ORIGINAL RESEARCH

Analysis of Bilateral Symmetry of Root Canal Anatomy in Permanent Dentition: An *In Vivo* CBCT Study in a Saudi Arabian Population

Mohammed Mashyakhy[1], Abdulaziz S Abu-Melha[2]

Abstract

Aim and objective: To evaluate the internal symmetry of roots and root canals of permanent maxillary and mandibular teeth. This study used cone-beam computed tomography (CBCT) to examine the bilateral symmetry of root canals, their configuration, and the number of roots in a Saudi Arabian population.

Materials and methods: CBCT images of 5,223 teeth from records of 208 patients (age of 28.74 ± 9.56 years) were analyzed using i-Dixel 3D imaging software. Sagittal, axial, and coronal serial sections were used to examine the root canal configuration, the number of roots, and the number of canals of all the teeth in the maxilla and mandible and compare them with the contralateral side for symmetry. Frequencies and percentages were used to represent the results. Cohen's Kappa test was employed to examine bilateral symmetry. The significance level was set at $p < 0.05$ for all statistical tests.

Results: Bilateral symmetry of the number of roots was 100% in maxillary central incisors, laterals, canines, first molars, and second molars. The mandibular arch showed greater variation with the roots of the central incisors and second premolars being 100% symmetrical. Maxillary first premolars were frequently asymmetrical (14.9%). Maxillary central and lateral incisors showed 100% bilateral symmetry of the canals. The number of canals in the maxillary second molars showed asymmetry (18.9%). For canal configuration, the bilateral symmetry was found 100% in maxillary central and lateral incisors. Maxillary second premolars (32.2%) showed frequent asymmetry in the canal configuration.

Conclusion: The mandibular arch showed greater asymmetry than the maxillary arch. Internal canal configurations displayed the highest bilateral asymmetry, followed by the number of canals. Bilateral symmetry was most evident in the number of roots present.

Clinical significance: The findings of this study will enable clinicians to anticipate the variations in canal morphology in both maxillary and mandibular teeth and be cognizant of the contralateral variations in canal contours and anatomy that affect endodontic therapy.

Keywords: Bilateral symmetry, Cone-beam computed tomography, Internal root anatomy, Root morphology, Root symmetry, Saudi population.

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Introduction

Successful endodontic treatment is the result of thorough debridement, disinfection, and complete obturation of the entire root canal. Anatomical variation in root canals is well documented. These variations include intricate canal spaces with isthmuses, deltas, or even multiple canals. Previous studies have highlighted the importance of canal geometry, reporting that variations in the canal morphology have an immense influence on the shaping and cleaning procedures than the instrumentation technique itself.[1] Missed canals have been identified as a common cause of the failure of endodontic therapy.[2,3] Certain teeth such as the maxillary molars show a high clinical failure rate due to the substantial variations in their canal configurations.[4] Root canal morphology has been widely studied using different techniques as it can influence endodontic treatment outcomes.[5–12]

Root canal morphology can exhibit variation in anatomy as a result of several factors, chief among them is ethnicity.[13–16] Vertucci, in his seminal paper, examined 1000s of permanent teeth to elucidate the anatomy of root canals.[17] In the years since few studies have evaluated the configuration, form, morphology, and symmetry of the roots and their canals bilaterally,.[18–23] techniques such as microscopic evaluation of slices, micro-CT, periapical, and digital radiography have been used to investigate the internal anatomy of teeth. Recent studies have used cone-beam computed tomography (CBCT) images to examine bilateral symmetry in mandibular incisors, canines,[18–20] and premolars.[21,22] CBCT examination overcomes the limitations in conventional radiographs such as distortion and superimposition.[24] *In vivo* CBCT studies have investigated the root canals of maxillary and mandibular molars, comparing their roots and canal morphology to the contralateral teeth in the same individuals.[22,23] However, previously published studies were limited by their sample size and methodology. Research on the subject has been restricted to evaluating a specific group of teeth.

[1]Department of Restorative Dental Sciences, College of Dentistry, Jazan University, Jazan, Saudi Arabia

[2]Department of Restorative Dental Sciences, College of Dentistry, King Khalid University, Abha, Saudi Arabia

Corresponding Author: Mohammed Mashyakhy, Department of Restorative Dental Sciences, College of Dentistry, Jazan University, Jazan, Saudi Arabia, e-mail: dr.mashyakhy@gmail.com

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Alqedairi et al. analyzed bilateral symmetries in the canal configuration and the number of roots in a Saudi population. They found that the first and second maxillary premolars showed 91.2 and 85.3% symmetries, respectively.[25] Mashyakhy et al. evaluated bilateral symmetry in mandibular first molars and reported that the number of roots showed perfect symmetry (100%). The number of canals was less symmetrical (56.4%) with the mesial roots, showing more symmetry with the contralateral side than the distal roots.[26] A recent CBCT study on mandibular canines reported that 97.7% of the teeth displayed a symmetrical number of roots and canal configuration.[27]

There is little research addressing bilateral symmetry of one-half of the dentition with the contralateral side in the same individuals. This study aimed to assess the bilateral symmetry of roots and their canal morphology and compare them to the teeth of the contralateral side in a full complement of dentition in a Saudi Arabian population using CBCT.

Materials and Methods

The Sample

This cross-sectional study was approved by the Institutional Ethics Review Board, College of Dentistry, Jazan University, Saudi Arabia (CODJU-19213). The CBCT scans were obtained from the archives of the College of Dentistry from 2016–2018. CBCT images of 208 patients (M/F:100/108; 48%/52%) aged between 17 and 59 years with a median age of 26 (mean age = 28.74 ± 9.56 years) were extracted. A total of 5,223 images of maxillary and permanent mandibular teeth were acquired from the database. This study was retrospective, and all scans used in this study were taken previously for other diagnostic and treatment purposes. No patient was exposed to unnecessary radiation for this study.

Only teeth that had fully developed roots and closed apices were included in the study. Teeth that had previously undergone endodontic treatment or showed evidence of incomplete or initial root canal treatment, teeth with evidence of underlying periapical lesions, resorption, calcification, the third molars, and distorted CBCT scans were excluded from the study.

CBCT Scans

The CBCT images were obtained using a 3D Accuitomo 170 CBCT unit (J Morita, Kyoto, Japan). The parameters for scanning were kept constant for all patients with 90 kV, 5–8 mA, and 17.5 seconds of exposure time with a voxel size of 0.25 mm, following manufacturer guidelines. The images obtained were analyzed and viewed using the i-Dixel 3D imaging suite provided by the manufacturer. Serial coronal, axial, and sagittal sections were created and used to assess the number and configuration of the canals and the roots based on Vertucci classification.[17] One observer evaluated 20% of the sample twice with an interval of 4 weeks in between each observation to ensure intrarater reliability.

Data Analysis

To assess the variables, SPSS v.25 (IBM, Chicago, Illinois, United States) was used on a system running Microsoft Windows. The canal system configuration, the number of canals, and roots of all the teeth that met the inclusion and exclusion criteria were assessed. Bilateral symmetries and asymmetries for all the variables were evaluated. For maxillary molars, only the mesiobuccal (MB) roots were presented in detail because distobuccal (DB) roots and palatal (P) roots had the same morphology of one root, one canal, and Vertucci type I.

Statistical Analysis

The results were expressed as frequencies and percentages. Cohen's Kappa test was used for bilateral symmetry. Kappa test was also used for intrarater reliability. The level of significance was set at $p < 0.05$ for all statistical tests.

Results

Cohen's Kappa test revealed an agreement of measurement with a value of 0.85 with a significance of $p < 0.001$.

Maxillary Teeth

The results of the total bilateral symmetry of the maxillary teeth are presented in Table 1. Details of bilateral symmetry by tooth type, according to the number of roots, the number of canals, and Vertucci types are presented in Table 2 and 3.

Central Incisors

The total bilateral symmetry was 100%. All 185 participants had one root with a single canal and displayed a Vertucci type I configuration on the left and right sides (100%). All 185 participants (100%) had one root, one canal, and Vertucci type I configuration on both sides. This is visible in Figure 1, which is an axial section showing the maxillary teeth with symmetrical in the number of roots and canals.

Table 1: Total bilateral symmetry in maxillary and mandibular teeth by number of roots, number of canal, and root canal configuration (numbers in percentages)

	Number of roots		*Number of canals*		*Canal configuration*	
	Symm	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*
Maxillary teeth						
Centrals	100	0	100	0	100	0
Laterals	100	0	100	0	100	0
Canines	100	0	98.9	1.1	98.9	1.1
First premolars	85.1	14.9	93.2	6.8	83	17
Second premolars	93	7	83	17	67.8	32.2
First molars	100	0	95.8	4.2	81.1	18.9
Second molars	100	0	81.1	18.9	69.3	30.7
Mandibular teeth						
Centrals	100	0	91.2	8.8	91.2	8.8
Laterals	100	0	85.3	14.7	85.3	14.7
Canines	95.5	4.5	91.1	8.9	90.1	9.9
First premolars	99	1	87.1	12.9	83.5	16.5
Second premolars	100	0	83.7	16.3	82.7	17.3
First molars	99.2	0.8	89.3	10.7	M (87.6), D (82.6)	M (12.4), D (17.4)
Second molars	98.1	1.9	92.9	7.1	M (74.2), D (97.4)	M (25.8), D (2.6)

M, mesial; D, distal

Table 2: Bilateral symmetry of maxillary teeth according to number of roots and number of canals

	Central		*Lateral*		*Canine*		*First premolar*		*Second premolar*		*First molar*		*Second molar*	
	Symm	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*
Number of roots														
1 root	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**183 (100.0)**	0 (0.0)	**53 (32.8)**	24 (14.8)	**140 (84.8)**	11 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**83 (51.2)**	24 (14.8)	**14 (8.6)**	11 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.2)**	0 (0.0)	0 (0.0)	0 (0.0)	**143 (100)**	0 (0.0)	**127 (100.0)**	0 (0.0)
Number of canals														
1 canal	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**180 (98.4)**	2 (1.1)	**2 (1.2)**	**8 (4.9)**	**49 (29.7)**	27 (16.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.1)**	**147(90.8)**	10 (6.2)	**87 (52.7)**	28 (17.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
3 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.2)	**2 (1.2)**	1 (0.6)	**1 (0.6)**	**18 (12.6)**	6 (4.2)	**30 (23.7)**	24 (18.8)
4 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.2)**	0 (0.0)	0 (0.0)	**119 (83.2)**	6 (4.2)	**73 (57.5)**	24 (18.8)

Bold numbers refer to the more frequent values. Mesiobuccal roots of first and second molars were the only roots included in analysis

Table 3: Bilateral symmetry of maxillary teeth according to canal configuration

	Central		*Lateral*		*Canine*		*First premolar*		*Second premolar*		*First molar*		*Second molar*	
	Symm	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*
Vertucci types														
Type I	**185 (100.0)**	0 (0.0)	**184 (100.0)**	0 (0.0)	**180 (98.4)**	2 (1.1)	**2 (1.2)**	**8 (4.9)**	**49 (29.7)**	27 (16.2)	**17 (11.9)**	6 (4.2)	**30 (23.7)**	22 (17.3)
Type II	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	2 (1.1)	8 (4.9)	**8 (4.9)**	11 (6.7)	**12 (7.2)**	**40 (28.0)**	21 (14.7)	21 (16.5)	**25 (19.7)**
Type III	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	8 (4.9)	**10 (6.2)**	15 (9.1)	**24 (14.4)**	0 (0.0)	**3 (2.1)**	1 (0.8)	**5 (3.9)**
Type IV	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**96 (59.3)**	15 (9.3)	**24 (14.5)**	14 (8.4)	**59 (41.3)**	20 (14.0)	**32 (25.2)**	18 (14.2)
Type V	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**18 (11.1)**	11 (6.9)	11 (6.7)	**19 (11.4)**	0 (0.0)	**2 (1.4)**	2 (1.6)	**7 (5.5)**
Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.6)**	1 (0.6)	**2 (1.2)**	0 (0.0)	**2 (1.4)**	**2 (1.6)**	1 (0.8)
Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**7 (4.8)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**3 (1.9)**	1 (0.6)	1 (0.6)	**1 (0.6)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values. Mesiobuccal roots of first and second molars were the only roots included in analysis

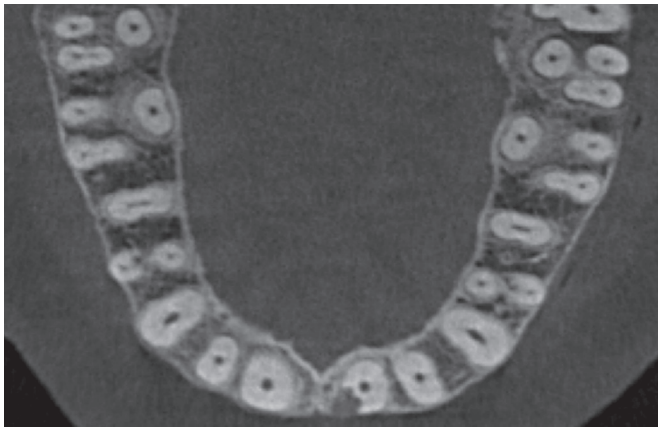


Fig. 1: CBCT axial section showing all maxillary teeth with bilateral symmetry in number of roots and number of canals

Lateral Incisors

The total bilateral symmetry was 100%. All lateral incisors displayed one root with a single canal running through it. Both sides presented with a Vertucci type I configuration (100%).

Canines

One hundred and eighty-three participants (88.0% of the total sample) displayed perfect symmetry in the number of roots. However, the canals were not perfectly symmetrical, with only 98.9% exhibiting symmetry on the right and left sides (p <0.001). Similarly, 98.9% of the canals were of Vertucci type (p <0.001). The most frequent bilateral symmetry was one canal (98.4%) and Vertucci type I configuration (98.4%).

First Premolars

The number of roots showed a bilateral symmetry of 85.1% (p <0.001), 93.2% for the number of canals (p <0.001), and 83.0% for Vertucci types (p <0.001). The most frequent bilateral symmetry was two roots (51.2%), two canals (90.8%), and Vertucci type IV (59.5%).

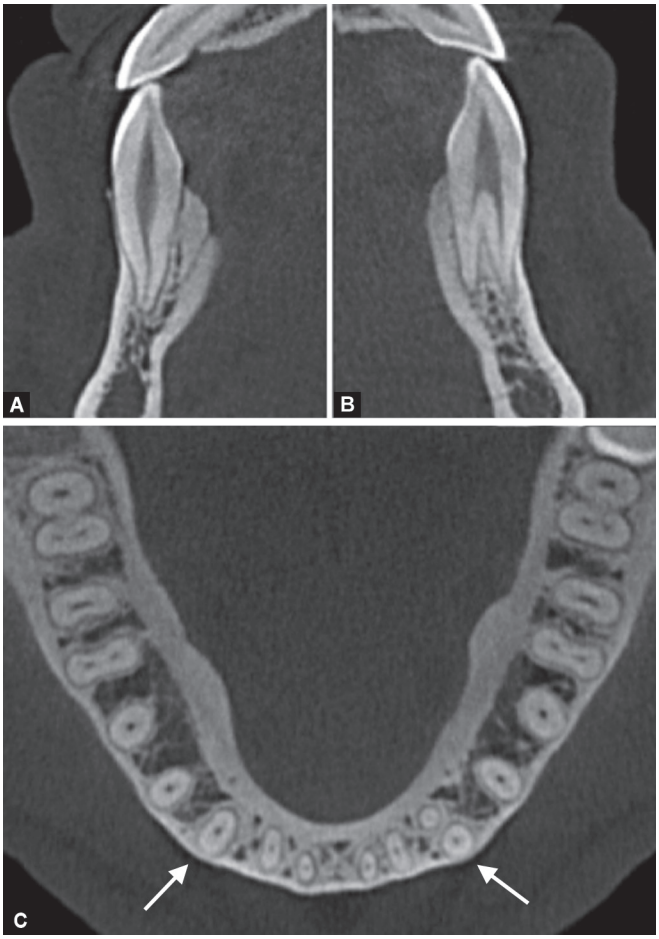
Second Premolars

The number of roots showed a bilateral symmetry of 93%, which was highly significant (p <0.001). The number of canals present showed a bilateral symmetry of 83% (p <0.001). Bilateral symmetry for canal configuration was less frequent (67.8%, p <0.001). The most frequent bilateral symmetry was one root (84.8%), two canals (52.7%), and Vertucci type I configuration (29.7%) (Fig. 2).

First Molars

Molars with three roots: One hundred and forty-three out of 208 participants (68.8% of the total sample) displayed perfect symmetry in the number of roots on both right and left sides. Within these 143 participants, 137 had a slight asymmetry in the number of canals, with only 95.8% being perfectly symmetrical (p <0.001). One-hundred and sixteen participants had symmetrical Vertucci types in mesiobuccal roots on both sides (81.1%; p <0.001). The most frequent bilateral symmetry was four canals (83.2%) and Vertucci type IV (41.3%).

Fused-rooted molars: Fifteen out of 208 participants had maxillary first molars with fused roots. Out of the 15, only seven participants (3.4% of the total sample) had bilateral symmetry.



Figs 2A to C: CBCT images of different coronal and axial sections of the same patient showing: (A) Mandibular right canine with one canal and Vertucci type I; (B) Left canine with two roots and two canals with type V Vertucci; (C) All mandibular teeth with bilateral symmetry in number of roots and number of canals except for right and left canines (arrows) which show asymmetry

Second Molars

Molars with three roots: Out of the evaluated (n = 208), 127 (61.1% of the total sample) showed perfect symmetry in the number of roots (100%). However, the symmetry for the number of canals was only 81.1% between the right and left sides (p <0.001). Canal configuration in mesiobuccal roots showed a bilateral symmetry of 69.3% (p <0.001). The second molars were similar to the maxillary first molars with four canals (57.5%) and Vertucci type IV (25.2%) showing bilateral symmetry.

Fused-rooted molars: Forty-two out of 208 participants had fused-rooted molars. Eleven participants (5.3% of the total sample) had bilateral symmetry.

Mandibular Teeth

The results of the total bilateral symmetry of the maxillary teeth are presented in Table 1. More details about the results of bilateral symmetry by tooth type according to the number of roots, the number of canals, and Vertucci types are presented in Tables 4 to 6.

Central Incisors

Mandibular central incisors showed perfect symmetry between the right and left sides in the number of roots (100%). The number of

Table 4: Bilateral symmetry of mandibular teeth (anteriors and premolars) according to number of roots and number of canals

	Central		*Lateral*		*Canine*		*First premolar*		*Second premolar*	
	Symm	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*
Number of roots										
1 root	**205 (100.0)**	0 (0.0)	**202 (99.0)**	2 (1.0)	**192 (95.1)**	9 (4.4)	**192 (99.0)**	2 (1.0)	**179 (100.0)**	0 (0.0)
2 roots	0 (0.0)	0 (0.0)	0 (0.0)	**2 (1.0)**	1 (0.5)	**9 (4.4)**	0 (0.0)	**2 (1.0)**	0 (0.0)	0 (0.0)
3 roots	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Number of canals										
1 canal	**142 (69.3)**	18 (8.8)	**127 (62.3)**	29 (14.2)	**174 (86.1)**	18 (9.0)	**122 (62.9)**	24 (12.3)	**171 (95.5)**	5 (2.8)
2 canals	**45 (21.9)**	18 (8.8)	**48 (23.5)**	29 (14.2)	10 (4.9)	**18 (9.0)**	**46 (23.7)**	24 (12.3)	2 (1.1)	**4 (2.2)**
3 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.0)**	**1 (0.6)**	**1(0.6)**
4 canals	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values

Table 5: Bilateral symmetry of mandibular teeth (anteriors and premolars) according to canal configuration

	Central		*Lateral*		*Canine*		*First premolar*		*Second premolar*	
	Symm	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*	*Symm*	*Asymm*
Vertucci types										
Type I	**142 (69.3)**	18 (8.8)	**127 (62.3)**	29 (14.2)	**174 (86.1)**	18 (8.8)	**122 (62.9)**	24 (12.4)	**171 (95.5)**	5 (2.9)
Type II	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type III	**45 (21.9)**	18 (8.8)	**46 (22.5)**	29 (14.2)	7 (3.5)	**11 (5.5)**	5 (2.6)	**14 (7.2)**	1 (0.6)	**4 (2.3)**
Type IV	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type V	0 (0.0)	0 (0.0)	1 (0.5)	**2 (1.0)**	1 (0.5)	**11 (5.5)**	**35 (18.0)**	22 (11.2)	0 (0.0)	**3 (1.8)**
Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**3 (1.5)**	0 (0.0)	**2 (1.2)**

Bold numbers refer to the more frequent values

Table 6: Bilateral symmetry of mandibular teeth (first and second molars) according to number of roots, number of canals, and canal configuration

	First molar		*Second molar*	
	Symm	*Asymm*	*Symm*	*Asymm*
Number of roots				
1 root	0 (0.0)	0 (0.0)	**1 (0.6)**	0 (0.0)
2 roots	**114 (94.2)**	1 (0.8)	**149 (96.2)**	3 (1.9)
3 roots	**6 (5.0)**	1 (0.8)	2 (1.3)	**3 (1.9)**
Number of canals				
1 canal	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
2 canals	0 (0.0)	**1 (0.8)**	6 (3.9)	**7 (4.5)**
3 canals	**73 (60.3)**	13 (10.7)	**131 (84.5)**	11 (7.0)
4 canals	**35 (28.9)**	12 (9.9)	**7 (4.5)**	4 (2.5)

	Mesial root		**Distal root**		**Mesial root**		**Distal root**	
Vertucci types	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**	**Symm**	**Asymm**
Type I	0 (0.0)	**2 (1.7)**	**77 (63.6)**	14 (11.6)	6 (3.9)	**6 (3.8)**	**147 (94.8)**	3 (1.9)
Type II	**38 (31.4)**	12 (9.9)	2 (1.7)	**2 (1.7)**	**29 (18.7)**	19 (12.2)	**1 (0.6)**	0 (0.0)
Type III	0 (0.0)	**3 (2.5)**	12 (9.9)	**18 (14.8)**	15 (9.7)	**19 (12.2)**	0 (0.0)	**2 (1.2)**
Type IV	**64 (52.9)**	12 (9.9)	**1 (0.8)**	0 (0.0)	**53 (34.2)**	19 (12.2)	0 (0.0)	0 (0.0)
Type V	**4 (3.3)**	1 (0.8)	**8 (6.6)**	8 (6.6)	12 (7.7)	**17 (10.9)**	3 (1.9)	**3 (1.9)**
Type VI	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Type VII	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Others	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Bold numbers refer to the more frequent values

canals was only 91.2% symmetrical (p <0.001) and 91.2% for Vertucci classification (p <0.001). The most frequent bilateral symmetry was one canal (69.3%) and Vertucci type I configuration (69.3%).

Lateral Incisors

Two hundred and two out of 204 (98.1% of the total sample) participants had one root on both sides. Bilateral symmetry for the number of canals was 85.8% (p <0.001). Bilateral symmetry was 85.3% for the Vertucci classification (p <0.001). The most frequent bilateral symmetry was one root (99.0%), one canal (62.3%), and Vertucci type I configuration (62.3%).

Canines

Mandibular canals were only 95.5% symmetrical between the right and left sides (p = 0.023). Bilateral symmetry for the number of canals was 91.1% (p <0.001). Total bilateral symmetry for canal configuration 90.1% (p <0.001). The most frequent bilateral symmetry was one root (95.1%), one canal (86.1%), and Vertucci type I configuration (86.1%) (Fig. 3).

First Premolars

The first premolars showed 99% symmetry between the right and left sides for the number of roots. The total bilateral symmetry for the number of canals was 87.1% (p = 0.001). The total bilateral symmetry for canal configuration was 83.5% (p <0.001). The most frequent bilateral symmetry was one root (99.0%), one canal (62.9%), and Vertucci type I configuration (62.9%).

Second Premolars

Second premolars exhibited a single root bilaterally. The number of canals showed 83.7% symmetry between the right and left sides (p <0.001). The total bilateral symmetry for canal configuration was 82.7% (p <0.001). The most frequent bilateral symmetry was one canal (95.5%) and Vertucci type I configuration (95.5%).

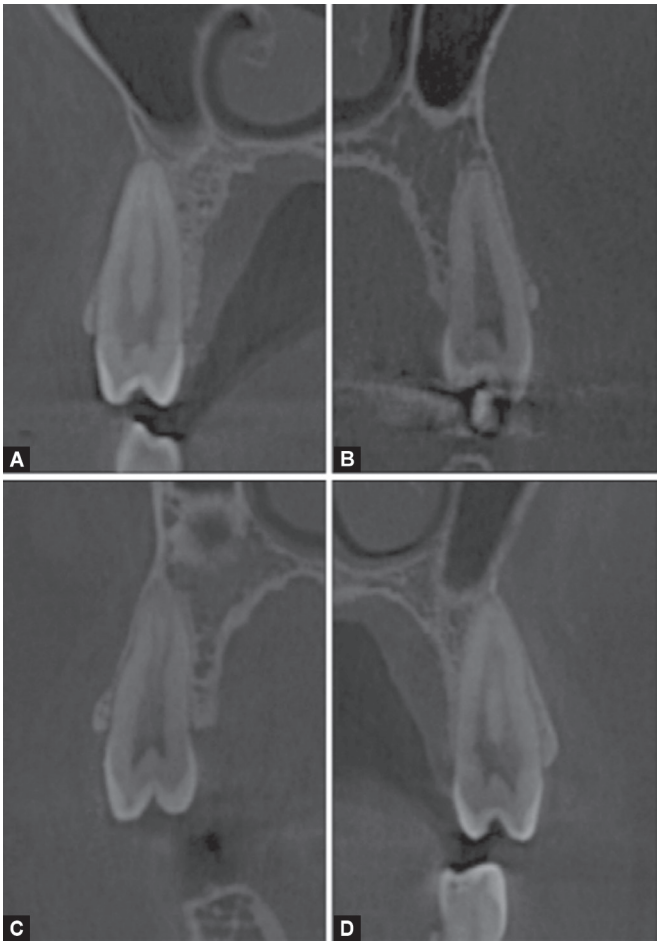
First Molars

The first molars were almost symmetrical for the number of roots between the right and left sides (99.2%, p <0.001). The total bilateral symmetry was 87.6% for Vertucci types in mesial roots (p <0.001) and 82.6% in distal roots (p <0.001). The most frequent bilateral symmetry was two roots (94.2%), three canals (60.3%), Vertucci type IV for mesial canals (62.9%), and Vertucci type I configuration for distal canals (63.6%).

Second Molars

The second molars were mostly symmetrical in the number of roots between the right and left sides (98.1%, p <0.001). The total bilateral symmetry was 92.9% for the number of canals (p <0.001). The total bilateral symmetry for Vertucci types in mesial canals was 74.2% (p <0.001) and 97.4% for distal canals (p <0.001). The most frequent bilateral symmetry was two roots (96.2%), three canals (84.5%), Vertucci type IV for mesial canals (34.2%), and Vertucci type I configuration for distal canals (94.8%).

Molars with C-shaped canal configurations: Nineteen out of 208 participants had a C-shaped configuration in their mandibular second molars. Out of them, 10 patients (4.8% of the total sample) had bilateral asymmetry of C-shaped canals.



Figs 3A to D: CBCT coronal sections of maxillary second premolars showing different canals configurations: (A and B) Contralateral premolars of the same patient; (C and D) Right and left premolars of the same patient

Discussion

Increased demand for endodontic treatment is evident in Saudi Arabia as it shows a higher caries prevalence in its neighboring countries.[28,29] With more clinicians devoted to providing quality endodontic care, it is imperative to develop a comprehensive understanding of the internal anatomy and morphology of the entire dentition. Unusual and diversified morphology presents a challenge to the clinician. The unique morphology of each root canal is considered an important factor in the successful outcome of endodontic therapy.[30] Trends in the number and morphology of roots and root canals vary with ethnicity and sex. Earlier studies have shown that clinicians can miss one or more root canals in up to 40% of the cases when solely relying on radiographs.[31] This study was designed to assess the internal morphology and symmetry of the entire dentition in a Saudi Arabian population using CBCT.

Since its introduction in dentistry, CBCT has proven to be a valuable and accurate technique for obtaining detailed data on the root canal system.[32,33] It is a noninvasive technique that provides high-resolution images comparable to histological sections with a reasonable dose of radiation exposure.[33] The images can be studied in three dimensions and rotated in any plane without superimposition or distortion of other related anatomic structures. High-resolution CBCT may be inferior to an extra-fine details micro-CT.[34,35] However, CBCT is less time-consuming and many

variables such as age, gender, and location of teeth in the jaw can be recorded for comparative studies.[36–40]

In the present study, all variables were analyzed independently from each other. Regardless of the number of roots per tooth, the number of canals and canals configurations were evaluated separately to establish a comprehensive conclusive study.

Earlier literature reveals that the maxillary premolars may have one to three roots.[41–43] A majority of the maxillary first premolar presented with two roots, suggesting that the two-root form is the main root anatomy of maxillary first premolars in a Saudi population. This is distinctly different from Chinese populations that exhibit a single-rooted maxillary first premolar.[41,44] We found that the total bilateral symmetry for canal configuration in the maxillary first premolar was 83.5 and 82.7% in the second premolar. Our findings were similar to an earlier study on a Saudi Arabian population that reported bilateral symmetries of 91.2 and 85.3% for first and second maxillary premolars, respectively.[25] A study of maxillary premolars in an Indian population reported an 81.5% symmetry of the number of roots and canals.[22]

In our study, we observed that root morphology showed greater variation in the maxillary second molars compared to the first. This result is consistent with previous studies on other ethnic populations. Studies examining maxillary molar teeth groups Indian[22] and Caucasian[23] populations showed 77.5 and 71.1% bilateral symmetry in maxillary first molar groups and 70.8 and 79.6% in second molar groups, respectively. However, the variations seen in our study in the maxillary first and second molars were lesser than obtained in the studies on Indian and Caucasian populations. This variation may be due to study design, sample size, or the method employed to identify the canals.

A study on a Chinese population revealed 95.2 and 93.8% bilateral symmetry in the number of canals in mandibular central and lateral incisors with 92.7 and 89.2% symmetry in canal configurations.[18] Kayaoglu et al. reported that in a Turkish population, the bilateral symmetry of the number of roots and number of canals for mandibular central incisors, lateral incisors, and canines groups ranged from 96–100% and 90–95%.[20] The results of both these studies closely mirror our data. We found that mandibular anterior teeth exhibit far more variation in canal anatomy than maxillary anterior teeth. Mandibular lateral incisors had a much higher incidence of double root canals in comparison to the mandibular central incisors. A CBCT study on a Chinese population with a large sample size analyzed the bilateral symmetry of mandibular anterior teeth with two canals. Zhao et al. reported the frequency to be 58.7% in central incisors, 76.1% in lateral incisors, and 29.6% in canines.[19] A similar study on a Turkish population by Kayaoglu et al. reported 45.0% for the central incisors, 29.0% for the lateral incisors, and 28.0% for the canines.[20] These findings are higher than our observations, where the frequency of bilateral symmetry of two canals was 21.9, 23.5, and 4.9% for central incisor, lateral incisor, and canine teeth groups, respectively. Al-Dahman et al. examined the symmetry of mandibular canines in a Saudi population and reported that 97.7% of the teeth showed an asymmetrical number of roots and canal configuration.[27] These results are consistent with our own. The differences observed in comparison with other studies may be due to ethnicity and population.[45]

Huang et al. examined mandibular first premolars in a Taiwanese population and found 81.3% symmetry in the root and root canal system between the right and left sides.[21] In an Indian population, Felsypremila et al. found a higher frequency of 96.1% bilateral symmetry in the number of roots and number of canals in mandibular first premolars and 98.3% mandibular second premolars groups.[22] These results of mandibular premolars are comparable to our findings.

Mashyakhy et al. studied a Saudi Arabian subpopulation to evaluate the bilateral symmetry in the mandibular first molars. They reported 100% symmetry in the number of roots and 56.4% in canals configurations, with mesial roots showing 54.1% symmetry and 47.6% in the distal roots. These results are in accord with our results concerning the number of roots (100%). However, we noted a higher frequency in symmetry of the number of canals (89.3%) and canals configurations in mesial (87.6%) and distal (82.6%) roots. Two other CBCT studies reported 78.6 and 70.6% bilateral symmetry in first molars groups, while second molars groups showed 70.8 and 81% in regard to the number of roots and root canals, respectively.[22,23] The findings of these two studies showed a lower frequency of bilateral symmetry compared to our results. A possible explanation for this could be different sample sizes, different ethnicity, and methodology used.

One interesting finding in the present study is that the maxillary and mandibular second premolar groups have similar percentages of bilateral symmetry in the number of canals. These results may be a statistical anomaly. Further studies are required to develop a fuller picture of this possible association. We found that teeth groups with a lower frequency of bilateral symmetry consequently had a higher percentage of bilateral asymmetry in morphology. These teeth groups are maxillary first premolars groups in regard to the number of roots and maxillary second premolars and second molars groups in regard to the number of canals and canals configurations.

In mandibular teeth groups, asymmetry was noticed in lateral incisors and premolars groups in the number of canals. However, the canal configurations displayed asymmetry in lateral incisors, premolars, distal roots of first molars, and mesial roots of second molars groups.

These findings are of immense clinical significance. Complete knowledge of internal root morphology and anatomy is vital for treatment success. Clinicians should be aware of possible variations while treating contralateral teeth in the same individual. To the best of our knowledge, this is the first study of its type to examine and describe the internal anatomy and symmetry of the entire dentition in a Saudi Arabian population. Further studies on specific subsets of the population could confirm and validate these findings. Future research with a larger sample size should investigate the similarity and asymmetry in canal morphology between groups of teeth and clarify the role of ethnicity.

Conclusion

This paper illustrates the various morphology of roots in a Saudi Arabian population that can guide clinicians in nonsurgical endodontic therapy. Within the limitation of the present study, we concluded that the mandibular arch showed greater asymmetry than the maxillary arch. Most groups of teeth (incisors, premolars, canines, molars) tend to have higher bilateral symmetry in the number of roots, followed by the number of canals and canals configurations. Teeth groups that are known to show asymmetry in morphology should be carefully evaluated before initiating endodontic treatment. CBCT (large field of view) could be used

to evaluate root morphology and symmetry of all groups of teeth when multiple teeth need to be treated in the same patient.

Ethics Approval and Consent to Participate

The study was approved by the Ethical Committee of College of Dentistry, Jazan University (CODJU-19722).

Authors' Contribution

MM and AA participated in the design of the study, data collection, and interpretation of the data and drafted the manuscript. All authors read and approved the final manuscript.

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