Keywords
Artificial intelligence; Root canal morphology; Cone beam computed tomography; Digital dentistry; Mandibular premolars; Endodontics; Restorative dentistry.

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Received: 01.04.2026
Revised: 24.04.2026
Accepted: 11.05.2026
DOI: 10.1922/ejprd.v34i1s.1365

European Journal of Prosthodontics and Restorative Dentistry (2026) 34(1s), 76–88

Artificial Intelligence-Assisted CBCT Evaluation of Root Canal Morphology and Cross-Sectional Anatomy of Permanent Mandibular Premolars: A Retrospective Study.

Abstract
Objective
Artificial intelligence (AI)-supported diagnostic imaging has emerged as a transformative approach in restorative dentistry and endodontics, improving the precision of anatomical interpretation and treatment planning. This retrospective CBCT-based study aimed to evaluate the root morphology, root canal configuration, and cross-sectional anatomy of permanent mandibular premolars with a focus on the clinical significance of AI-assisted imaging technologies in contemporary dental diagnostics.
Materials and Methods
A retrospective analysis was conducted on 249 cone beam computed tomography (CBCT) scans from Iraqi patients between the ages of 15 and 45. The root number, canal number, Vertucci-classified canal configuration, and root cross-sectional morphology at the coronal, middle, and apical levels of mandibular first and second premolars were assessed. After calibrated observer training, standardised CBCT image evaluation was carried out in the axial, sagittal, and coronal planes. Pearson's Chi-square test was used for statistical analysis to identify differences based on tooth side and sex ($p < 0.05$).
Results
In mandibular first premolars (85.6%) and second premolars (98.7%), single-root morphology predominated. Similarly, 83.1% and 98.1% of first and second premolars, respectively, had single canals. The Vertucci Type I canal configuration was the most prevalent morphology in mandibular first (81.4%) and second (97.5%) premolars, followed by Type V configurations. Cross-sectional analysis revealed elongated oval morphology as the dominant configuration at coronal and middle levels, whereas round morphology predominated apically. Mandibular first premolars demonstrated greater anatomical complexity and variability compared with second premolars.
Conclusion
Considerable anatomical variation exists in mandibular premolar root canal systems despite the predominance of single-rooted and single-canaled patterns. CBCT imaging provides detailed three-dimensional anatomical visualization essential for restorative and endodontic procedures. The integration of AI-assisted CBCT interpretation may further enhance automated canal detection, morphological classification, and precision-guided treatment planning in restorative dentistry and oral rehabilitation.

Introduction
In the dental field, learning about root canal morphology is crucial, particularly if successful endodontics is the goal. The intricacy of root canal

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system makes it necessary for a dental professional to know in detail about the variations to diagnose and treat cases related to pulp. Modern researches have pointed out that the description of endodontic systems, such as the configuration and occurrence of lateral and accessory canals, is a key factor in achieving better treatment results (1). Furthermore, the morphology of the mandibular premolars has been emphasised in a comprehensive literature that reflects the particular features that are significant in clinical practice, such as tooth development and morphology. This knowledge allows for accurate interventions, decrease in risk of procedural complication, and complete instrumentation and cleaning of the canals. Finally, a thorough knowledge of the morphology of the root canals, accessed with modern imaging technology, can not only aid in improving clinical success, but can play a major role in the overall success of endodontic therapy to maintain natural dentition (2).

Permanent mandibular premolars have a complicated root canal anatomy (3), characterized by their unique root canal configurations, which may significantly affect endodontic treatment outcomes. Many researchers have indicated that these premolars typically possess one or two roots, with the majority exhibiting a variable root canal system that may include multiple canals within a single root(4). Studies using µCT have shown that the prevalence of lateral canals is substantial (up to 85%), especially in the first mandibular premolars in which associations with accessory canals (1) also contribute to the complexity of the root canal systems morphology. Recognising these anatomical characteristics is essential because differences in the quantity and kind of canals may make dental procedures less successful. Interestingly, historical studies (such as those on the canal diversity of Radom, Poland) also support the evolutionary part of canal diversity, and relate the historical variability to the modern anatomical ones (5). This knowledge is the basis for highly effective diagnosis and therapies in today's dental practice.

Medical radiological imaging, including cone beam computed tomography (CBCT), has evolved to a new level of sophistication and have revolutionized the ability to diagnose complex canal configurations, allowing clinicians to deal with the challenges presented by complex anatomy with greater precision (6). The changing perception highlights the need for evidence-based clinical management in endodontics for maximizing clinical outcomes. Further, by studying historical populations, it has been found that root canal morphology may have been subject to change over time, indicating that both anatomical and evolutionary factors may be essential (7).

The primary objective of this paper is to characterise the number of roots, the number and arrangement of root canals, and the cross-sectional appearance of canals of mandibular permanent premolars using CBCT.

Materials and methods

Sample collection

To achieve the sample size of 249 scans for the study, 2400 CBCT files were chosen from various private and public dental clinics across different districts of Babylon governorate. That information was previously stored in the radiology departments for patients who came to the clinics for various purposes including dental and maxillofacial surgery, trauma, periodontics, endodontics, orthodontics or other reasons.

Sample selection

The collected CBCT images were filtered and examined thoroughly across three successive steps; **first**, the image validity includes: (1.) The radiographs should be captured in a period between 2019 to 2024. (2.) FOV for the scanning device should cover the target teeth, peri-radicular areas, and the entire bone in the jaw (favorably medium-sized scan). **Second**, the patients aged within 15-45 years old age limit. **Third**, the mandibular jaw aspects: each scan should contain mature fully developed mandibular first (M4) and second premolar (M5), with intact pulp chamber and root canal space, normal density enamel and dentin, and normal width periodontal area. On the other hand, the exclusion criteria were: skeletal asymmetry or trauma; external or internal resorption; periodontal or periapical pathology; immature apex; root canal treatment; crown and/or post space treatment; radicular caries; deep coronal caries endangering the pulp ; root trauma or fracture; bony disease; and unclear or deranged anatomy as a result of physiologic or pathologic conditions (8-10).

Before starting the study, the researcher (a general practitioner) underwent comprehensive training by a qualified radiologist on operating the CBCT machine, managing and configuring images, and illustrating root canal anatomy from various perspectives. Subsequently, two endodontists and the researcher conducted independent evaluations in the same room under natural light, using the same screen.

Sample examination

The examiners performed two separate one-hour examinations of the scans, ensuring a minimum of seven days' interval between sessions to reduce eye fatigue. During these evaluations, they documented the following aspects of the teeth:

(1) How many root for each tooth.
(2) How many canal for every root.
(3) Canal configuration for every root based on Vertucci classification (11).
(4) The frequency of specific anatomical anomalies.
(5) Axial Cross-sectional shape of roots at coronal (the last slide before roots furcation), middle (midpoint from orifice to apex), and apical (3mm coronal to radiographic apex) axial planes.

For standardization, the cross-sectional shapes of the roots defined as follows: **(Figure 1)**

• Round (circular shape of the root cross-section with a single dimension).
• Oval (where one dimension of the circular shape is longer than the other).
• Elongated oval (where the long dimension of the circular shape is double the short one).
• Tape shape (elongated-oval shape but the long dimension is more than double the short dimension).

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• Kidney shape (oval or elongated oval shape with a median indentation from one side of the long dimension and rounded line angles)
• Semilunar (elongated-oval shape with an indentation on the middle for one side of the long dimension and with pointed line angles)
• Elliptical (elongated-oval shape section with a median indentation from both sides of the long dimension both on the same line that does not meet).
• Figure 8: (elongated oval shape section with deep indentation in the middle that meet in the middle of the long dimension on the same line).
• Triangular (cross-section of the root with three dimensions meet at rounded line angles).
• Y-shape (tape shape that extends in three directions with centre point in the middle).
• Irregular shape (cross section that does not resemble any of the above-mentioned shapes).
All these factors were statistically compared according to sex (male and female) and tooth side (right and left).

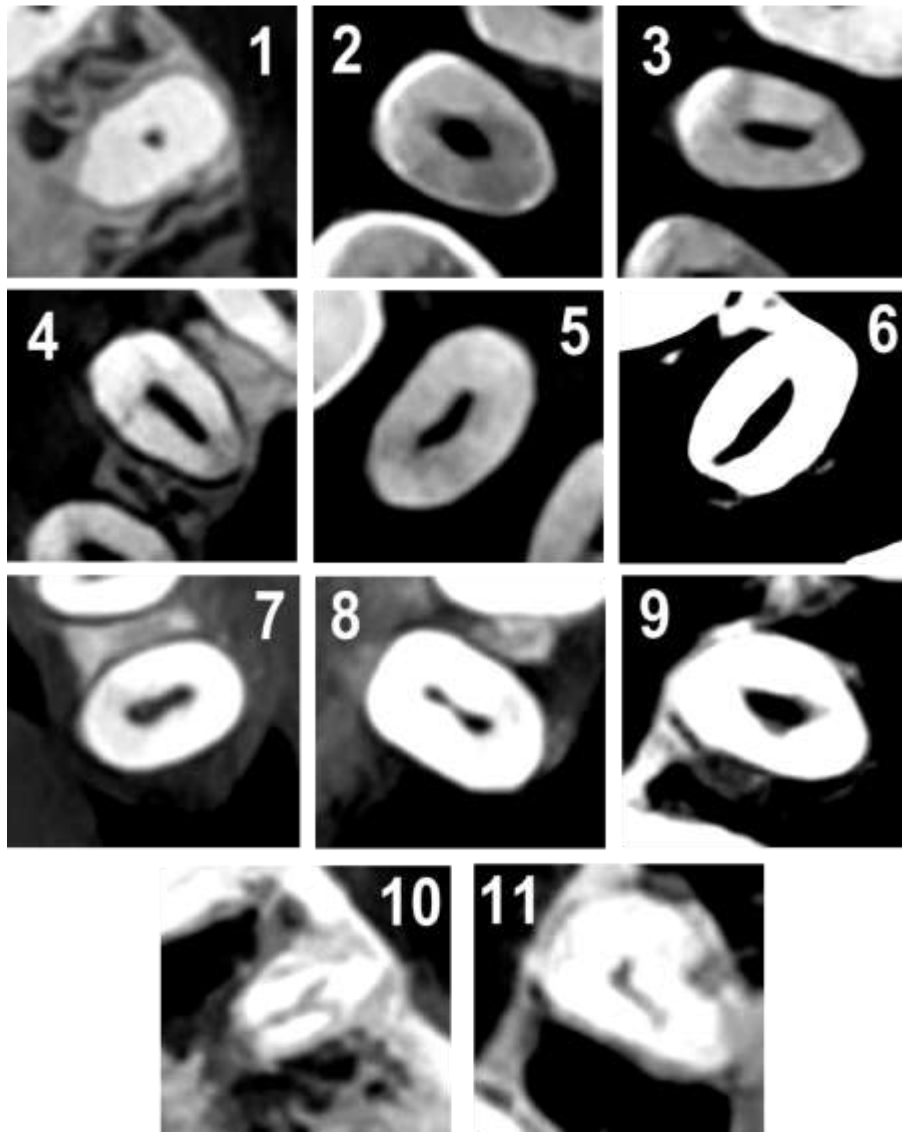

Figure 1: The cross-sectional shapes of permanent mandibular premolars' roots; **1.** Round **2.** Oval **3.** Elongated oval **4.** Tape shape **5.** Kidney shape **6.** Semilunar **7.** Elliptical **8.** Figure 8 **9.** Triangular **10.** Y-shape **11**. Irregular shape

Statistical analysis
A statistical package of social science software (SPSS IBM version 26) was used to obtain statistics for the current study. Microsoft Office Excel Professional Plus 2013 was used to plot the tables. Data for this study were non-parametric.
The analyzing statistics included:
• The The data's normality was examined using the Kolmogorov-Smirnov test.
• Descriptive statistics: Based on frequency and percentage.
• Inferential statistics: Non-parametric test (Pearson Chi-Square test) used for nonparametric data, at a 95% confidence interval, and error margin (α) = (0.05%).

Calibration:
Observers went through a rigorous training and calibration process to guarantee reliable and consistent interpretation of CBCT images. An experienced endodontist assisted with this procedure, offering direction and validating the training results. The training was carried out in a structured session using a pilot

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sample of 50 CBCT images that were carefully chosen to represent the variable morphologies, such as variations in the number of root and canal anatomy (e.g., single, double, or more). The observers were trained to analyse the CBCT images in three planes (coronal, sagittal, and axial) using some of the criteria outlined in the categorisation system by Ahmed et al. All magnifications and brightness and contrast used throughout this stage were done to ensure the best possible visualization. Observations were made independently by the observers, taking into account significant variables such as morphology of canals and number of roots , presence of fusion and deviations from the normal anatomical pattern. A consensus approach was used to settle interpretation disputes, entailing a thorough examination of the pictures by the endodontist expert and observers. This discussion was guided by predetermined standards for the shape of the canal and root, confirming that the choices were reliable with the organization system used. The Intraclass Correlation Coefficient (ICC) was calculated to assess interobserver reliability based on this pilot study. The reliability of the observer's evaluation was ascertained by good ICC value (0.85) between the observers. This thorough calibration procedure guaranteed consistency in picture interpretation, improving the study findings' validity and reproducibility.

Results

Descriptive statistics were displayed as percentages and frequencies for the first mandibular premolar (M4) and second mandibular premolar (M5). For both premolars, inferential statistics were used to show the relationship between gender and root number. There was no discernible difference in the number of roots between males and females ($p<0.05$). As shown in Table 1, males reported a higher incidence (17.4%) of two roots compared to females ($p<0.05$), and females reported a higher percentage of one root. For M5, there was no variance in the number of roots between females and males; Table 1 shows that most cases had a single root.

Gender and root number						
			Root No.		Total	p-value*
M4	Gender		1	2		
	Female	Count	249	35	284	0.117
		% within Gender	87.70%	12.30%	100.00%	
	Male	Count	161	34	195	
		% within Gender	82.60%	17.40%	100.00%	
M5			Root No.		Total	p-value*
			1	2		
	Female	Count	279a	5a	284	0.228
		% within Gender	98.20%	1.80%	100.00%	
	Male	Count	194a	1a	195	
		% within Gender	99.50%	0.50%	100.00%	
A subset of Root No. categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.						

Table 1: illustrates the relation between the gender and quantity of roots number for both mandibular premolars.

Root morphology and gender:

For both mandibular premolars, the correlation between root morphology and gender was examined using the Pearson Chi-Square test. It can be noted that the highest percentage of M4 teeth have one root. A much lower proportion (15%) reported with two roots, however, a higher proportion of these was two fused with significantly higher proportion in males. No three roots were reported. On the other side, in M5 a very high incidence was for single roots (99%), but if two roots were reported then the highest incidence was for two fused roots, without any report of three roots. The Pearson Chi-Square test revealed a significant difference for both teeth, but there was no difference in the morphology of the roots between males and females (Table 2).

			Gender		Total	*p*-value*
			Female	Male		
M4	One-root	Count	249_a	161_a	410	0.069
		% within Gender	87.70%	82.60%	85.60%	
	Two-fused roots	Count	30_a	33_b	63	
		% within Gender	10.60%	16.90%	13.20%	
		Count	5_a	1_a	6	

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	Two-apically separated roots	% within Gender	1.80%	0.50%	1.30%	
M5			Female	Male	Total	p-value*
	One-root	Count	279a	194a	473	0.451
		% within Gender	98.20%	99.50%	98.70%	
	Two-fused roots	Count	4a	1a	5	
		% within Gender	1.40%	0.50%	1.00%	
	Two-apically separated roots	Count	1a	0a	1	
		% within Gender	0.40%	0.00%	0.20%	
A subset of gender categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.						

Table 2: illustrates the correlation between the gender and root morphology for both mandibular premolars.

Gender and Root canal number:

Inferential and descriptive statistics for canal number of the examined M4 and M5 were described by using frequency and percentage see (Table 3). In M4, it was noted that a higher percentage (83%) was reported with one canal with a slightly higher percentage in females than males, followed by two canals in 17%. No three canals were reported. In M5, a higher percentage of one canal was reported (98%) than two canals. Additionally, the canal number did not differ between males and females (Chi-square test).

	Canal No.		Gender		Total	p-value*
			Female	Male		
M4	1	Count	243a	155a	398	0.098
		% within Gender	85.60%	79.50%	83.10%	
	2	Count	41a	40a	81	
		% within Gender	14.40%	20.50%	16.90%	
Total		Count	284	195	479	
		% within Gender	100.00%	100.00%	100.00%	
			Female	Male	Total	p-value*
M5	1	Count	278a	192a	470	
		% within Gender	97.90%	98.50%	98.10%	0.464
	2	Count	6a	3a	9	
		% within Gender	2.10%	1.50%	1.90%	
Total		Count	284	195	479	
		% within Gender	100.00%	100.00%	100.00%	
A subset of gender categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.						

Table 3: shows the relationship between the root canal number and gender for both mandibular premolars.

Root canal classification:

For descriptive statistics, the endodontic system configuration of both premolars was described by frequency and percentage as illustrated in Table 3. The inferential statistics between configuration of canals and study variables were measured employing the Pearson Chi-square test. Configuration class I was the largest percentage in M4 (81% with a pointedly higher percentage in females than males) followed by class V.

In M5, class I reported as the highest prevalence followed by class V then class III. Most of the classes were higher in females than males with no significance except in type III configuration in M5 was significantly higher in males as seen in table 4. The Pearson Chi-Square test was employed to find the relation of endodontic system configuration with study variables and shows no significant difference.

	Canal Config		Gender		Total	p value
			Female	Male		
M4.	Type I	Count	240a	150b	390	0.243
		% within Gender	84.50%	76.90%	81.40%	
	Type II	Count	0a	1a	1	

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	Canal Config.		Female	Male	Total	p value
		% within Gender	0.00%	0.50%	0.20%	
	Type III	Count	2a	5a	7	
		% within Gender	0.70%	2.60%	1.50%	
	Type V	Count	41a	39a	80	
		% within Gender	14.40%	20.00%	16.70%	
	Type VI	Count	1a	0a	1	
		% within Gender	0.40%	0.00%	0.20%	
	Total	Count	284	195	479	
		% within Gender	100.00%	100.00%	100.00%	
	Canal Config.		Gender		Total	p value
			Female	Male		
M5	Type I	Count	278a	189a	467	0.101
		% within Gender	97.90%	96.90%	97.50%	
	Type III	Count	0a	3b	3	
		% within Gender	0.00%	1.50%	0.60%	
	Type V	Count	6a	3a	9	
		% within Gender	2.10%	1.50%	1.90%	
	Total	Count	284	195	479	
		% within Gender	100.00%	100.00%	100.00%	
A subset of gender categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.						

Table 4: shows how the root canal configuration of both mandibular premolars is correlated with gender.

Root canal cross-section:
C1 represents the buccal canal's cross-section at the coronal level, and so forth. Coronal (C), middle (M), and apical (A) cross-sectional shape frequencies and percentages for each canal in both premolars.
The M4 root's cross-sectional shape in the coronal third (C1) is primarily elongated oval-shaped (88%), followed by a tape-flat outline shape and, in smaller percentages, triangular. Males and females did not differ in the cross-sectional C1 (p=0.243) (Chi-square test). The cross-sectional shape of M5 in the coronal third is primarily elongated oval-shaped (86%), with a tape outline shape coming in second. In tape and triangular cross-sections, there was a significant difference (p=0.009) in the cross-sectional C1 between males and females (Chi-square test). Column proportions were compared using the Bonferonni method's adjusted p-value. According to Table 5, there was a significantly higher percentage of the Tape category in males than in females, and a significantly higher percentage of the Triangular category in females than in males (p<0.05).

M4						**M5**				
			Gender		Total			Gender		Total
			Female	Male				Female	Male	
Cross sectional C1	Oval	Count	2a	4a	6	Oval	Count	5_a	2_a	7
		% within Gender	0.70%	2.10%	1.30%		% within Gender	1.80%	1.00%	1.50%
	Elongated Oval	Count	251a	172a	423	Elongated Oval	Count	248_a	165_a	413
		% within Gender	88.40%	88.20%	88.30%		% within Gender	87.30%	84.60%	86.20%
	Tape	Count	11a	10a	21	Tape	Count	8_a	16_b	24
		% within Gender	3.90%	5.10%	4.40%		% within Gender	2.80%	8.20%	5.00%
	Elliptical	Count	0a	2a	2	Irregular	Count	1_a	3_a	4
		% within Gender	0.00%	1.00%	0.40%		% within Gender	0.40%	1.50%	0.80%

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	Kidney	Count	2a	2a	4	Elliptical	Count	3_a	2_a	5
		% within Gender	0.70%	1.00%	0.80%		% within Gender	1.10%	1.00%	1.00%
	Semilunar	Count	2a	1a	3	Kidney	Count	3_a	3_a	6
		% within Gender	0.70%	0.50%	0.60%		% within Gender	1.10%	1.50%	1.30%
	Figure 8	Count	2a	0a	2	Figure 8	Count	0_a	2_a	2
		% within Gender	0.70%	0.00%	0.40%		% within Gender	0.00%	1.00%	0.40%
	Triangular	Count	14a	4a	18	Triangular	Count	16_a	2_b	18
		% within Gender	4.90%	2.10%	3.80%		% within Gender	5.60%	1.00%	3.80%
	Total	Count	284	195	479	Total	Count	284	195	479
		% within Gender	100.00%	100.00%	100.00%		% within Gender	100.00%	100.00%	100.00%

Table 5: shows the relationship between both mandibular premolars' gender and cross-sectional appearance at C1. a subset of gender categories in which there is no discernible difference between the column proportions. Each subscript letter denotes the 05 level**.**

In the middle third (M1) M4, Elongated oval is still the top-ranked outline shape (80%), followed by triangular. A significant difference was observed between males and females (p=0.019) (Chi-square test). Adjusted p-value (Bonferonni method) was used to compare column proportions. It showed that there was a significantly higher proportion of irregular category in males compared to females and a higher proportion of triangular category in females compared to males (p<0.05) as shown in table 6. In M5, the highest proportion was also elongated oval (85%) followed by triangular. No difference was observed in the cross-sectional M1 between males and females (p=0.162) (Chi-square test).

	M4					M5				
	cross section		Gender		Total	cross section		Gender		Total
			Female	Male				Female	Male	
Cross sectional M1	Round	Count	10_a	6_a	16	Round	Count	15a	11a	26
		% within Gender	3.50%	3.10%	3.30%		% within Gender	5.30%	5.60%	5.40%
	Oval	Count	72_a	42_a	114	Oval	Count	122a	64b	186
		% within Gender	25.40%	21.50%	23.80%		% within Gender	43.00%	32.80%	38.80%
	Elongated Oval	Count	155_a	118_a	273	Elongated Oval	Count	121a	107b	228
		% within Gender	54.60%	60.50%	57.00%		% within Gender	42.60%	54.90%	47.60%
	Tape	Count	16_a	16_a	32	Tape	Count	4a	4a	8
		% within Gender	5.60%	8.20%	6.70%		% within Gender	1.40%	2.10%	1.70%
	Irregular	Count	0_a	3_b	3	Irregular	Count	1a	0a	1
		% within Gender	0.00%	1.50%	0.60%		% within Gender	0.40%	0.00%	0.20%
	Kidney	Count	0_a	2_a	2	Kidney	Count	1a	2a	3
		% within Gender	0.00%	1.00%	0.40%		% within Gender	0.40%	1.00%	0.60%
	Semilunar	Count	3_a	0_a	3	Semilunar	Count	1a	0a	1
		% within Gender	1.10%	0.00%	0.60%		% within Gender	0.40%	0.00%	0.20%

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	Figure 8	Count	1_a	0_a	1	Triangular	Count	18a	6a	24
		% within Gender	0.40%	0.00%	0.20%		% within Gender	6.30%	3.10%	5.00%
	Triangular	Count	27_a	7_b	34	Y-shaped	Count	1a	1a	2
		% within Gender	9.50%	3.60%	7.10%		% within Gender	0.40%	0.50%	0.40%
	Y-shaped	Count	0_a	1_a	1					
		% within Gender	0.00%	0.50%	0.20%					
	Total	Count	284	195	479	Total	Count	284	195	479
		% within Gender	100.00%	100.00%	100.00%		% within Gender	100.00%	100.00%	100.00%

Table 6: shows the relationship between both mandibular premolars' cross-sectional appearance at M1 and gender. A subset of gender categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.

Regarding the M4 in the apical third (A1), a round cross-sectional shape occupies the top scale (63%) followed by the oval. Males and females differed significantly (p=0.019) (Chi-square test). Adjusted p-value (Bonferonni method) was used to compare column proportions and showed a higher proportion of Y-shaped category in females compared to males (p<0.05) as shown in table 7.

In M5, the most prevalent cross-sectional shape was round (69%) followed by an oval (20%). No difference was observed in the cross-sectional A1 between males and females (p=0.151) (Chi-square test) but adjusted p-value (Bonferonni method) was used to compare column proportions and showed a higher proportion of tape category in females compared to males (p<0.05) as shown in table 6.

M4						**M5**				
	Cross section	**Cross section**	**Gender**		**Total**	**Cross section**		**Gender**		**Total**
			Female	**Male**				**Female**	**Male**	
Cross sectional A1	**Round**	**Count**	178_a	123_a	301	**Round**	**Count**	200_a	132_a	332
		% within Gender	62.70%	63.10%	62.80%		**% within Gender**	70.40%	67.70%	69.30%
	Oval	**Count**	30_a	28_a	58	**Oval**	**Count**	40_a	40_a	80
		% within Gender	10.60%	14.40%	12.10%		**% within Gender**	14.10%	20.50%	16.70%
	Elongated Oval	**Count**	22_a	20_a	42	**Elongated Oval**	**Count**	11_a	5_a	16
		% within Gender	7.70%	10.30%	8.80%		**% within Gender**	3.90%	2.60%	3.30%
	Tape	**Count**	11_a	4_a	15	**Tape**	**Count**	9_a	0_b	9
		% within Gender	3.90%	2.10%	3.10%		**% within Gender**	3.20%	0.00%	1.90%
	Irregular	**Count**	6_a	6_a	12	**Irregular**	**Count**	3_a	4_a	7
		% within Gender	2.10%	3.10%	2.50%		**% within Gender**	1.10%	2.10%	1.50%
	Kidney	**Count**	0_a	1_a	1	**Kidney**	**Count**	1_a	1_a	2
		% within Gender	0.00%	0.50%	0.20%		**% within Gender**	0.40%	0.50%	0.40%
	Semilunar	**Count**	8_a	4_a	12	**Semilunar**	**Count**	3_a	4_a	7
		% within Gender	2.80%	2.10%	2.50%		**% within Gender**	1.10%	2.10%	1.50%
	Figure 8	**Count**	0_a	2_a	2					

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		% within Gender	0.00%	1.00%	0.40%						
	Triangular	Count	6_a	5_a	11		Triangular	Count	7_a	4_a	11
		% within Gender	2.10%	2.60%	2.30%			% within Gender	2.50%	2.10%	2.30%
	Y-shaped	Count	**23_a**	**2_b**	25		Y-shaped	Count	10_a	5_a	15
		% within Gender	**8.10%**	**1.00%**	5.20%			% within Gender	3.50%	2.60%	3.10%
Total		Count	284	195	479	Total		Count	284	195	479
		% within Gender	100.00%	100.00%	100.00%			% within Gender	100.00%	100.00%	100.00%

Table 7: shows the relationship between the cross-sectional appearance at A1 and gender for both mandibular premolars. A subset of gender categories whose column proportions do not significantly differ from one another at the.05 level is indicated by each subscript letter.

Discussion

Root canal configurations are important in defining the classification of root canals, especially in permanent mandibular premolars, which show significant variability. The knowledge of these classifications, including those set forth by Vertucci, enables practitioners to predict possible problems with procedures like cleaning and obturation. For example, the research carried out by (12-14) . The canal configuration of the mandibular second premolar varies significantly, with Type I, Type II, and Type III being the most prevalent. The anatomical variations have significant clinical implications, as they are directly related to the outcomes of treatment. Similarly, Aldawla, Mufadhal (15) reminds us of the need to understand the internal root morphology, as the differences in the canal morphology may have a great impact on the success rate of the procedure. To plan the best course of action and lower the risk of complications in endodontics, it is crucial to have a comprehensive understanding of the variations in root canal configuration.

Endodontists should be aware of the anatomical variations of mandibular premolars and carefully evaluate each case using both clinical and radiographic techniques because these teeth frequently exhibit a wide range of root canal morphology. This tool's ability to show all pertinent information and variations will lead to a successful endodontic treatment (16).

When it comes to treatment planning, CBCT is always recommended. It has been suggested that CBCT should be utilized to illustrate variations and complexities in the internal root canal morphology (2, 17, 18) since three-dimensional images grant valuable details that can assist the endodontist throughout root canal therapy (19-22). The field of view (FOV) for the scanning device should cover the target teeth, peri-radicular areas, and the entire bone in the jaw (favorably medium-sized scan). Otherwise, a small FOV fails to show the whole volume of interest, on the other hand, a very large FOV attenuates the image clarity by enlarging the voxel size. Moreover, another added advantage of CBCT is the absence of any report that assumes intra observer variations (23, 24).

The age limit was set to ensure complete root apex formation of the examined tooth and exclude the possibility of physiologic changes, which could be present in older age groups.

Human mandibular premolars are not an exception to the wide range of variations found in the literature regarding the root and canal anatomy of teeth (25). Anatomy is complex in terms of the number of roots, the canals, and their widely varied shapes. The factors that could contribute to these variations include gender, age, geography, ethnicity, and study architecture (26, 27).

Root number:

The outcomes of the current study exposed that the most frequent number of roots in M4 and M5 is single roots with more than 86% and 98.8% respectively with no differences between males and females just like (Karobari 2023). These findings are in accordance with other studies (28-32). Double roots were reported as low as 15% and 1.2% respectively which is higher than some studies (4, 16, 28, 30, 33-35) and comparable to others (32, 36) and lower than some studies (30, 37). No three roots were reported at all in contrast to other studies (28, 29, 32, 35, 36, 38, 39). Regarding the two roots premolars, only 9% were with two apically separated roots while the majority had two fused roots.

Moreover, the majority of the target teeth reported with single canal while about 17% and 2% of investigated mandibular premolars respectively reported two canals which were inconsistent with other papers with an average of 20% in M4 (28, 30-32) and 7% in M5 (16, 28, 33). Other studies reported an extremely higher percentage of two or more canals in M4 (16, 34, 39). No three canals were reported in both premolars in contrast to other studies (28, 29, 36).

Root canal number:

Findings from the current study regarding the canal numbers nearly reflected the root numbers findings. According to the current findings, 83% of M4 had one canal with more than 17% having two canals with no observation of three canals, which is very close to a previous study (38). Some variations were reported

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compared to other studies e.g. In (16, 39) where 69% were reported with one canal followed by 30% with two canals and 1% with three roots. On the other hand, 98% of M5 showed one canal and the remaining was with two canals and complete absence of any case with three canals. These results are comparable to other studies (30, 34, 37) and different from others (38).

Root canal configuration:
In the current study regarding M4, the most frequent configuration was Type I (81%) followed by Type V (17%) which is very close to other study (38, 40). These prevalent configurations are consistent throughout previous researches but with variable percentages e.g Type I and Type V are the most prevalent with 74% and 25% respectively (41), 63% and 28% (35), 70% and 10% (42), 40% and 24% (3), 70% and 17% (30). Most of the classes were higher in females than males with no significance. Similarly, in M5, the most prevalent configuration was Type I (98%) followed by Type V (2%) which is quite close to other studies (35). Type I is consistently the most prevalent classification throughout previous studies with variable frequency e.g. 91% (42), 96% (40), 76% (30) and 83% (38). In contrast, the second most common configuration is inconsistent, e.g. it was Type III (4), Type IV (30, 42) or Type II (38). Again, most of the classes were higher in females than males with no significance except in type III configuration was significantly higher in males.

Root canal cross section:
The cross-section of the canals of mandibular premolars was checked at three levels to ensure a good interpretation of the internal shape of the canals as well as the transformation from one shape to another, which may affect the three-dimensional cleaning, and obturation of the canals. Regarding the coronal section in M4, the most prevalent cross-section was the elongated oval (90%) followed by tape with no significance between females and males. On the other hand, in M5 the elongated oval still the top frequency without any significance between males and females, followed by triangular (which was significantly higher in females) and tape which was pointedly higher in males. In the literatures, oval is the highest reported shape in the coronal section of M4 and M5 but reported at lower percentages than the current study as low as 52% (43) and 44% and 40% in M4 and M5 respectively (44).
In the middle part of the canal of both premolars, elongated oval cross-section was the most prevalent (81% and 88% respectively) followed triangular with no significance between males and females except that for triangular was significantly higher in females and irregular was significantly higher in females in M4. These results were in contrast to other study in nearby country where the round cross-section was the most prevalent and the oval was the second most common (44).
Apically, both premolars showed that the round cross-section was the top observed shape (61% and 69% respectively) followed by oval with no significance everywhere except in Y cross-section being higher in males in M4. These results coincides with other researches but with variable frequencies (43, 44).
The current study may suggest that M4s have more variable internal anatomy with higher incidence of multiple canals (45) compared with M5 regarding the roots number and the internal canal configuration, as proposed by previous studies (28, 29, 40).

Limitation
It is necessary to solve a few constraints. It would be more informative utilizing larger sample size this study was only carried out at one place. The frequency of this distribution in the Iraqi population may be more accurately estimated by multicenter studies with larger sample sizes. Additionally, the results may have been impacted by the lower resolution and accuracy of the CBCT used in this study when compared to micro- and nano-CT.

Conclusion
Lastly, the morphology of the roots and root canals of mandibular permanent premolars exhibits a wide variety of root and root canal morphologies, which is significant to dentists in endodontic therapy. These results can inform clinical practices and help increase our understanding of human dental variation in various populations. Hence, understanding the canal internal anatomy is crucial to improve therapeutic results and adapt the treatment strategy to the individual patient's anatomical requirements, thereby advancing the field of endodontics.

Author Contributions: Conceptualization, A.A.; methodology, I.A.; software, I.A.; validation, I.A., H.H. and A.A.; formal analysis, H.H.; investigation, I.A.; resources, A.A.; data curation, H.H.; writing—original draft preparation, A.A.; writing—review and editing, I.A.; visualization, H.H.; supervision, A.A.; project administration, I.A. All authors have read and agreed to the published version of the manuscript.

Ethics Statement: The research ethics committee of the College of Dentistry, University of Babylon, reviewed and approved the research project.

ACKNOWLEDGMENTS: The authors deny any conflicts of interest related to this study.

Source of Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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