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Analysis of root number and canal morphology of maxillary premolars using cone-beam computed tomography

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ABSTRACT

Purpose: This study aimed to evaluate the number of roots and type of root canals in maxillary first and second premolars within a selected Korean population utilizing cone-beam computed tomography (CBCT). Additionally, it sought to investigate potential differences in these features according to sex and tooth type.

Materials and Methods: CBCT images of 585 maxillary first premolars and 578 maxillary second premolars from 303 patients were retrospectively reviewed. The number of roots was classified based on root morphology, and canal configurations were categorized into 8 types according to the Vertucci classification. For statistical analysis, chi-square or Fisher exact tests were employed to compare root number and canal morphology according to sex and tooth type.

Results: CBCT analysis revealed that 71.5% of maxillary first premolars and 97.6% of maxillary second premolars had 1 root. The most common canal configuration in maxillary first premolars was Vertucci type IV (42.6%), whereas type I predominated in maxillary second premolars (76.5%). Significant differences in root number and canal configurations were found between men and women ($P<0.05$), with single roots and Vertucci type I canals more commonly observed in women.

Conclusion: Both maxillary first premolars and maxillary second premolars typically had 1 root, with a smaller percentage possessing 2 roots. Significant sex differences were observed in root number and canal type. This study highlights the variability in root number and canal configuration, emphasizing the importance of recognizing these variations to achieve successful endodontic treatment. ***(Imaging Sci Dent 2024; 54: 370-80)***

KEY WORDS: Bicuspid; Dental Pulp Cavity; Cone-Beam Computed Tomography; Anatomy

Introduction

The morphology of roots and canals in permanent dentition exhibits considerable variation.[1,2] Among maxillary teeth, premolars are second only to first molars in the frequency with which they require root canal treatment.[3] Reports have indicated wide variations in the root and canal anatomy of maxillary premolars.[1-9] A comprehensive understanding of these variations is crucial for increasing the success rate of such treatment.[9] One of the most common causes of root canal treatment failure is the lack of recognition of variations in root and canal morphology, such as bifurcations in the middle or apical third of the root canal.[1,5,10,11] Dentists should consider the possibility of double root canals or canal bifurcation if the outcomes after endodontic treatment are unexpectedly unfavorable.[1] Missed canals are also frequently reported as factors contributing to endodontic treatment failure.[10]

Various methods, including clearing,[12,13] 2-dimensional radiographic imaging,[14] cone-beam computed tomography (CBCT),[5,8,15] and micro-computed tomography (micro-CT),[16-18] have been utilized to assess root anatomy and canal morphology.[19] While micro-CT provides more detailed information than CBCT, it is costly, time-intensive, and involves high radiation doses, making it unsuitable for clinical application.[16,19] In contrast, CBCT is commonly em-

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ployed in clinical settings and has advantages over micro-CT, despite its limitations in detecting complex morphological features such as accessory canals or intercanal communications.[19] Compared to conventional periapical radiography, CBCT represents an excellent tool for the 3-dimensional evaluation of root and canal anatomy.[14,16] The American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology (AAE/AAOMR) Joint Position Statement on using CBCT in endodontics suggests that this modality is a useful diagnostic imaging technique for complex and irregular root canal cases.[20]

The number of maxillary premolar roots is typically categorized as 1, 2, or 3. However, a more nuanced classification is warranted to account for variations in root morphology. Teeth with bifurcations in the coronal, middle, or apical third are usually considered to have 2 roots.[5] Any division occurring in the coronal or middle third is also commonly classified as 2 roots. Root classification becomes a subject of debate when bifurcation occurs in the apical third, particularly near the apex.[21] Ahmed et al.[16] suggested a more detailed description of root numbers based on the location of bifurcation within the apical third. They proposed that roots with a distinct apical bifurcation be classified as 2 roots, whereas roots with a bifurcation in the middle portion of the apical third (bifid tip) and those with a slight double apex should be considered to have 1 root.[16] Bifid tip may be related to complex root canal morphology, including the presence of accessory canals.[18]

Several classification systems have been proposed to categorize root canal configurations, with the Weine, Vertucci, and Ahmed classifications widely recognized as the most common.[1,21,22] The Weine classification categorizes root canal types from type I to type IV but does not consider multi-rooted teeth and complex configurations.[22] Vertucci et al.[1] identified more detailed root canal systems and reported 8 configurations based on the pattern of division in the main root canal, from the pulp chamber floor to the root apex. Although the Vertucci classification is the most widely used system for classifying root canal configuration, it does not account for the number of roots in anterior and premolar teeth.[1,8] Ahmed et al.[21] developed a new coding system to provide complete information about root number and canal morphology. While the Ahmed classification can describe complex root morphology in detail, comparing study results with previous research can be challenging. The Vertucci classification is straightforward to use, and its results can be easily compared with those of previous studies.[15] Most maxillary premolars can be easily classified using the Vertucci classification, with only a small number of teeth not sufficiently described by this system.[15]

CBCT has been recognized as a valuable tool for assessing the root and canal morphology of maxillary premolars.[5-8,15] The number of roots in maxillary premolars ranges from 1 to 3, and various root canal morphologies have been observed.[1,5,12,15] Numerous studies have suggested that maxillary first premolars most frequently possess 2 roots and 2 root canals,[8,23,24] although some research indicates that a single root is more common.[4,25] Typically, maxillary second premolars have 1 root and 1 root canal, but notable variation exists in the prevalence of single-rooted teeth and the types of root canals present.[4,12,15,24] These variations are influenced by geographic origin and sex.[4-8,12,15,24-26] To date, no studies have utilized CBCT to examine the number of roots and types of root canals in maxillary premolars among Koreans. Given the varied results observed in different ethnic groups from previous research, it is crucial to explore these anatomical differences within the Korean population.

This study aimed to evaluate the number of roots and the types of root canals in maxillary first and second premolars within a selected Korean population, utilizing CBCT. Additionally, it sought to determine whether variations in root number and root canal type were associated with sex and tooth type.

Materials and Methods

The Institutional Review Board of Pusan National University Dental Hospital approved this study (PNUDH2004 06006). Participants were retrospectively selected at random from patients who visited Pusan National University Dental Hospital and underwent CBCT examinations between 2013 and 2014. Eligible patients were 20 years of age or older with sound maxillary premolars. Teeth with periapical lesions, root resorption, root fracture, previous endodontic treatment, or blurred radiographic images were excluded from the study. The final sample comprised 303 patients (162 men and 141 women) with a mean age of 28.5 ± 7.1 years, ranging from 20 to 50 years. The study included a total of 1,163 teeth: 585 first premolars and 578 second premolars.

CBCT scans were conducted with a PaX-Zenith 3D scanner (Vatech, Hwaseong, Korea) using parameters of 5.2-5.7 mA, 106-110 kV, an exposure time of 24 seconds, a voxel size of 200 μm, and a field of view measuring 16 × 14 cm. CBCT data were stored in the Digital Imaging and Communications in Medicine format. Image analysis was performed using Ez3D Plus Professional CBCT software (version 1.2.6.27; Vatech). The number of roots and canal morphology of the maxillary premolars were evaluated on axial,

Fig. 1. Cone-beam computed tomographic images illustrating the number of roots and root morphology. A. Single root, clearly defined. B. Single root with a small double apex. C. Single root with a bifid tip located in the middle portion of the apical third. D. Two roots, with bifurcation occurring in the coronal third of the root. E. Two roots, with bifurcation in the middle third of the root. F. Two roots, with bifurcation in the apical third of the root.

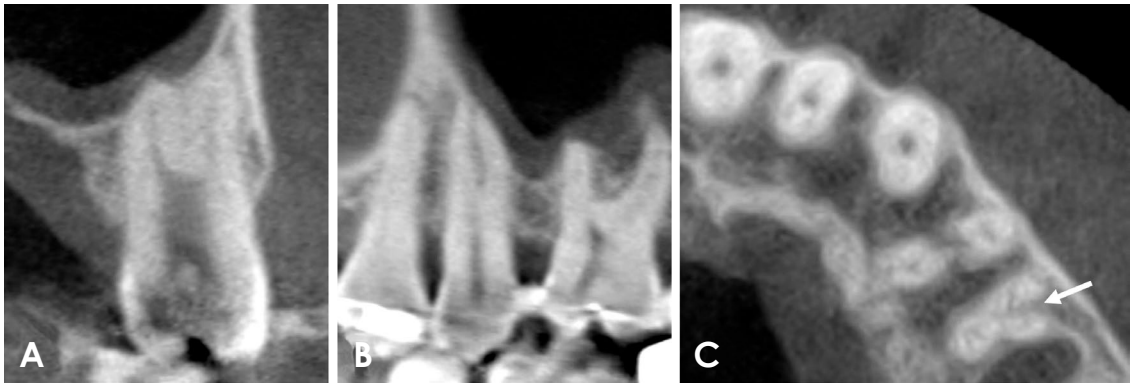

Fig. 2. Cone-beam computed tomography images of a 3-rooted maxillary second premolar. A. Coronal view displaying buccal and palatal roots. B. Sagittal view illustrating bifurcation in the middle third of the buccal root. C. Axial view revealing 2 buccal roots and 1 palatal root.

coronal, sagittal and cross-sectional CBCT views. To assess root morphology, cross-sectional images were reconstructed perpendicular to the long axis of the tooth.

The number of roots was classified based on root morphology as follows: 1 root, indicating the tooth has a single clearly defined root, a small double apex, or a bifid tip in the middle portion of the apical third; 2 roots, where the tooth exhibits bifurcation in the coronal third, middle third,

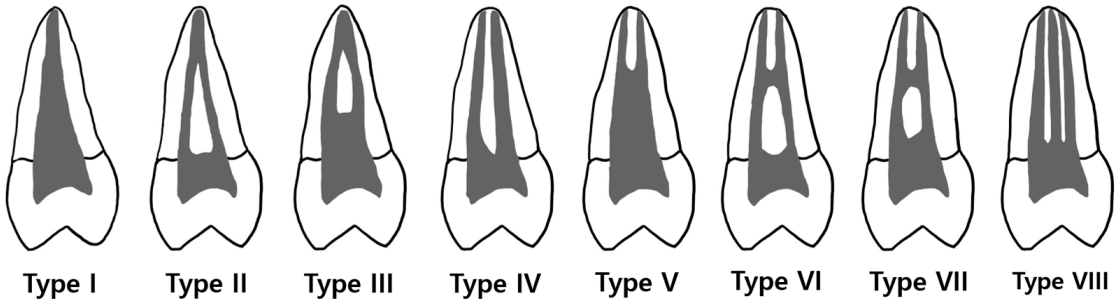

Fig. 3. Schematic representation of the Vertucci classification.

Fig. 4. Cone-beam computed tomographic images in cross-sectional (A-F) and axial (G) views, displaying root canal morphology according to the Vertucci classification. A. Type I. B. Type II. C. Type III. D. Type IV. E. Type V. F. Type VII. G. Type VIII.

or apical third of the root; and 3 roots, denoting the presence of 3 roots regardless of partial versus complete separation (Figs. 1 and 2).[16] Root canal configurations were categorized into the 8 types defined by the Vertucci classification: type I, where a single canal extends from the pulp chamber to the apex; type II, in which 2 separate canals leave the pulp chamber and join short of the apex to form a single canal; type III, where 1 canal leaves the pulp chamber, divides into 2 within the root, and then merges to exit as a single canal; type IV, featuring 2 separate and distinct canals that extend from the pulp chamber to the apex; type V, where 1 canal leaves the pulp chamber and divides short of the apex into 2 separate and distinct canals with their own apical foramina; type VI, in which 2 separate canals leave the pulp chamber, merge in the body of the root, and then redivide short of the apex to exit as 2 distinct canals; type VII, where 1 canal

leaves the pulp chamber, divides and then rejoins within the body of the root, and finally redivides into 2 distinct canals short of the apex; and type VIII, which consists of 3 separate and distinct canals extending from the pulp chamber to the apex (Figs. 3 and 4).[1]

An oral and maxillofacial radiologist conducted the interpretation and analysis of CBCT images. Reassessment was performed 1 month after the initial assessment to evaluate intra-examiner reliability. The intra-examiner agreement was analyzed using the Cohen kappa coefficient. Kappa statistics were interpreted as follows: values ≤ 0 indicated no agreement, 0.01-0.20 represented no to slight agreement, 0.21-0.40 indicated fair agreement, 0.41-0.60 denoted moderate agreement, 0.61-0.80 signified substantial agreement, and 0.81-1.00 reflected almost perfect agreement. The McNemar test was utilized to identify differences between the right and left sides. The chi-square or Fisher exact test was employed to compare the number of roots and canal morphology types according to sex and tooth type. A *P*-value of less than 0.05 was considered to indicate statistical significance. The data were statistically analyzed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 585 maxillary first premolars (283 bilateral and 19 unilateral) and 578 maxillary second premolars (278 bilateral and 22 unilateral) met the inclusion criteria and were included in the evaluation. The kappa value for intra-examiner agreement was 0.953, indicating an almost perfect level of agreement. No statistically significant difference was found in the root number or canal configuration between the right and left sides ($P > 0.05$) (Table 1).

Table 2 presents the distribution of root numbers in the maxillary first and second premolars, categorized by sex. Women exhibited a higher prevalence of teeth with a single root, whereas teeth with 2 roots were more common in men. A significant correlation was found between root number

Table 1. Comparison of root number and canal morphology between left and right maxillary premolars

		Maxillary first premolar			Maxillary second premolar		
		Right	Left	*P*	Right	Left	*P*
Number of roots	One	207 (71.6)	211 (71.3)	1.000	279 (96.9)	285 (98.3)	0.135
	Two	82 (28.4)	85 (28.7)		7 (2.4)	4 (1.4)	
	Three	0 (0.0)	0 (0.0)		2 (0.7)	1 (0.3)	
	Total	289 (100.0)	296 (100.0)		288 (100.0)	290 (100.0)	
Root canal morphology	Type 1	86 (29.8)	84 (28.4)	0.811	221 (76.7)	221 (76.2)	0.541
	Type 2	39 (13.5)	39 (13.2)		17 (5.9)	13 (4.5)	
	Type 3	28 (9.7)	30 (10.1)		26 (9.0)	30 (10.3)	
	Type 4	123 (42.6)	126 (42.6)		10 (3.5)	8 (2.8)	
	Type 5	12 (4.2)	16 (5.4)		11 (3.8)	17 (5.9)	
	Type 7	1 (0.3)	1 (0.3)		1 (0.3)	0 (0.0)	
	Type 8	0 (0.0)	0 (0.0)		2 (0.7)	1 (0.3)	
	Total	289 (100.0)	296 (100.0)		288 (100.0)	290 (100.0)	

Table 2. Distribution of the number of roots in maxillary premolars by sex and tooth type

Tooth type	Sex	One root	Two roots	Three roots	Total
Maxillary first premolar[a]	Male[b]	205 (65.9)	106 (34.1)	0 (0.0)	311 (100.0)
	Female[b]	213 (77.7)	61 (22.3)	0 (0.0)	274 (100.0)
	Total	418 (71.5)	167 (28.5)	0 (0.0)	585 (100.0)
Maxillary second premolar[a]	Male[c]	298 (95.8)	10 (3.2)	3 (1.0)	311 (100.0)
	Female[c]	266 (99.6)	1 (0.4)	0 (0.0)	267 (100.0)
	Total	564 (97.6)	11 (1.9)	3 (0.5)	578 (100.0)

Superscripts with the same letters indicate significance at $P < 0.05$.

and sex ($P<0.05$). In maxillary first premolars, a single root (71.5%) was most common, followed by 2 roots (28.5%). Most maxillary second premolars had 1 root (97.6%), with only 11 (1.9%) exhibiting 2 roots. None of the maxillary first premolars had 3 roots, and only 3 (0.5%) of the maxillary second premolars did, featuring 2 buccal roots and 1 palatal root. A significant difference in root number was noted between the maxillary first and second premolars ($P<0.05$) (Table 2).

Among the maxillary first premolars with a single root, 324 (77.5%) exhibited a clear single root, 62 (14.8%) had a double apex, and 32 (7.7%) presented with a bifid tip. Most single-rooted maxillary second premolars also had a distinct single root. The bifurcation of the root in maxillary first premolars most commonly occurred in the middle third of the root (53.9%), followed by the apical third (27.5%) and the coronal third (18.6%). In the maxillary second premolar, root bifurcation was rare, with the highest occurrence in the apical third (Table 3).

The prevalence of root canal types in maxillary premolars is presented in Table 4. A statistically significant association was observed between sex and root canal type ($P<0.05$). Type I was more prevalent among female participants, whereas types IV and V were more frequently observed in male patients. All canal configurations, except for type VI, were observed in the maxillary premolars. In the maxillary first premolars, the most common configuration was type IV (42.6%), followed by type I (29.1%) and type II (13.3%). Type VII was found in only 2 teeth (0.3%), and type VIII was not observed in these teeth. Among maxillary second premolars, type I was the predominant canal configuration (76.5%), with types III (9.7%) and II (5.2%) also present. Types VII (0.2%) and VIII (0.5%) were infrequently found in maxillary second premolars. Significant differences in the distribution of root canal types were noted between the maxillary first and second premolars ($P<0.05$) (Table 4).

In maxillary first premolars with a single root, type I configuration was the most common (40.7%), followed by type IV (21.8%) and type II (18.7%). In those with 2 roots, type IV was the predominant configuration (94.6%). For maxil-

Table 3. Number of roots in maxillary premolars based on root morphology

Number of roots	Root morphology	Maxillary first premolar	Maxillary second premolar
One root	One apex	324 (77.5)	532 (94.3)
	Double apex	62 (14.8)	24 (4.3)
	Bifid tip	32 (7.7)	8 (1.4)
	Total	418 (100.0)	564 (100.0)
Two roots	Cervical bifurcation	31 (18.6)	1 (9.1)
	Middle bifurcation	90 (53.9)	4 (36.4)
	Apical bifurcation	46 (27.5)	6 (54.5)
	Total	167 (100.0)	11 (100.0)
Three roots		0 (0.0)	3 (100.0)
Total		585 (100.0)	578 (100.0)

Table 4. Distribution of root canal configurations of maxillary premolars by sex and tooth type

Tooth type	Sex	Vertucci root canal configuration							
		Type I	Type II	Type III	Type IV	Type V	Type VII	Type VIII	Total
Maxillary first premolar[a]	Male[b]	81 (26.0)	33 (10.6)	28 (9.0)	150 (48.2)	17 (5.5)	2 (0.6)	0 (0.0)	311 (100.0)
	Female[b]	89 (32.5)	45 (16.4)	30 (10.9)	99 (36.1)	11 (4.0)	0 (0.0)	0 (0.0)	274 (100.0
	Total	170 (29.1)	78 (13.3)	58 (9.9)	249 (42.6)	28 (4.8)	2 (0.3)	0 (0.0)	585 (100.0)
Maxillary second premolar[a]	Male[c]	230 (74.0)	19 (6.1)	27 (8.7)	8 (2.6)	24 (7.7)	0 (0.0)	3 (1.0)	311 (100.0)
	Female[c]	212 (79.4)	11 (4.1)	29 (10.9)	10 (3.7)	4 (1.5)	1 (0.4)	0 (0.0)	267 (100.0)
	Total	442 (76.5)	30 (5.2)	56 (9.7)	18 (3.1)	28 (4.8)	1 (0.2)	3 (0.5)	578 (100.0)

Superscripts with the same letters indicate significance at $P<0.05$.

Table 5. Classification of maxillary premolars by number of roots and canal type

	Root number	Vertucci root canal configuration							
		Type I	Type II	Type III	Type IV	Type V	Type VII	Type VIII	Total
Maxillary first premolar	One	170 (40.7)	78 (18.7)	58 (13.9)	91 (21.8)	19 (4.5)	2 (0.5)	0 (0.0)	418 (100.0)
	Two	0 (0.0)	0 (0.0)	0(0.0)	158 (94.6)	9 (5.4)	0 (0.0)	0 (0.0)	167 (100.0)
	Three	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Total	170 (29.1)	78 (13.3)	58 (9.9)	249 (42.6)	28 (4.8)	2 (0.3)	0 (0.0)	585 (100.0)
Maxillary second premolar	One	442 (78.4)	30 (5.3)	56 (9.9)	13 (2.3)	22 (3.9)	1 (0.2)	0 (0.0)	564 (100.0)
	Two	0 (0.0)	0 (0.0)	0 (0.0)	5 (45.5)	6 (54.5)	0 (0.0)	0 (0.0)	11 (100.0)
	Three	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (100.0)	3 (100.0)
	Total	442 (76.5)	30 (5.2)	56 (9.7)	18 (3.1)	28 (4.8)	1 (0.2)	3 (0.5)	578 (100.0)

Table 6. Number of roots and root canal morphologies of maxillary first premolars in previous studies

Author (year)	Population (sample size)	Method	Number of roots (%)			Vertucci canal type (%)							
			One	Two	Three	I	II	III	IV	V	VI	VII	VIII
Kartal et al.[12] (1998)	Turkish (300)	Clearing	37.3	61.3	1.3	8.7	1.0	0.0	71.3	14.7	2.3	0.3	1.3
Abella et al.[29] (2015)	Spanish (430)	CBCT	46.0	51.4	2.6	25.1	10.2	4.4	52.8	1.9	1.6	1.4	2.6
Li et al.[4] (2018)	Chinese (1387)	CBCT	69.7	29.8	0.5	11.8	14.7	16.1	42.7	12.1	0.6	0.7	0.7
Saber et al.[5] (2019)	Egyptian (358)	CBCT	45.8	53.1	1.1	1.1	15.6	1.4	73.2	1.4	3.9	1.7	1.4
Maghfuri et al.[27] (2019)	Saudi (100)	CBCT *in vitro*	36.0	61.0	3.0	0.0	7.0	0.0	75.0	13.0	2.0	0.0	3.0
de Lima et al.[24] (2019)	Chinese (496)	CBCT	18.2	80.2	1.6	6.5	7.7	0.6	82.2	0.8	0.6	0.0	1.6
Wu et al.[30] (2020)	Chinese (1268)	CBCT	67.4	32.0	0.6	10.4	24.2	0.4	58.6	4.9	0.9	0.0	0.4
Buchanan et al.[15] (2020)	South African (316)	CBCT	44.0	54.1	1.9	8.9	7.3	4.7	71.8	2.2	2.2	0.0	2.8
Asheghi et al.[6] (2020)	Iranian (1462)	CBCT	50.2	48.1	1.7	8.9	15.2	0.9	71.6	1.3	0.2	0.0	2.0
Liu et al.[25] (2021)	Chinese (880)	CBCT	70.2	29.3	0.5	27.8	20.6	1.0	44.3	3.3	1.5	1.0	0.5
Al-Zubaidi et al.[7] (2021)	Saudi (500)	CBCT	39.8	58.6	1.6	5.2	32.8	0.6	57.8	2.0	0.0	0.0	1.6
Olczak et al.[8] (2021)	Polish (350)	CBCT	28.3	69.1	2.6	1.7	8.6	2.6	78.5	5.1	0.0	0.6	2.9
Khanna et al.[28] (2023)	India (137)	CBCT	32.8	67.1	0.0	8.0	8.7	8.0	65.6	2.9	4.3	0.0	0.0
Present study	Korean (585)	CBCT	71.5	28.5	0.0	29.1	13.3	9.9	42.6	4.8	0.0	0.3	0.0

CBCT: cone-beam computed tomography.

lary second premolars with 1 root, type I was again the most frequent, found in 78.4% of cases, while type III was present in 9.9%. In maxillary second premolars with 2 roots, type V was slightly more prevalent (54.5%) than type IV (45.5%) (Table 5).

Discussion

Understanding the morphology of roots and root canals is essential for achieving successful outcomes in root canal treatment. Consequently, this study aimed to explore the number of roots and to classify the various root canal configurations present in maxillary premolars using CBCT.

Most studies have reported that maxillary first premolars with 2 roots are common, which contrasts with the findings of this research.[5,7,8,12,15,24,27-29] However, some reports have indicated that approximately two-thirds of maxillary first premolars possess a single root, aligning with the present results (Table 6).[4,25,30] In one study, Asian participants displayed a higher prevalence of single-rooted maxillary first premolars (83.2%) compared to white patients (48.7%).[31] Regarding maxillary second premolars, 1 root is generally more prevalent than 2 roots. This study found that nearly all maxillary second premolars (97.6%) had 1 root, representing a higher percentage than reported in other studies.[5,7,12,15,23,24,28,29,32,33] Consistent with these findings, some

Table 7. Number of roots and root canal morphologies of maxillary second premolars in previous studies

Author (year)	Population (sample size)	Method	Number of roots (%)			Vertucci canal type (%)							
			One	Two	Three	I	II	III	IV	V	VI	VII	VIII
Kartal et al.[12] (1998)	Turkish (300)	Clearing	69.6	29.7	0.7	48.7	6.3	0.0	38.0	5.7	0.7	0.0	0.7
Yang et al.[33] (2014)	Chinese (392)	CBCT	86.5	13.5	0.0	45.4	16.3	11.4	20.2	6.4	0.0	0.0	0.3
Abella et al.[29] (2015)	Spanish (374)	CBCT	82.9	15.5	1.6	39.3	22.5	7.2	19.8	4.3	3.2	2.1	1.6
Li et al.[4] (2018)	Chinese (1403)	CBCT	96.2	3.8	0.0	50.3	10.4	23.9	5.9	8.0	0.3	0.4	0.0
Alqedairi et al.[23] (2018)	Saudi (318)	CBCT	85.2	14.5	0.3	49.4	25.8	5.0	11.6	5.7	1.6	0.0	0.9
Saber et al.[5] (2019)	Egyptian (342)	CBCT	72.8	26.0	1.2	16.1	22.2	1.8	44.4	2.9	4.1	7.3	1.2
de Lima et al.[24] (2019)	Chinese (503)	CBCT	71.2	28.4	0.4	49.9	9.3	2.2	32.6	4.0	0.8	0.8	0.4
Buchanan et al.[15] (2020)	South African (285)	CBCT	78.2	20.4	1.4	37.5	11.9	5.3	33.7	7.4	1.4	0.7	2.1
Asheghi et al.[6] (2020)	Iranian (400)	CBCT	91.0	8.5	0.5	63.0	19.5	0.8	14.3	1.0	0.5	0.0	1.0
Yan et al.[34] (2021)	Chinese (1053)	CBCT	94.2	5.8	0.0	55.1	31.9	0.6	10.2	1.5	0.4	0.1	0.2
Al-Zubaidi et al.[7] (2021)	Saudi (500)	CBCT	83.2	15.8	1.0	60.4	16.4	6.4	12.8	2.8	0.0	0.2	1.0
Olczak et al.[32] (2021)	Polish (324)	CBCT	88.9	11.1	0.0	59.6	9.3	6.2	15.7	7.1	0.9	0.9	0.3
Khanna et al.[28] (2023)	India (125)	CBCT	57.6	42.4	0.0	35.2	11.2	12.0	32.0	4.0	5.6	0.0	0.0
Present study	Korean (578)	CBCT	97.6	1.9	0.5	76.5	5.2	9.7	3.1	4.8	0.0	0.2	0.5

studies have reported that over 90% of maxillary second premolars have 1 root (Table 7).[4,6,34]

In this study, none of the maxillary first premolars exhibited 3 roots, a phenomenon reported to occur in 0-3% of cases in other studies (Table 6).[4,5,15,27,28] Three-rooted maxillary second premolars were identified in only 3 instances (0.5%), which aligns with the findings of some prior investigations.[6,24] The reported prevalence of 3-rooted maxillary second premolars ranges from 0% to 1.6% (Table 7).[4,5,15,28,29,32,34] Research has suggested that most 3-rooted maxillary premolars possess 2 buccal roots and 1 palatal root.[35] In the present results, the 3-rooted maxillary premolars also had 2 buccal roots and 1 palatal root, with the buccal root bifurcating at the middle third. Clinicians should be cognizant of these anatomical variations, as they may complicate treatment.[36]

Two-rooted maxillary premolars may bifurcate in any third of the root, with bifurcation most commonly occurring in the middle third.[5,25,32] In the present study, approximately half (53.9%) of the maxillary first premolars bifurcated in the middle third. This finding contrasts with another study that reported the highest frequency of bifurcation in the coronal third.[8] Among maxillary second premolars, the occurrence of 2 roots was notably low (1.9%), with most bifurcations found in the apical third. Previous research has shown variable bifurcation frequencies for maxillary second premolars, with some studies identifying the apical third[33] as the most common site, while others have found the middle third to be more prevalent.[32]

Understanding the prevalence of various root canal configurations is essential for successful endodontic treatment.[6] Clinicians must be cognizant of the locations at which root canals may bifurcate or converge.[5] This study revealed a wide range of root canal configurations in maxillary premolars, with all types except VI being observed. In maxillary first premolars, Vertucci type IV (42.6%) was the most common, followed by type I (29.1%) and type II (13.3%). Consistent with the present findings, Liu et al.[25] reported that over two-thirds (70.2%) of maxillary first premolars had a single root, with type IV (44.3%) being the most prevalent, followed by type I (27.8%) and type II (20.57%). However, numerous studies have indicated a greater frequency of 2 roots in maxillary first premolars, along with a higher prevalence of type IV (Table 6).[5,8,12,15,24,27] The lower prevalence of type IV in the present study compared to these reports can be attributed to the much less frequent presence of 2 roots. In this study, most maxillary second premolars were type I (76.5%), followed by type III (9.7%). Other research has generally indicated a lower prevalence of type I and a higher incidence of type II following type I.[6,7,23,29,34] As the occurrence of 1 root in maxillary second premolars decreased, after type I, type IV was more commonly seen than type II.[12,15,24,28] In previous research, the prevalence of type VIII maxillary second premolars has ranged from 0% to 2.1% (Table 7).[4,5,7,15,29,33] Type VIII morphology has been found in maxillary premolars with 2 and 3 roots.[6,35] In the present study, type VIII was identified in only 3 teeth (0.5%), all 3-rooted maxillary second pre-

molars, which displayed 2 buccal and 1 palatal canal. The variable prevalence of root numbers and root canal morphologies across studies may stem from differences in populations, sample sizes, or evaluation methods.

The Vertucci classification does not specify the number of roots for incisors and premolars.[21] For maxillary premolars with 2 root canals, such as types IV and V, the classification does not clarify whether the tooth has 1 or 2 roots. The system has limitations when describing the morphology of roots with complex canal systems, such as type VIII morphology, which includes 3 canals. The present study detailed the prevalence of root canal types based on the number of roots (Table 5). The distribution of types by root number differed between maxillary first and second premolars. Less than half of the single-rooted maxillary first premolars were classified as type I, with type IV and type II following in prevalence. In contrast, over three-quarters of the single-rooted maxillary second premolars were type I, with type III the next most common. Among the 2-rooted maxillary first premolars, more than 90% were type IV, while approximately half of the 2-rooted maxillary second premolars were type V.

As in previous studies, no significant difference was noted in the distribution of the number of roots and canal morphology between the right and left sides.[6-8,15,23-25,29,30,32,37,38] Bilateral symmetry of maxillary premolars can be clinically meaningful; when one side displays a complex root canal morphology, the other side may also have a complex shape.[9]

This study identified statistically significant sex-based differences in the distribution of root number and canal configuration type. Single roots were more commonly observed in women for both maxillary first and second premolars, whereas men more frequently had 2 roots. Women exhibited a higher prevalence of Vertucci type I configurations in both maxillary first and second premolars. Conversely, men had a higher prevalence of Vertucci type IV in maxillary first premolars and Vertucci type V in maxillary second premolars. These results align with previous research indicating that root numbers and canal types may vary according to sex.[6,7,24,25,32,39-41] Nonetheless, other studies have found no significant link between sex and root number or canal morphology.[8,23,29,30]

The present study employed CBCT, which is recognized as a reliable method for evaluating root and canal configurations. By analyzing axial, coronal, sagittal, and cross-sectional CBCT images, it was possible to effectively identify the morphology of roots and root canals in 3 dimensions. Nevertheless, CBCT has limitations in detecting finer structures, such as accessory canals or intercanal communications, which may represent a limitation of this study.

In conclusion, maxillary first premolars more commonly had 1 root rather than 2, while most maxillary second premolars had a single root. Type IV and type I were the most frequently identified root canal configurations in maxillary first and second premolars, respectively. Statistically significant differences in the number of roots and root canal type were observed between men and women, with higher prevalence rates of single roots and Vertucci type I configurations in women. The findings indicated significant variations in root number and canal configurations between maxillary first and second premolars. Two roots and root canal types other than type I were more commonly found in maxillary first premolars compared to maxillary second premolars. To minimize the incidence of missed canals, a primary cause of root canal treatment failure, it is imperative to recognize the various root canal types in maxillary premolars beyond type I. Understanding these differences is crucial for the success of root canal treatment and can assist clinicians in identifying and managing complex root canal systems.

Conflicts of Interest: None

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