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Cone-beam computed tomography analysis of maxillary premolar canal anatomy: Ahmed's versus Vertucci's classifications in a Jordanian cohort

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ABSTRACT

Objectives: This study analyzed the root and canal configurations of maxillary premolars in a Jordanian subpopulation using cone-beam computed tomography (CBCT) and classified them based on Vertucci's and Ahmed's systems.
Methods: Two hundred CBCT scans of 800 maxillary premolars were retrospectively assessed for root morphology, canal configurations, and root canal divergence and merging. Data was statistically analyzed.
Results: The study included 70 males and 130 females. Most right and left maxillary first premolars (RFPM, LFPM) had two roots (59.0% and 58.5%), with a significant association between sex and root number for RFPM and LFPM ($p < 0.05$). In contrast, the right and left maxillary second premolars (RSPM, LSPM) mostly had a single root (87.5% and 88.5%), with no association with sex. Vertucci's classification showed type IV as the predominant configuration in first premolars (RFPM, 65.0% and LFPM, 67.0%) and type I in second premolars (RSPM, 44.0% and LSPM, 49.0%). A significant sex association was found only with RSPM. Ahmed's classification revealed that maxillary premolar with two separated roots and two separated canals (^{2}MP B^{1} P^{1}) was mostly found in first premolars (RFPM, 58.0% and LFPM, 56.0%), and maxillary premolar with one root and one canal (^{1}MP^{1}) in second premolars (RSPM, 44.0% and LSPM, 49.0%), with a significant sex association for RSPM and LSPM ($p < 0.05$). Age had no impact, and symmetry was observed between the right and left sides. Three-rooted premolars were identified in four cases. Almost all of Vertucci's types and numerous codes from Ahmed's classification were documented.
Conclusions: CBCT revealed diverse anatomical variations in the Jordanian subpopulation, with Ahmed's classification providing more detailed canal configurations than Vertucci's, uncovering previously overlooked variations.

Keywords: Bicuspid; Cone-beam computed tomography; Dental pulp cavity; Jordan; Tooth root

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INTRODUCTION

Understanding tooth morphology is a key to successful endodontic treatment [1]. One of the main reasons for treatment failure and the need for retreatment is the presence of untreated root canals, which can occur due to the complex, varied structure of the root and its canal system. These complex systems harbor hidden microbial infections [2].

Over the years, several classification systems have been developed by Wein [3] and Vertucci [4] to describe the different root canal configurations. Vertucci [4] described eight standard canal configurations (types I–VIII) based on the ways canals branch and rejoin from the pulp chamber to the apex, a system that is still commonly applied. However, the diversity of tooth anatomy and root canal configurations reveals limitations in existing classifications. Furthermore, the increasing use of advanced imaging techniques has uncovered many previously unrecognized anatomical complexities [4]. To overcome this limitation, Ahmed *et al.* [5] proposed a coding method in which (i) the number of roots is indicated as a superscript before the tooth code, and (ii) the canal configuration for each root is noted as superscripts following the tooth code (for instance, ^{2}MP B^{1} P^{1} denotes a maxillary premolar with two roots, each containing a single independent canal). This approach enables the detailed notation of canal divergence and convergence within individual roots (e.g., MP$^{1\text{-}2\text{-}1}$, signifying a 1-2-1 canal pathway), providing greater accuracy than earlier classification systems [5].

Historically, various methods have been employed to study the internal and external anatomies of teeth. The *in vitro* clearing method involved several complex steps for preparing the teeth before injecting the ink, in preparation for examining the tooth canals [6]. Certain clinical studies employed the SLOB (Same Lingual, Opposite Buccal) technique, using two radiographs from different angulations and magnifying loupes to facilitate inspection of the pulp chamber floor and localization of root canal orifices [7].

Two previous studies have examined maxillary premolars in the Jordanian population. Awawdeh *et al.* [6] using extracted teeth and India ink, found that the first premolars were predominantly two-rooted with a Vertucci's system type IV canal configuration, though rarer configurations, such as Vertucci's system type XVI (2–3), where two canals leave the chamber; one subdivides, so the root ends with three foramina, were also observed. The prevalence of multiple canals (79.7%) in maxillary premolars was higher than in other populations, underscoring the importance of accounting for these variations in endodontic treatment [6]. Al-Ghananeem *et al.* [7] conducted a study on maxillary second premolars in a Jordanian population, examining 217 teeth to determine the number of roots and canals. The study utilized parallel and cone-shift radiographic techniques during routine endodontic procedures, and canal orifices were identified using 3.5× magnification loupes. The results revealed that 55.3% of the teeth had a single root, 44.2% had two roots, and 0.46% had three roots. In terms of root canal configurations, classified using Vertucci's system, 13.8% of the teeth had type I, 24.9% had type II, 60.8% had type IV, and 0.46% had type VIII.

Cone-beam computed tomography (CBCT) in dentistry has significantly enhanced diagnostic capabilities by providing detailed three-dimensional (3D) views of both internal structures and surrounding anatomy in coronal, sagittal, and axial planes [8]. Additionally, it has simplified the root and canal configuration procedure [9,10]. In contrast, the two-dimensional nature of periapical radiographs can lead to the missed detection of roots and canals [8]. While micro computed tomography (micro-CT) is recognized as a more accurate radiological technique for examining tooth morphology due to its higher resolution, it subjects patients to much higher radiation doses [11]. Despite this advancement, no previous study has examined the morphology of the roots and canals in Jordanian maxillary premolars using CBCT, nor has it compared the Vertucci's and Ahmed's classifications simultaneously. Therefore, the aim of this study was to assess the root morphology and canal configurations in a Jordanian subpopulation using CBCT scans, applying the Vertucci's and Ahmed's classification systems, and to compare these findings with those obtained using conventional techniques.

METHODS

This retrospective cross-sectional study was reported

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in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [12]. Ethical approval was obtained from the Institutional Research Committee of Jordan University of Science and Technology (JUST) in Irbid, Jordan, under protocol number 2023/161/36.

The CBCT images analyzed in this study were initially obtained for various diagnostic purposes as part of comprehensive treatment planning at JUST's Dental Teaching Clinics in the period from September 2016 to September 2022. As the data were anonymized and no additional interventions were involved, the ethics committee waived informed consent.

The sample size was calculated using a sample size calculator (RaoSoft, Seattle, WA, USA) with a 50% prevalence, a 5% margin of error, and a 95% confidence interval, yielding a target sample size of 384 teeth per type.

Inclusion criteria

The inclusion criteria were CBCT scans of bilateral maxillary first and second premolars with fully developed apices obtained from subjects aged 13 years or older, provided that the scans were of sufficient quality to allow visualization of individual root and canal morphology and had voxel sizes of 0.2 mm or smaller.

Exclusion criteria

Exclusion criteria included the following: missing contralateral premolar, immature teeth, teeth in which individual roots or canals were not clearly visualized, or that showed evidence of prior dental treatment or surgery altering the natural anatomy (e.g., root canal treatment, posts, metal restorations, 'apicoectomy,' root resection, resorption, etc.).

Cone-beam computed tomography imaging and analysis

CBCT scans were taken using a CS 9500 cone-beam 3D system (Carestream Health, Rochester, NY, USA) with a flat-panel detector. The CBCT machine's parameters were as follows: tube current, 10 mA; tube voltage, 90 kVp; and focal spot diameter, 0.6 mm. The possible voxel size is 0.20 or less, with an exposure time of 8.01 seconds.

The CBCT scans were analyzed independently by two specialists with 15 years of clinical experience, who were calibrated prior to the assessment using 20 CBCT scans of maxillary premolar teeth showing root canal morphology according to the Vertucci's and Ahmed's classification systems (Figure 1). Inter- and intra-examiner reliability was assessed with a 3-week interval between the first and second assessments. Disagreements were resolved through open discussion and a consensus-based approach.

The DICOM files were analyzed using Blue Sky Plan 64-bit (V4.13.64-bit; Blue Sky Bio, LLC, Libertyville, IL, USA), with adjustments to contrast, brightness, and sharpness to improve visualization. Three planes (axial, coronal, and sagittal) were assessed for tooth anatomy based on the following criteria: (1) root morphology, including i) root numbers, classified into single, double, or three-rooted [11] and ii) root bifurcation, assessed by means of a software ruler and divided into three equal sections (coronal, middle, and apical) as per Saber *et al* [11]; (2) root canal configuration: categorized based on Vertucci's scheme [4] and the updated coding system of Ahmed *et al*. [5]; and (3) levels of divergence and merging in root canals, measured using a software ruler by dividing each root canal into three equal portions (coronal, middle, and apical), as described in previous studies [11,13].

Sex and age were recorded. Age was divided into five groups in accordance with a previous report [14]: (1) 13–24 years; (2) 25–34 years; (3) 35–44 years; (4) 45–54 years; (5) ≥55 years.

Statistical analysis

Data analysis was conducted using IBM SPSS Statistics ver. 29.0 (IBM Corp., Armonk, NY, USA). The Pearson chi-square test evaluated the association of root canal morphologies based on Vertucci's and Ahmed's classifications across age and sex. Analysis of variance and independent t-tests were used to compare canal divergence and merging levels. The significance level was set at $p < 0.05$.

RESULTS

The kappa coefficients indicated excellent reliability, with inter-examiner values ranging from 0.803 to 1 and

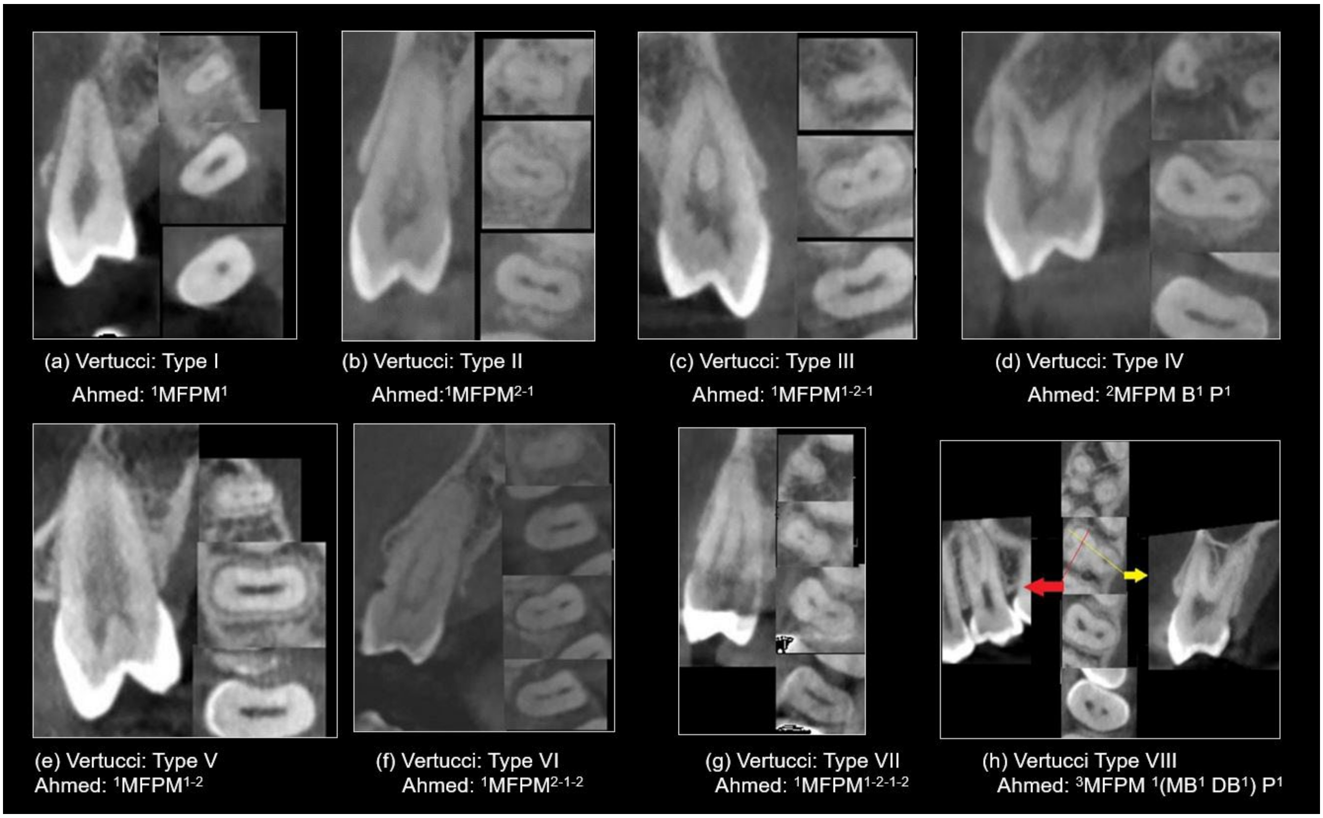

Figure 1. Representative cone-beam computed tomography images in sagittal and axial views (apical, middle, coronal), showcasing various root canal system configurations in maxillary first premolars (MFPM) based on Vertucci's and Ahmed's classifications.

intra-examiner values ranging from 0.854 to 1.

A total of 200 patients' scans have been included, meeting the inclusion criteria (400 maxillary first premolars and 400 maxillary second premolars), with 140 males (35%) and 260 females (65%). The subjects' ages ranged from 13 to 72 years (mean age, 22.8 years).

Root morphology (Table 1)

1. Maxillary first premolars

The majority of the right maxillary first premolars (RFPM) had two roots (118/200, 59%), occurring in 71.4% of males and 52.3% of females. Likewise, the majority of the left maxillary first premolars (LFPM) had two roots (117/200, 58.5%), with frequencies of 67.1% in males and 53.8% in females. Single-rooted RFPMs were less common, occurring in 81 of 200 teeth (40.5%), with a prevalence of 47.7% in females and 27.1% in males. In LFPM, single roots were also less common (82/200, 41.0%), occurring in 46.2% of females and 31.4% of males. Three-rooted configurations were rare, occurring in only 0.5% of both RFPM and LFPM, and were exclusively observed in males. The association between root number and sex was statistically significant in both RFPM and LFPM ($p = 0.004$ and $p = 0.039$, respectively).

2. Maxillary second premolars

The right maxillary second premolars (RSPM) had mostly a single root (175/200, 87.5%), with 81.4% occurring in males and 90.8% in females. Similarly, most left maxillary second premolars (LSPM) had one root (177/200, 88.5%), with a rate of 84.3% in males and 90.8% in females. Two-rooted RSPM were less frequent, found in 25 out of 200 teeth (12.5%), with 18.6% in males and 9.2% in females. In LSPM, two roots were also less common (21/200, 10.5%), with 14.3% in males and 8.5% in females. Three-rooted configurations were rare, occurring in only one case each for LSPM in both sexes. The association between root number and sex was not statistical-

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Table 1. Frequency distribution of number of roots and levels of root bifurcations according to sex

Sex	Number of roots					Bifurcations level[a)]				
	Single root	Double roots	Three roots	Total	Pearson χ^2, p-value	Coronal	Middle	Apical	Total	Pearson χ^2, p-value
RFPM										
Male	19 (27.1)	50 (71.4)	1 (1.4)	70 (100)		19 (38.0)	25 (50.0)	6 (12.0)	50 (100)	1.957, 0.418
Female	62 (47.7)	68 (52.3)	0 (0)	130 (100)	9.421, 0.004*	18 (26.1)	42 (60.9)	9 (13.0)	69 (100)	
Total	81 (40.5)	118 (59.0)	1 (0.5)	200 (100)		37 (31.1)	67 (56.3)	15 (12.6)	119 (100)	
LFPM										
Male	22 (31.4)	47 (67.1)	1 (1.4)	70 (100)		15 (31.3)	28 (58.3)	5 (10.4)	48 (100)	0.236, 0.893
Female	60 (46.2)	70 (53.8)	0 (0)	130 (100)		20 (27.8)	43 (59.7)	9 (12.5)	72 (100)	
Total	82 (41.0)	117 (58.5)	1 (0.5)	200 (100)	5.639, 0.039*	35 (29.2)	71 (59.2)	14 (11.6)	120 (100)	
RSPM										
Male	57 (81.4)	13 (18.6)	0 (0)	70 (100)		4 (33.3)	5 (41.7)	3 (25)	12 (100)	2.873, 0.328
Female	118 (90.8)	12 (9.2)	0 (0)	130 (100)	3.630, 0.073	1 (9.1)	4 (36.4)	6 (54.5)	11 (100)	
Total	175 (87.5)	25 (12.5)	0 (0)	200 (100)		5 (21.8)	9 (39.1)	9 (39.1)	25 (100)	
LSPM										
Male	59 (84.3)	10 (14.3)	1 (1.4)	70 (100)		1 (11.1)	5 (55.6)	3 (33.3)	9 (100)	0.413, 0.850
Female	118 (90.8)	11 (8.5)	1 (0.8)	130 (100)		2 (16.6)	5 (41.7)	5 (41.7)	12 (100)	
Total	177 (88.5)	21 (10.5)	2 (1.0)	200 (100)	1.884, 0.367	3 (14.3)	10 (47.6)	8 (38.1)	23 (100)	

Values are presented as number (%).
RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar.
[a)]Calculated among teeth with ≥2 roots only.
*$p < 0.05$, statistically significant.

ly significant for either RSPM or LSPM ($p \geq 0.05$).

3. Bifurcation location

In RFPM, most buccal and palatal root bifurcations were located in the middle third of the roots (56.3%), followed by the coronal and apical thirds (31.1% and 12.6%), respectively. Similarly, in LFPM, bifurcations were mainly found in the middle third of the roots (59.2%), followed by the coronal (29.2%) and apical thirds (11.6%). In RSPM, bifurcations were equally common in the middle and apical thirds (39.1%), followed by the coronal third (21.8%). In LSPM, bifurcations were most common in the middle third (47.6%), then the apical third (38.1%), and least common in the coronal third (14.3%). No association was found between root bifurcation level and sex ($p > 0.05$).

Canal configuration by sex: Vertucci's classifications (Table 2)

1. Maxillary first premolars

In both RFPM and LFPM, type IV was the most common canal configuration, seen in 65.0% and 67.0% of cases, respectively. Type V followed at 13.5% in RFPM and 12.5% in LFPM. In RFPM, types II and III were found in 7.5% and 6.0% of cases, respectively, while type I was slightly less common at 5.5%. Rare configurations included types VII and VIII, appearing in only 2.0% and 0.5% of cases, respectively, and type VI was not observed at all. In LFPM, types I and II accounted for 7.5% and 8.0%, respectively, while type III was slightly less frequent at 4.0%. The rarest configurations included types VI and VIII, each appearing in only 0.5% of cases, with type VII not observed at all. The association between canal configurations based on Vertucci and sex was not significant.

2. Maxillary second premolars

In both RSPM and LSPM, the most prevalent Vertucci's classification was type I (44.0% in RSPM, 49.0% in LSPM), followed by type V (22.5% in RSPM, 23.0% in LSPM). Less common types included type IV (16.0% in RSPM, 12.0% in LSPM) and type III (13.0% in RSPM, 9.0% in LSPM). Rare types included type II (3.0% in both RSPM and LSPM). The least frequent types in RSPM

Table 2. Maxillary premolars distribution by sex according to Vertucci's classification

Sex	Type I (1)	Type II (2-1)	Type III (1-2-1)	Type IV (2-2)	Type V (1-2)	Type VI (2-1-2)	Type VII (1-2-1-2)	Type VIII (3-3)	Total	Pearson χ^2, *p*-value
RFPM										
Male	4 (5.7)	5 (7.1)	1 (1.4)	51 (72.9)	6 (8.6)	0 (0)	2 (2.9)	1 (1.4)	70 (100)	8.992, 0.158
Female	7 (5.4)	10 (7.7)	11 (8.5)	79 (60.8)	21 (16.2)	0 (0)	2 (1.5)	0 (0)	130 (100)	
Total	11 (5.5)	15 (7.5)	12 (6.0)	130 (65.0)	27 (13.5)	0 (0)	4 (2.0)	1 (0.5)	200 (100)	
LFPM										
Male	3 (4.3)	4 (5.7)	2 (2.9)	53 (75.7)	7 (10.0)	0 (0)	0 (0)	1 (1.4)	70 (100)	6.693, 0.339
Female	12 (9.2)	12 (9.2)	6 (4.6)	81 (60.4)	18 (13.8)	1 (0.8)	0 (0)	0 (0)	130 (100)	
Total	15 (7.5)	16 (8.0)	8 (4.0)	134 (67.0)	25 (12.5)	1 (0.5)	0 (0)	1 (0.5)	200 (100)	
RSPM										
Male	26 (37.1)	4 (5.7)	6 (8.6)	15 (21.4)	16 (22.9)	1 (1.4)	2 (2.9)	0 (0)	70 (100)	12.981, 0.029*
Female	62 (47.7)	2 (1.5)	20 (15.4)	17 (13.1)	29 (22.3)	0 (0)	0 (0)	0 (0)	130 (100)	
Total	88 (44.0)	6 (3.0)	26 (13.0)	32 (16.0)	45 (22.5)	1 (0.5)	2 (1.0)	0 (0)	200 (100)	
LSPM										
Male	30 (42.9)	5 (7.1)	3 (4.3)	11 (15.7)	17 (24.3)	2 (2.9)	1 (1.4)	1 (1.4)	70 (100)	13.075, 0.053
Female	68 (52.3)	1 (0.8)	15 (11.5)	13 (10.0)	29 (22.3)	3 (2.3)	0 (0)	1 (0.8)	130 (100)	
Total	98 (49.0)	6 (3.0)	18 (9.0)	24 (12.0)	46 (23.0)	5 (2.5)	1 (0.5)	2 (1.0)	200 (100)	

Values are presented as number (%).
RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar.
*$p < 0.05$, statistically significant.

were type VII (1.0%), type VI (0.5%), and no cases of type VIII. In LSPM, type VI (2.5%), type VIII (1.0%), and type VII (0.5%) were the least common.

A significant association between sex and Vertucci's classification was found in RSPM ($p = 0.029$) but not in LSPM ($p = 0.053$).

Canal configuration by sex: Ahmed's classification (Table 3)

1. Maxillary first premolars

In both right (RFPM) and left first premolars (LFPM), the most common canal configuration was $^{2}MP\ B^{1}\ P^{1}$ (58.0% in RFPM, 56.0% in LFPM), followed by $^{1}MP^{1\text{-}2}$ (12.5% in RFPM, 11.5% in LFPM). Other configurations, such as $^{1}MP^{2\text{-}1}$, $^{1}MP^{2}$, $^{1}MP^{1}$, and $^{1}MP^{1\text{-}2\text{-}1}$, were observed with percentages ranging from 4.5% to 9.0%. Rare types included $^{1}MP^{1\text{-}2\text{-}1\text{-}2}$, $^{2}MP\ ^{1}B^{1}\ P^{1}$, and $^{3}MP\ ^{1}(MB^{1}\ DB^{1})\ P^{1}$, with none of the cases exhibiting $^{1}MP^{2\text{-}1\text{-}2}$ in RFPM or $^{1}MP^{1\text{-}2\text{-}1\text{-}2}$ in LFPM. There was no significant sex association with Ahmed's classification for RFPM ($p = 0.064$) or LFMP ($p = 0.446$).

2. Maxillary second premolars

In both RSPM and LSPM, the most common canal configuration was $^{1}MP^{1}$ (44.0% in RSPM, 49.0% in LSPM), followed by $^{1}MP^{1\text{-}2}$ (18.0% in RSPM, 20.0% in LSPM) and $^{1}MP^{1\text{-}2\text{-}1}$ (13.0% in RSPM, 9.5% in LSPM). Less prevalent types included $^{2}MP\ B^{1}\ P^{1}$ and $^{1}MP^{2}$, with rare configurations like $^{1}MP^{2\text{-}1}$, $^{1}MP^{2\text{-}1\text{-}2}$, and $^{1}MP^{1\text{-}2\text{-}1\text{-}2}$, while $^{3}MP\ ^{1}(MB^{1}\ DB^{1})\ P^{1}$ was either absent or very rare. The association between sex and Ahmed's classification was statistically significant for both sides, with $p = 0.0381$ for RSPM and $p = 0.023$ for LSPM.

Canal configuration by age: Vertucci's classification (Table 4)

When analyzing Vertucci's classification of maxillary first premolars across different age groups, no statistically significant association with age was found. Type IV is the most common among all age groups for both RFPM and LFPM, with the highest prevalence observed in the 13–24-year age group (66.4% for RFPM and 64.9% for LFPM). All other types of Vertucci's classification were also observed, except for type VI (Table 4).

Similarly, when examining Vertucci's classification of maxillary second premolars across different age groups, no statistically significant association was found with age. Type I is the most common among all age groups

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Table 3. Maxillary premolars distribution by sex according to Ahmed's classification

Sex	$^{1}MP^{1}$	$^{1}MP^{2-1}$	$^{1}MP^{1-2-1}$	$^{1}MP^{2}$	$^{1}MP^{1-2}$	$^{1}MP^{2-1-2}$	$^{1}MP^{1-2-1-2}$	$^{2}MP\ B^{1}\ P^{1}$	$^{2}MP\ ^{1}B^{1}\ P^{1}$	$^{3}MP^{1}\ (MB^{1}\ DB^{1})\ P^{1}$	Total	Pearson χ^2, *p*-value
RFPM												
Male	4 (5.7)	5 (7.1)	1 (1.4)	2 (2.9)	5 (7.1)	0 (0)	2 (2.9)	49 (70.0)	1 (1.4)	1 (1.4)	70 (100)	14.016, 0.064
Female	7 (5.4)	10 (7.7)	11 (8.5)	12 (9.2)	20 (15.4)	0 (0)	2 (1.5)	67 (51.5)	1 (0.8)	0 (0)	130 (100)	
Total	11 (5.5)	15 (7.5)	12 (6.0)	14 (7.0)	25 (12.5)	0 (0)	4 (2.0)	116 (58.0)	2 (1.0)	1 (0.5)	200 (100)	
LFPM												
Male	3 (4.3)	4 (5.7)	2 (2.9)	5 (7.1)	8 (11.4)	0 (0)	0 (0)	46 (65.7)	1 (1.4)	1 (1.4)	70 (100)	7.951, 0.446
Female	12 (9.2)	12 (9.2)	7 (5.4)	13 (10.0)	15 (11.5)	1 (0.8)	0 (0)	66 (50.8)	4 (3.1)	0 (0)	130 (100)	
Total	15 (7.5)	16 (8.0)	9 (4.5)	18 (9.0)	23 (11.5)	1 (0.5)	0 (0)	112 (56.0)	5 (2.5)	1 (0.5)	200 (100)	
RSPM												
Male	26 (37.1)	4 (5.7)	6 (8.6)	7 (10.0)	11 (15.7)	1 (1.4)	2 (2.9)	11 (15.7)	2 (2.9)	0 (0)	70 (100)	15.341, 0.038*
Female	62 (47.7)	2 (1.5)	20 (15.4)	9 (6.9)	25 (19.2)	0 (0)	0 (0)	11 (8.5)	1 (0.8)	0 (0)	130 (100)	
Total	88 (44.0)	6 (3.0)	26 (13.0)	16 (8.0)	36 (18.0)	1 (0.5)	2 (1.0)	22 (11.0)	3 (1.5)	0 (0)	200 (100)	
LSPM												
Male	30 (42.9)	5 (7.1)	3 (4.3)	2 (2.9)	16 (22.9)	2 (2.9)	1 (1.4)	10 (14.3)	0 (0)	1 (1.4)	70 (100)	17.932, 0.023*
Female	68 (52.3)	1 (0.8)	16 (12.3)	6 (4.6)	24 (18.5)	3 (2.3)	0 (0)	8 (6.2)	3 (2.3)	1 (0.8)	130 (100)	
Total	98 (49.0)	6 (3.0)	19 (9.5)	8 (4.0)	40 (20.0)	5 (2.5)	1 (0.5)	18 (9.0)	3 (1.5)	2 (1.0)	200 (100)	

Values are presented as number (%).
RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar.
*$p < 0.05$, statistically significant.

for both RSPM and LSPM, with the highest prevalence observed in the 13–24- and 25–34-year age groups (43.3% for RSPM and 50% for LSPM). Among patients aged 55 years or older, there was an equal distribution of types I, II, and IV (33.3% each) in LSPM. All other types of Vertucci's classification were also observed.

Canal configuration by age: Ahmed's classification (Table 5)

For the maxillary first premolars, the most prevalent root and canal configuration was $^{2}MP\ B^{1}\ P^{1}$ across all age groups, with a total of $n = 228/400$ (57.0%), followed by $^{1}MP^{1-2}$ with total $n = 48/400$ (12.0%). The association between age and Ahmed's classification was not statistically significant on either the right or left side ($p > 0.05$).

For the maxillary second premolar, the most prevalent configuration across all age groups was $^{1}MP^{1}$, comprising 186/400 (46.5%), followed by $^{1}MP^{1-2}$, which accounted for 75/400 (19.0%). The association between age and Ahmed's classification was statistically insignificant for both the right and left ($p > 0.05$) sides.

Levels of merging and divergence of canals (Table 6)

The levels of merging and diverging of canals are summarized in Table 6. In the $^{1}MP^{2-1}$ configuration, canal merging occurred at the middle of the root for both RFPM and LFPM, while in the apical third in RSPM and LSPM. There was no statistical significance in the level of merging across the teeth.

For the $^{1}MP^{1-2}$ configuration, the divergence occurred at the middle of the root for RSPM and LSPM, whereas divergence occurred apically for RFPM and LFPM. Again, there was no significant difference in divergence levels across all teeth ($p > 0.05$).

In all right and left maxillary premolars, merging and diverging of the canals having the configuration $^{1}MP^{2-1-2}$ occurred at the middle and apical levels, respectively; however, this was not statistically significant ($p > 0.05$).

In canals with $^{1}MP^{1-2-1-2}$ configuration, divergence occurred at the coronal level, merging at the middle root level, and divergence again at the apical root, which was observed only in right-side teeth. The apical divergence in this configuration was statistically significant ($p < 0.001$).

DISCUSSION

Root canal treatment failure, especially in posterior

Table 4. Maxillary premolars distribution by age according to Vertucci's classification

Age (yr)	Type I (1-1)	Type II (2-1)	Type III (1-2-1)	Type IV (2-2)	Type V (1-2)	Type VI (2-1-2)	Type VII (1-2-1-2)	Type VIII (3-3)	Total	Pearson χ^2, *p*-value
RFPM										
13–24	6 (4.5)	7 (5.2)	10 (7.5)	89 (66.4)	18 (13.4)	0 (0)	4 (3.0)	0 (0)	134 (100)	19.179, 0.742
25–34	3 (6.8)	5 (11.4)	1 (2.3)	28 (63.6)	6 (13.6)	0 (0)	0 (0)	1 (2.3)	44 (100)	
35–44	1 (8.3)	2 (16.7)	0 (0)	8 (66.7)	1 (8.3)	0 (0)	0 (0)	0 (0)	12 (100)	
45–54	1 (14.3)	0 (0)	1 (14.3)	3 (42.9)	2 (28.6)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	0 (0)	1 (33.3)	0 (0)	2 (66.7)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	
Total	11 (5.5)	15 (7.5)	12 (6.0)	130 (65.0)	27 (13.5)	0 (0)	4 (2.0)	1 (0.5)	200 (100)	
LFPM										
13–24	10 (7.5)	9 (6.7)	5 (3.7)	87 (64.9)	21 (15.7)	0 (0)	1 (0.7)	1 (0.7)	134 (100)	15.846, 0.894
25–34	2 (4.5)	4 (9.1)	3 (6.8)	33 (75.0)	2 (4.5)	0 (0)	0 (0)	0 (0)	44 (100)	
35–44	1 (8.3)	1 (8.3)	0 (0)	9 (75.0)	1 (8.3)	0 (0)	0 (0)	0 (0)	12 (100)	
45–54	2 (28.6)	1 (14.3)	0 (0)	3 (42.9)	1 (14.3)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	0 (0)	1 (33.3)	0 (0)	2 (66.7)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	
Total	15 (7.5)	16 (8.0)	8 (4.0)	134 (67.0)	25 (12.5)	0 (0)	1 (0.5)	1 (0.5)	200 (100)	
RSPM										
13–24	58 (43.3)	0 (0)	16 (11.9)	25 (18.7)	32 (23.9)	1 (0.7)	2 (1.5)	0 (0)	134 (100)	23.953, 0.465
25–34	18 (40.9)	4 (9.1)	8 (18.2)	6 (13.6)	8 (18.2)	0 (0)	0 (0)	0 (0)	44 (100)	
35–44	6 (50.0)	1 (8.3)	1 (8.3)	0 (0)	4 (33.3)	0 (0)	0 (0)	0 (0)	12 (100)	
45–54	4 (57.1)	1 (14.3)	1 (14.3)	0 (0)	1 (14.3)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	2 (66.7)	0 (0)	0 (0)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	
Total	88 (44.0)	6 (3.0)	26 (13.0)	32 (16.0)	45 (22.5)	1 (0.5)	2 (1)	0 (0)	200 (100)	
LSPM										
13–24	67 (50.0)	2 (1.5)	10 (7.5)	19 (14.2)	34 (25.4)	1 (0.7)	0 (0)	1 (0.7)	134 (100)	41.246, 0.051
25–34	22 (50.0)	3 (6.8)	4 (9.1)	4 (9.1)	7 (15.9)	2 (4.5)	1 (2.3)	1 (2.3)	44 (100)	
35–44	4 (33.3)	0 (0)	3 (25.0)	0 (0)	3 (25.0)	2 (16.7)	0 (0)	0 (0)	12 (100)	
45–54	4 (57.1)	0 (0)	1 (14.3)	0 (0)	2 (28.6)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	1 (33.3)	1 (33.3)	0	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	
Total	98 (49.0)	6 (3.0)	18 (9.0)	24 (12.0)	46 (23.0)	5 (2.5)	1 (0.5)	2 (1)	200 (100)	

Values are presented as number (%).
RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar

teeth such as molars and premolars, can occur due to the inability to identify and disinfect canals, resulting from a lack of knowledge of internal canal anatomy [15].

Advances in radiographic technology have made CBCT an increasingly valuable tool in dentistry, resulting in significant progress in diagnosing and evaluating oral disorders [16]. Numerous studies have demonstrated greater accuracy in identifying additional canals with CBCT than with conventional intraoral radiography [17,18].

This study investigated the root and canal morphology of maxillary premolars in a Jordanian subpopulation using CBCT, using two systems: Vertucci's and Ahmed's classifications [4,5].

Our study revealed a higher prevalence of two-rooted maxillary first premolars (Table 1), consistent with a previous study among the Jordanian population, which found that 63.2% of the studied teeth had two roots [6]. This result was consistent across both RFPM (59.0%) and LFPM (58.5%), indicating symmetry. Similarly, results from other populations have shown a high prevalence of double-rooted teeth, as in the Egyptian population (53.1%) [11] and the South African population (54.1%) [19]. The effect of sex was statistically significant (Table 1), with females having a relatively high likelihood of having a single-rooted maxillary first premolar (RFPM, 47.7% and LFPM, 46.2%), whereas this was not the case for males (RFPM, 27.1% and LFPM, 31.4%). This finding is somewhat comparable to that of Al-Zubaidi *et al.* [20], who reported that women had a high-

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Table 5. Maxillary premolars distribution by age according to Ahmed's classification

Age (yr)	$^{1}MP^{1}$	$^{1}MP^{2-1}$	$^{1}MP^{1-2-1}$	$^{1}MP^{2}$	$^{1}MP^{1-2}$	$^{1}MP^{2-1-2}$	$^{1}MP^{1-2-1-2}$	$^{2}MP\ B^{1}\ P^{1}$	$^{2}MP\ ^{1}B^{1}\ P^{1}$	$^{3}MP\ ^{1}(MB^{1}\ DB^{1})\ P^{1}$	Total	Pearson χ^2, p-value
RFPM												
13–24	6 (4.5)	7 (5.2)	10 (7.5)	11 (8.2)	18 (13.4)	0 (0)	4 (3.0)	77 (57.5)	1 (0.7)	0 (0)	134 (100)	31.991, 0.467
25–34	3 (6.8)	5 (11.4)	1 (2.3)	1 (2.3)	5 (11.4)	0 (0)	0 (0)	28 (63.6)	0 (0)	1 (2.3)	44 (100)	
35–44	1 (8.3)	2 (16.7)	0 (0)	2 (16.7)	0 (0)	0 (0)	0 (0)	6 (50.0)	1 (8.3)	0 (0)	12 (100)	
45–54	1 (14.3)	0 (0)	1 (14.3)	0 (0)	2 (28.6)	0 (0)	0 (0)	3 (42.9)	0 (0)	0 (0)	7 (100)	
≥55	0 (0)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (66.7)	0 (0)	0 (0)	3 (100)	
Total	11 (5.5)	15 (7.5)	12 (6.0)	14 (7.0)	25 (12.5)	0 (0)	4 (2.0)	116 (58.0)	2 (1.0)	1 (0.5)	200 (100)	
LFPM												
13–24	10 (7.5)	8 (6.0)	6 (4.5)	8 (6)	20 (14.9)	0 (0)	1 (0.7)	76 (56.7)	4 (3.0)	1 (0.7)	134 (100)	31.261, 0.504
25–34	2 (4.5)	5 (11.4)	3 (6.8)	5 (11.4)	2 (4.5)	0 (0)	0 (0)	27 (61.4)	0 (0)	0 (0)	44 (100)	
35–44	1 (8.3)	1 (8.3)	0 (0)	4 (33.3)	0 (0)	0 (0)	0 (0)	5 (41.7)	1 (8.3)	0 (0)	12 (100)	
45–54	2 (28.6)	1 (14.3)	0 (0)	1 (14.3)	1 (14.3)	0 (0)	0 (0)	2 (28.6)	0 (0)	0 (0)	7 (100)	
≥55	0 (0)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (66.7)	0 (0)	0 (0)	3 (100)	
Total	15 (7.5)	16 (8.0)	9 (4.5)	18 (9.0)	23 (11.5)	0 (0)	1 (0.5)	112 (56.0)	5 (2.5)	1 (0.5)	200 (100)	
RSPM												
13–24	58 (43.3)	0 (0)	16 (11.9)	12 (9.0)	26 (19.4)	0 (0)	1 (0.7)	2 (1.5)	17 (12.7)	2 (1.5)	134 (100)	24.609, 0.822
25–34	18 (40.9)	4 (9.1)	8 (18.2)	3 (6.8)	6 (13.6)	0 (0)	0 (0)	0 (0)	4 (9.1)	1 (2.3)	44 (100)	
35–44	6 (50.0)	1 (8.3)	1 (8.3)	1 (8.3)	3 (25.0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	12 (100)	
45–54	4 (57.1)	1 (14.3)	1 (14.3)	0	1 (14.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	2 (66.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (33.3)	0 (0)	3 (100)	
Total	88 (44.0)	6 (3.0)	26 (13.0)	16 (8.0)	36 (18.0)	0 (0)	1 (0.5)	2 (1.0)	22 (11.0)	3 (1.5)	200 (100)	
LSPM												
13–24	67 (50.0)	2 (1.5)	11 (8.2)	5 (3.7)	28 (20.9)	1 (0.7)	0 (0)	16 (11.9)	3 (2.2)	1 (0.7)	134 (100)	48.785, 0.076
25–34	22 (50.0)	3 (6.8)	4 (9.1)	2 (4.5)	7 (15.9)	2 (4.5)	1 (2.3)	2 (4.5)	0 (0)	1 (2.3)	44 (100)	
35–44	4 (33.3)	0 (0)	3 (25.0)	0 (0)	3 (25.0)	2 (16.7)	0 (0)	0 (0)	0 (0)	0 (0)	12 (100)	
45–54	4 (57.1)	0 (0)	1 (14.3)	0 (0)	2 (28.6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	7 (100)	
≥55	1 (33.3)	1 (33.3)	0 (0)	1 (33.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (100)	
Total	98 (49.0)	6 (3.0)	19 (9.5)	8 (4.0)	40 (20.0)	5 (2.5)	1 (0.5)	18 (9.0)	3 (1.5)	2 (1.0)	200 (100)	

Values are presented as number (%).
RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar.

er prevalence of single-rooted first premolars than men (56.5% vs 29.3%), whereas men exhibited a higher prevalence of double-rooted maxillary first premolars than women (67.2% vs 51.1%). In addition to this, although a three-rooted Maxillary first premolar is rare to be found (Table 1), it still needs to be considered, especially in males (0.5% for both RFPM and LFPM). The finding appears comparable to the pattern reported by Olczak *et al.* [21], who also observed a higher prevalence in males than in females (4.1% vs 1.5%), with similar frequencies on the right and left sides (2.8% and 2.3%, respectively).

It is crucial to understand the degree of root bifurcation in maxillary premolars, as it has both anatomical and clinical implications [11]. In the present study, the bifurcation level in the first premolar in more than half of the cases was in the middle third of the roots (57.8%) (Table 1), with comparable results in both RFPM (56.3%) and LFPM (59.3%), followed by the coronal third level (29.95%), with no sex difference significance. These results align with the findings of Saber *et al.* [11], who found that 78.9% of Egyptians had middle-level bifurcation. In contrast, Olczak *et al.* [21] recorded a higher incidence of bifurcation in the coronal third of the root (44.2%) in the Polish population, followed by the middle third (40.5%). Furthermore, they observed a statistically significant sex difference, with a higher incidence of the coronal bifurcation in males and a higher incidence of the middle bifurcation in females [21]. This variation might reflect racial disparities in root canal morphology, as highlighted in numerous previous studies [1]. Clinically, the bifurcation level may affect the complexity of endodontic treatment; hence, the operating microscope often enables clinicians to directly observe the site where the main canal divides into two or three branches, as well as the alignment of the canal orifices. Nevertheless, when the furcation lies deep within the tooth, or the orifices are calcified, their detection may remain difficult, even with microscopic assistance [22].

The most prevalent canal configuration in this study, according to Vertucci's classification, was type IV (2-2) (Table 2), observed in both RFPM (65.0%) and LFPM (67.0%), and a similarly high prevalence of type IV configuration has been reported across various populations [11,19,21,23]. These findings are somewhat aligned with those of Awawdeh *et al.*[6], in the Jordanian population, type IV was also identified as the most prevalent configuration in maxillary first premolars with two canals, with a reported incidence of 79.7%. However, their study, conducted on 600 extracted teeth, neither assessed the association between age and sex nor considered symmetry [6]. In contrast, the current study incorporated these variables. Furthermore, Awawdeh *et al.* [6] reported no examples of type III, VI, or VII canals in maxillary first premolars. In the present study, type III canals were observed in a few cases, while types VI, VII, and VIII were observed rarely, with seven, seven, and four occurrences, respectively (Table 2). This enhanced detection is likely due to the use of CBCT imaging, which provides more detailed insights into canal morphology than earlier techniques.

This is the first study to use Ahmed's classification among Jordanians. Type ^{2}MP B^{1} P^{1} had the highest prevalence in both RFPM and LFPM (58.0% and 56.0%, respectively), with no significant differences by sex or age (Tables 3 and 5). This is in line with research by Saber *et al.* [11] and Buchanan *et al.* [19], which also revealed that ^{2}MP B^{1} P^{1} had the highest prevalence (52.5% and 52.53%, respectively).

Using Ahmed's classification, 10 different root canal configuration types were identified among right and left side first maxillary premolars, showing a detailed canal configuration within the root, which confirms the aim of this new classification. Different configurations based on this classification were identified, highlighting the canal's divergence and merging levels. The loca-

Table 6. ANOVA and independent t-test to compare the levels of merging and divergence of canals (mm)

Variable	^{1}MP$^{2-1}$ Level of merging	^{1}MP$^{1-2}$ Level of divergence	^{1}MP^{2-1-2} Level of merging/divergence	^{1}MP^{1-2-1} Level of divergence/merging	^{1}MP$^{1-2-1-2}$ Level of divergence/merging/divergence
RFPM	5.78 ± 0.922 (middle)	6.27 ± 1.35 (apical)	4.81 ± 1.44/8.81 ± 1.46 (middle/apical)	4.81 ± 1.44/8.81 ± 1.46 (middle/apical)	4.03 ± 0.577/7.49 ± 0.12/8.46 ± 0.11 (coronal/middle/apical)
LFPM	5.76 ± 1.270 (middle)	6.52 ± 1.12 (apical)	4.43 ± 1.22/7.72 ± 1.78 (middle/apical)	4.43 ± 1.22/7.72 ± 1.78 (middle/apical)	-
RSPM	8.03 ± 1.616 (apical)	5.47 ± 1.68 (middle)	5.11 ± 1.56/8.10 ± 1.42 (middle/apical)	5.11 ± 1.56/8.10 ± 1.42 (middle/apical)	5.84 ± 0.586/7.93 ± 0.04/9.36 ± 1.29 (coronal/middle/apical)
LSPM	7.95 ± 0.924 (apical)	4.98 ± 1.74 (middle)	4.09 ± 1.00/7.34 ± 1.54 (middle/apical)	4.09 ± 1.00/7.34 ± 1.54 (middle/apical)	-
p-value	0.945	0.182	0.126/0.078	0.126/0.078	0.972/0.299/<0.001[a)]*

Values are presented as mean ± standard deviation (mm).
ANOVA, analysis of variance; RFPM, right maxillary first premolar; LFPM, left maxillary first premolar; RSPM, right maxillary second premolar; LSPM, left maxillary second premolar.
[a)]Independent *t*-test. *$p < 0.05$, statistically significant.

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tion of canal divergence and merging is critical during root canal treatment, as detecting a divergence in the middle and apical thirds of the root is difficult, challenging, and may be missed [13]. For example, within the single-rooted premolars, a rare occurrence of canal divergence, followed by merging, and then again divergence was found, as indicated by code $^{1}\text{MP}^{1-2-1-2}$, which might have been missed in previous classifications. Similarly, in two-rooted premolars, the code $^{2}\text{MP B}^{1}\text{ P}^{1}$ denotes a separate canal in each root, whereas $^{2}\text{MP }^{1}\text{B}^{1}\text{ P}^{1}$ describes a canal originating from the pulp chamber that bifurcates into two canals, one within each root. Such examples illustrate the greater descriptive capacity of Ahmed's system, which, when combined with CBCT imaging, provides precise characterization of complex canal patterns.

Regarding maxillary second premolars, the results of this study showed a high prevalence of single-rooted maxillary second premolars with a percentage of 88% (87.5 % in RSPM, 88.5% in LSPM), with no association between sex and number of roots (Table 1). This finding is comparable to a previous study of the Jordanian population, which reported that of 217 maxillary second premolars, 120 (55.3%) had one root, 96 (44.2%) had two roots, and 1 (0.5%) had three roots. The study reported an almost double likelihood of females having single-rooted premolars compared to those with double-rooted ones (64% vs 36%), whereas in males, the likelihood of having double-rooted premolars is higher than that of having single-rooted ones (51.2% vs 49.9%). Additionally, three-rooted premolars were very rare, occurring in only 0.8% of cases [7]. These results are consistent with previous studies [11,19]. A recent systematic review analyzed 16,371 maxillary premolars and reported that 84.3% had a single root, suggesting that the higher prevalence of single-rooted second premolars is likely a universal trend [1]. The study reported a prevalence of three-rooted maxillary second premolars (0.3%), comparable to our 1% prevalence, observed only in LSPM. Watanabe *et al.* [24] reported a similar rare occurrence of three-rooted maxillary second premolar among the Japanese population (0.3%).

In the less common multirooted second premolars, it is important to consider the bifurcation level. In RSPM, bifurcation occurred equally in the middle and apical thirds of the root (39.1%) and was least frequent in the coronal third level (21.8%). A comparable distribution was observed in LSPM, where bifurcation predominantly occurred in the middle third (47.6%), followed by the apical third (38.1%), and least frequently in the coronal third (14.3%) (Table 1). Saber *et al.* [11] reported that the middle third bifurcation was the most prevalent (78.5%), followed by the apical third (14%). These variations may reflect true anatomical differences between populations, as well as methodological factors, such as differences in imaging protocols, with sample size potentially contributing to the observed discrepancies.

The second maxillary premolars in this study showed a high prevalence of type I Vertucci's Classification (44% in RSPM, 49% in LSPM), followed by type V (22.5% in RSPM, 23% in LSPM) across all age groups (Table 4). This finding differs from a previous study conducted among the Jordanian population, which reported a higher prevalence of type IV at 60.8%, while type I was observed in only 13.8% [7]. Discrepancies among subpopulations may be attributed to genetic diversity, environment, and regional variations in diet and oral hygiene habits [25].

The Egyptian population also showed that type IV was the most prevalent in maxillary second premolars (44.4%), followed by type II (22.2%), with type I being less frequent (16.1%) [11]. These discrepancies across different populations may suggest that genetics plays a significant role in controlling root and canal configurations.

A significant sex effect was observed in RSPM, with females exhibiting a higher prevalence of type III than males (15.4% vs 8.6%), while males showed a higher prevalence of type IV than females (21.4% vs 13.1%). Additionally, type VII and type VI were observed in males but not in females (Table 2). These differences support the idea that maxillary second premolars exhibit considerable anatomical variation in their internal root configurations [11].

Using Ahmed's classification, the most prevalent canal configuration was $^{1}\text{MP}^{1}$ in both RSPM (44.0%) and LSPM (49.0%), among all age groups, with no significant difference between these age groups (Table 5). However, sex showed a significant difference on both sides (Table 3). While $^{2}\text{MP B}^{1}\text{ P}^{1}$ and $^{1}\text{MP}^{1-2}$ are equally the second most prevalent canal configuration in males' RSPM (15.7%), females showed a higher prevalence of $^{1}MP^{1-2}$ (19.2%) and $^{1}MP^{1-2-1}$ (15.4%) on the same side. For LSPM, the frequency of $^{1}MP^{1-2-1}$ was higher in females than in males (12.3% vs 4.3%), although the prevalence of $^{2}MP\ B^{1}\ P^{1}$ and $^{1}MP^{2-1}$ was higher in males than in females (14.3% vs 6.2% and 7.1% vs 0.8%, respectively). This aligns with findings by Algarni *et al.* [26], who also reported sex-related variation in certain Ahmed's codes on both RSPM and LSPM, with females showing higher frequencies of multi-branching patterns, such as $^{1}MP^{1-2-1}$, and males more often exhibiting $^{1}MP^{1}$ or $^{1}MP^{2-1}$ configurations. In contrast, Watanabe *et al.* [24] found no significant sex effect. These mixed results suggest that sex-related differences in canal configuration may be population-dependent rather than universal.

In this study, a significant apical level of divergence was observed in the right-side premolars of teeth with Ahmed's classification $^{1}MP^{1-2-1-2}$, with a p-value of <0.001 (Table 6). This is in line with a study by Martins *et al.* [13] that found that the maxillary second premolar had the highest frequency of merging root canals in the middle third and divergence in the apical third.

The findings of this investigation demonstrated consistent outcomes for the left and right sides across various parameters, highlighting possible anatomical similarities in homonymous teeth, and supporting the notion that symmetry is a universal phenomenon [1]. A previous study [27] involved 1,387 maxillary first premolars and 1,403 maxillary second premolars and found that 80.2% of the maxillary first premolars and 81.8% of the maxillary second premolars showed bilateral symmetry in the number of root canals. Furthermore, the number and shape of root canals in 72.3% of maxillary first premolars and 73.2% of maxillary second premolars displayed bilateral symmetry, underscoring the pervasive symmetry in premolar root and canal morphology. Similarly, Mashyakhy [28] found no significant differences for root number, canal number, and canal configuration between the right and left sides. Age and sex were also considered, as canal morphology can change over time due to secondary dentin deposition, apical maturation, and calcification [29], and may vary between males and females due to X-linked genetic influence [30]. Including these variables broadens the anatomical understanding and supports more informed clinical decision-making.

Utilizing CBCT in this study provided high-quality images, offering more detailed canal configurations compared to conventional radiographs. However, it is considered less accurate than micro-CT, primarily due to its lower spatial resolution and larger voxel size, which limit its ability to capture extremely fine anatomical details, such as accessory canals [31]. While this may be considered a limitation of the study, the lower radiation dose of CBCT compared to micro-CT represents a significant advantage that outweighs this limitation. Another limitation of this study is the uneven distribution of age groups, with some age categories having notably larger sample sizes than others. This imbalance may obscure potential correlations between age and specific canal configurations that are more common in older age groups.

CONCLUSIONS

Maxillary premolars in the Jordanian subpopulation showed a wide range of anatomical variations. The majority of first premolars displayed a two-rooted morphology consistent with Vertucci type IV or Ahmed $^{2}MP^{1-1}$ patterns, whereas second premolars were mainly single-rooted, corresponding to Vertucci type I or Ahmed $^{1}MP^{1}$. Applying both Vertucci's and Ahmed's classification systems in this study provided a more robust assessment of canal morphology, as Ahmed's detailed coding system captured variations that extended beyond the broader patterns defined by Vertucci. Dental practitioners need to be aware of the various possible configurations of the root and root canal to avoid missing canals, which can lead to treatment failure. Clinicians need to benefit from new radiographic advances, such as CBCT, which can improve diagnosis and treatment planning by providing a useful tool for detecting complex tooth morphology. Ahmed's classification provided a simplified, detailed canal configuration.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal analysis: Ba-Hattab R. Data curation: Ba-Hattab R, Taha NA, Abu Alhaija ES. Investigation: Ba-Hattab R, Shaweesh MM, Taha NA. Funding acquisition, Resources: Taha NA.
Writing - original draft: Ba-Hattab R, Shaweesh MM. Writing - review & editing: all authors. All authors have read and agreed to the published version of the manuscript.

DATA SHARING STATEMENT

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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