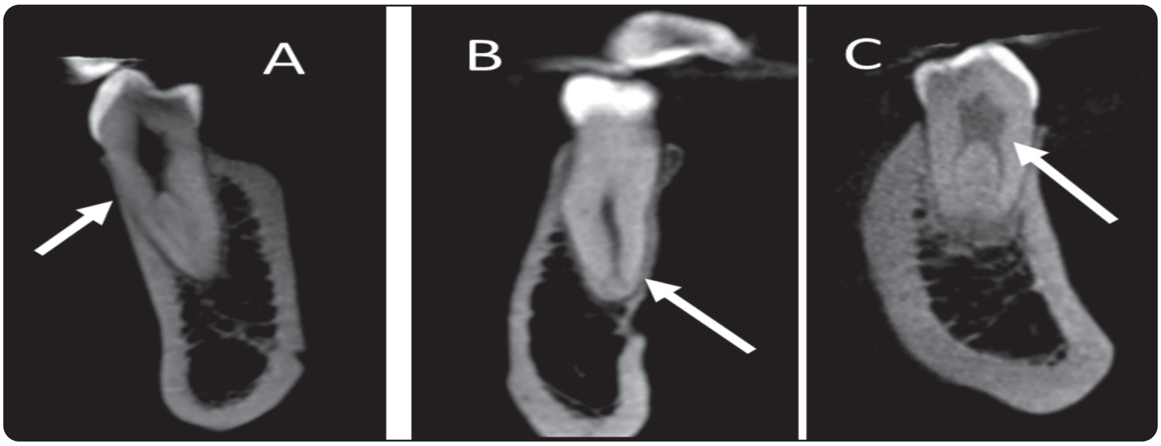

Fig. (4): CBCT Coronal views A) Lower right first premolar showing root canal type V with bifurcation at middle one third. B) Lower left second premolar showing root canal type V with bifurcation at apical one third. C)Lower left second premolar showing root canal type V with bifurcation at cervical one third.

TABLE (2): Descriptive statistics of tooth length of mandibular 1st and 2nd premolars in both genders.

	Mandibular 1st premolar		**Mandibular 2nd premolar**	
	Tooth length		**Tooth length**	
	Male	**Female**	**Male**	**Female**
Mean	22.7	21.8	22.7	21.8
SD	1.8	1.7	1.7	1.7
Median	22.6	21.9	22.7	21.8
Minimum	18.6	16.6	18.5	17.6
Maximum	27.4	27.9	26.8	27.0

TABLE (3): Descriptive statistics and the results of independent t test for comparison of length from CEJ to furcation between mandibular 1st and 2nd premolars:

	Length from CEJ to furcation		
	1st premolar	**2nd premolar**	***P* - Value**
Mean	5.7	6.6	
SD	2.7	3.4	
Median	4.8	5.8	0.251
Minimum	1.0	2.5	
Maximum	13.6	13.2	

TABLE (4): Frequencies (N) and percentages (%) of gender distribution and root number and the results of Chi-square test for correlation between gender distribution and number of roots and number of root canals of mandibular 1st and 2nd premolars:

				Number of roots		
				One root	**Two roots**	***P* -Value**
Mandibular 1st premolar	**Gender**	**Male**	N	116	8	0.265
			%	93.5%	6.5%	
		Female	N	176	6	
			%	96.7%	3.3%	
Mandibular 2nd premolar	**Gender**	**Male**	N	113	2	1
			%	98.3%	1.7%	
		Female	N	171	2	
			%	98.8%	1.2%	
				Number of canals		
				One canal	**Two canals**	***P* -Value**
Mandibular 1st premolar	**Gender**	**Male**	N	105	19	1
			%	84.7%	15.3%	
		Female	N	154	28	
			%	84.6%	15.4%	
Mandibular 2nd premolar	**Gender**	**Male**	N	111	4	0.221
			%	96.5%	3.5%	
		Female	N	171	2	
			%	98.8%	1.2%	

Percentages are within gender distribution

DISCUSSION

Missed canals significantly reduce treatment success; an untreated canal, whether infected or not, raises the likelihood of failure by retaining bacteria in large enough numbers to sustain or cause disease, or by serving as a potentially vulnerable site for reinfection [4]. The goal of this investigation was to identify the prevalence of root and root canal configurations in the adult Egyptian population. During the course of this study, Mohamed and Abdallah [23] published a study using CBCT to investigate the root canal morphology of mandibular premolars in Egyptians. However, this research was carried out in a different governorate and did not address the prevalence of C-shaped canals, direction of root curvature, average tooth length, or distance to canal bifurcation if present. Additionally, we used small voxel size CBCT scans to visualize anatomical changes more precisely. However, the results of this published study were compared to ours.

CBCT was chosen in this investigation because it is a reliable, noninvasive imaging method that gives high-resolution three-dimensional pictures with the option of eliminating overlapping structures [15,24]. It's been utilized in a number of studies to evaluate root and root canal morphology in diverse populations [16–19]. Neelakantan et al. showed that the accuracy of CBCT was comparable to that obtained from modified canal staining and clearing techniques used for root canal anatomy identification [25]. Also, when data from reconstructions of CBCT images was compared to histological sections for root canal anatomy identification, a strong correlation was found, as reported by Michetti et al. [24]. It's also worth noting that CBCT studies in vivo have some limits because additional artefacts such as noise, scattering, and motion artefacts can impair image quality. However, the most significant disadvantage of CBCT imaging is its low spatial resolution, which makes it unsuitable for distinguishing fine anatomic features such as lateral canals or apical foramina. That is why these fine features were not assessed in the present study [26]. 95.4% and 98.6% of 1st and 2nd mandibular premolars respectively had single roots, this was in agreement with Alhadainy in a previous in-vitro Egyptian study where (96.8%) of 1st mandibular premolars were single rooted [20]. Our percentages were close to those reported by Alfawaz et al. on the Saudi population, where 96.4% and 95.6% of 1st and 2nd premolars, respectively, had single roots [16]. We had a slightly higher percentage of double-rooted first mandibular premolars (4.6%) than that reported by Alhadainy (3.2%) [20] and Mohamed and Abdallah (1.8 %) [23] and Alfawaz (3.1%) [16]. It was comparable to that reported on the Iranian population (4.1%) [17]. However, it was lower than the 5.2 % recorded by Corbella et al. on Caucasian populations [18], Alenezi et al. on the Kuawiiti population, where they reported a high percentage of 24.9 % and 20.8 % for mandibular 1st and 2nd premolars, respectively [19]. The paucity of three rooted first premolars in our investigation was consistent with previous observations of a rare occurrence [6].

The mandibular second premolars evaluated in our study had lower two-rooted morphology (1.4%) and two-canal incidence (2.1%) than mandibular first premolars, which was consistent with Mohamed and Abdallah's [23] findings that reported (1%) of two-rooted teeth and (3.9%) of two-canal incidence. This was also in accordance with previous literature [27]. Other in vitro research on Turkish [5] and Jordanian [9] populations found higher prevalence rates.

In this study, the classification adopted by Vertucci [12] was considered because it was extensively employed in the literature. The most frequently encountered configuration in mandibular first premolars was Vertucci Type I (62.4%) and (96.2%) in second premolar teeth. That came in agreement with most studies in the literature [6,27]. In the current investigation, type V canal configuration was reported to be the second most common canal configuration in mandibular first premolars. (27.1%), which is consistent with a previously published review [27] and numerous studies [8,9,17,28]. These findings also match a prior study conducted by Alhadainy et al. [20], in which type V was the second most prevalent root canal type (16.4%). It also agrees with a multicenter cross-sectional study on the prevalence of lingual canals in mandibular premolars worldwide, which showed that Africa had the highest percentage of lingual canals in mandibular first premolars, with Egypt having a range of 27.4%–38.0% [29]. However, these findings contradict those found by Mohamed and Abdallah [23], who reported that types II and III are the second and third most abundant anatomical types in mandibular first premolars in the Egyptian population. These findings highlight the significance of looking for the second root canal to ensure complete debridement. Extra root canals can be easily missed on periapical radiographs due to their difficult recognition, especially when they are present in a single root.

Type V was likewise the second most frequently encountered configuration in mandibular second premolars (2.1%), which is consistent with earlier research on the Spanish [30] and Jordanian populations [9]. On the other hand, several studies in the Iranian [17], Saudi [16], and Korean (28) populations found that types III and II were the second most prevalent anatomical types in lower 2nd premolars. The absence of type IV in our results was consistent with earlier research [28,30]. In general, the prevalence of type V was lower in mandibular 2nd premolars than in mandibular 1st premolars, that matched a previous study. which showed that the prevalence of 2nd lingual canal was 5.3% [29].

In general, there was a scarcity of type VI, VII, and VIII configurations in mandibular 1st and 2nd premolars in the literature [17,18]. Nonetheless, our study's low prevalence of mandibular first premolars with type VIII (0.3%) was within the reported range in earlier CBCT studies in the Egyptian population (0.5%) [23].

In terms of the number of root canals in mandibular first premolars, our findings were (84.6%) with one canal, (15.4%) with two canals, which agreed with Mohamed and Abdallah [23] who found 86.3% of teeth with one canal, 13.3% with two canals, and 0.8% with three canals, but no three root canal system was documented in our study.

The mean length of the mandibular first and second premolars was 22.2 mm and 22.1 mm, respectively, which was consistent with Alhadainy's prior in vitro study on the Egyptian population [20]. The Jordanian population had an average length of 22.6 mm [9]. The mean length of the first mandibular premolars in the Spanish population was 22.3 mm, and 21.8 mm for the second premolars [30]. Straight roots were observed in the majority of the investigated first and second mandibular premolars (70.9% and 79.2% respectively), followed by distal root curvature, accounting for a percentage of 23.9% and 18.1%. This is in accordance with the research on the Kuwaiti population [19]. Hajihassani et al. also recorded comparable findings [17]. The roots of almost all teeth are angled along their long axis [7]. According to Khedmat et al. [8], root curvature was found to be more common in the first than the second mandibular premolars, with distal curvature being most prevalent in the first premolars, which was consistent with our results.

Due to its complicated structure, including fins and isthmuses, a C-shaped root canal is difficult to treat. Only one mandibular second premolar (0.3%) had a C-shaped root canal morphology, whereas none was detected in mandibular first premolars. Our findings cannot be compared to earlier findings on the Egyptian population since no previous in vitro studies or the previously conducted CBCT research [23] have addressed C-shaped canals. Our findings were consistent with those of recent research performed on a Kuwaiti population [19] in which C-shaped canals (1.3%) were only found in the second premolars and were classified as category III (C3) by Fan et al. [22]. However, we reported a lower proportion than that of the study. No C-shaped canals were reported in mandibular premolars in Saudi [16] or Iranian [17] populations. C-shaped canals were observed to be more prevalent (18%) in the mandibular first premolars of the Chinese population [3]. The disparities are mostly related to racial differences.

In the double-canalled mandibular 1st and second premolars, the mean length to furcation from cementoenamel junction came in agreement with a study done on the Spanish population where bifurcation was located at 6.87 mm [30]. The findings are consistent with those of other investigators who have published studies [3, 8, 15]. In this study, the great majority of the additional root canal orifices in mandibular premolars developed apical to the CEJ. The use of a dental operating microscope with its enhanced illumination and variable degrees of magnification is required to visualise the deep portion of the root canal anatomy. When the presence of additional canals is suspected, like with a bulb shaped exterior root morphology on the periapical radiograph, it is advisable to extensively scout the interior root canal wall for additional canals.

No correlation between gender and the number of roots or root canals in mandibular first or second premolars, which was consistent with Mohamed and Abdallah [23] and previous research on Saudi [16], Iranian [17] and Italian populations [18]. More research with larger cohorts may be required to confirm a significant sex difference. The symmetry on both sides regarding the number of roots, root canals or root canal configuration couldn't be assessed in this study as the CBCT scans used for this retrospective study were of different sizes (16 x 10 cm and 4 x 5 cm). The smaller field of view scans made it hard to assess bilateral symmetry. Also, the presence of missing or endodontically treated mandibular premolars made the present criteria difficult to assess.

Vertucci classification was used in this study as it is the most commonly used classification, however it has its drawbacks as it is more focused on describing root canal configuration only , but not giving information about whether these root canals are present in single, double or triple rooted teeth. Ahmed's classification is a new classification that provides precise information about the root and root canal arrangement simultaneously; it can be used in future investigations [31].

CONCLUSIONS

In terms of the number of roots and root canal configuration, we observed that mandibular first premolars exhibit greater anatomical variances than mandibular second premolars. The current study's findings provided some insight into the internal anatomy of the mandibular premolar in the Egyptian population, which can be used by endodontists and dental clinicians to aid in decision making and achieve successful root canal therapy. It also proved the existence of ethnic differences across various races. Finally, dentists should be mindful of the mandibular premolars' anatomical diversity, where identification of possible complex root canal morphology requires the use of CBCT with a small field of view as it provides crucial information regarding tooth anatomy, root canal number and location, and a dental operating microscope, in addition to a good understanding of various root canal configurations.

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