



ORIGINAL ARTICLE

Evaluation of root canal morphology of maxillary second premolars in a Saudi Arabian sub-population: An in vitro microcomputed tomography study



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KEYWORDS

Maxillary second premolars;
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Abstract *Aim:* To investigate the root canal morphology of maxillary second premolars in a Saudi Arabian subpopulation using microcomputed tomography (micro-CT).

Methodology: Micro-CT analysis was performed on 100 maxillary second premolars. The anatomy of each tooth (number of roots, canals, orifices, and apical foramina, and the presence of apical deltas and accessory canals) was analyzed from reconstructed three-dimensional images.

Results: The most common morphology was a single root (67%), followed by two roots (30%), and three roots (3%). Regarding the canal morphology, most teeth (65%) contained two canals, followed by 30% with one canal, and 5% with three canals. One orifice was observed in 55% of teeth, and two orifices were detected in 45% of teeth. According to the Vertucci classification, the most common canal types were IV and V (both found in 23% of teeth), followed by type I (17%), type III (9%), type II (7%), and type VII (2%). Additional types that were inconsistent with the Vertucci classification were recorded in 19% of teeth.

Conclusion: The root canal morphology of maxillary second premolars in the Saudi Arabian subpopulation is complex and requires cautious evaluation prior to endodontic treatment.

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1. Introduction

Teeth have highly complex internal and external anatomical variation (Vertucci, 2005; Abella et al., 2015). This variation makes it a challenge to treat maxillary second premolars endodontically (Pecora et al., 1993). Maxillary second premolars have variation in the number of roots and canals, the course and longitudinal concavity of the root, and the pulp

cavity outline, and it is difficult to determine the apical border with radiographs (Pecora et al., 1993).

In a study of North American patients, Vertucci et al. (1974) reported that 75% of maxillary second premolars exhibited one canal at the apex, with type I, II, and III canal configurations in 48%, 22%, and 5% of teeth, respectively. Two canals were present at the apex in 24% of maxillary second premolars, with type IV, V, VI, and VII configurations in 11%, 6%, 5%, and 2% of teeth, respectively (Vertucci et al., 1974). Only 1% of teeth exhibited three canals at the apex (Vertucci et al., 1974).

A Turkish study examining maxillary second premolars using light microscopy revealed a 50.64% incidence of type II to type VII (two canals) Vertucci configurations, with type I (one canal) and type VIII (three canals) configurations present in 48.66% and 0.66% of the total sample, respectively (Kartal et al., 1998). Weng et al. (2009) reported that 72.3% of maxillary second premolars possessed two canals with type II, IV, or VI canal configurations, whereas 27.7% of teeth exhibited one canal with a type I configuration. In a stereomicroscopic study of maxillary second premolars from Indian patients, Jayasimha Raj and Mylswamy (2010) found that 64.1% of the teeth sampled contained one canal at the apex; the remaining teeth (35.4%) exhibited two canals at the apex. In contrast to the previous studies, Vertucci type II canals were the most common (33.6%), followed by type IV and type I canals in 31.1% and 29.2% of the sample, respectively (Jayasimha Raj and Mylswamy, 2010). An additional canal configuration, type XIX, was found in one tooth (Jayasimha Raj and Mylswamy, 2010).

Numerous techniques have been utilized to study root canal anatomy, such as canal staining and tooth clearing (Vertucci 1984; Awawdeh et al., 2008), visual and conventional radiography (Atieh, 2008), conventional radiography (Pattanshetti et al., 2008), alternative radiographic techniques (de Oliveira et al., 2009), and modified root canal staining techniques (Weng et al., 2009). Recently, microcomputed tomography (micro-CT), a simple and noninvasive technique, has been utilized for the three-dimensional assessment of the root canal system (Rhodes et al., 1999; Plotino et al., 2006; Sberna et al., 2009; Grande et al., 2012). In contrast to the scan thickness of conventional computed tomography (1.5 mm) (Gambill et al., 1996), the scan thickness of micro-CT is substantially reduced to 12.5 μm (Bergmans et al., 2003) allowing for the production of higher quality images. Therefore, micro-CT can be useful for training purposes in preclinical endodontic courses and may also provide researchers and clinicians with an innovative method to study the root canal system (Plotino et al., 2006).

The aim of this study was to investigate the root canal morphology of maxillary second premolars in a Saudi Arabian subpopulation using micro-CT and to compare the findings with existing canal morphology classifications.

2. Materials and methods

2.1. Ethical approval

Ethical approval for this study was obtained from the Ethical Committee, University of Dammam, Saudi Arabia.

2.2. Inclusion criteria

Saudi Arabian patients were randomly selected for inclusion in the study, without regard to sex or age, from dental practices across the Eastern province of Saudi Arabia. The patients underwent tooth extraction for orthodontic or periodontal reasons. A total of 100 maxillary second premolars, with intact clinical crowns and fully developed apices, were collected and stored in 10% formalin. Before examining the teeth, the adherent tissues were removed with a dental scalar, and the teeth were washed under running water. The teeth were carefully evaluated under a surgical microscope and in radiographs. Any tooth with caries lesion, previously restored, a fracture, calcification, or resorption that did not meet the inclusion criteria was excluded.

2.3. Scanning

All teeth were scanned using a SkyScan 1172 X-ray micro-CT scanner (Bruker Corp., Antwerp, Belgium). The roots of the maxillary second premolars were mounted in sticky wax and then placed vertically on the scanning platform. The scanning procedure was performed using a sealed X-ray tube operated at 90 kV and 112 μA . The scanning duration for each specimen varied between 30 and 40 min. The transmission X-ray images were set for 360° rotation with a camera pixel size of 27.4 μm . After scanning the specimens, they were reimmersed in formalin solution to preserve them for further study.

2.4. Evaluation

The specimens were evaluated using SkyScan CT-Volume v2.2 software (Bruker Corp., Antwerp, Belgium). A single observer analyzed the reconstructed three-dimensional images obtained from the software and recorded the following: the number of roots, existing canals, root canal orifices, and apical foramina (i.e., the circumference or rounded edge, which is funnel-like or crater-like, that differentiates the termination of the cemental canal from the exterior surface of the root) (Vertucci, 2005). In addition, the observer noted the presence of apical deltas (complex ramification of pulp canal branches located near the anatomical apex, with an indiscernible main canal) and accessory canals (branches of the main pulp canal or chamber that communicate with the external root surface) (Vertucci, 2005). Canal configurations were categorized based on Vertucci's classification (1974), and any canals that were inconsistent with this classification were grouped separately as "additional canal configurations."

3. Results

This evaluation of maxillary second premolar root morphology and canal systems revealed that 67% of teeth possessed a single root, 30% had two roots, and 3% had three roots. The majority of teeth had two canals (65%), followed by 30% with one canal, and 5% with three canals. The distribution of canal configuration types in maxillary second premolars is presented in Table 1. The representative images showed complexity of different morphological patterns and canal configurations showed in Figs. 1 and 2. Tables 2 and 3 present comparisons of the number of roots and canals in maxillary second premolars between the current and previous studies.

Table 1 Distribution of morphologic configurations in the root canal system of maxillary second premolars.

Type of canal	Canal pattern	Percentage (%)
Type I	1-1	17
Type II	2-1	7
Type III	1-2-1	9
Type IV	2	23
Type V	1-2	23
Type VI	2-1-2	-
Type VII	1-2-1-2	2
Type VIII	3	-
Additional type	1-3	3
Additional type	1-4	1
Additional type	2-1-2-1	1
Additional type	1-2-3	2
Additional type	3-2	2
Additional type	2-3	4
Additional type	2-4	1
Additional type	1-2-1-3	1
Additional type	2-3-2-3	1
Additional type	1-2-4	2
Additional type	1-2-5	1

3.1. Number of root canal orifices, apical foramina, and apical deltas

One canal orifice was observed in 55% of teeth, and the remaining 45% of teeth exhibited two canal orifices. The frequency of apical foramina was variable, with a single apical foramen detected in 34% of teeth, two apical foramina in 50%, three in 11%, four in 4%, and five apical foramina in 1% of teeth. An apical delta was only observed in 7% of teeth.

3.2. Accessory canals, intercanal communications, and isthmuses

Accessory canals were present in 8% of teeth; 3% were located in the bifurcation (Fig. 3a), 3% were in the middle third (Fig. 3b), and 2% were in the apical third of the root. Intercanal communications were present in 8% of teeth; the majority were located in the middle third (6%), followed by 1% in the coronal, and 1% in the apical third of the root (Fig. 3c-e). Isthmuses were detected only in the middle (1%) and coronal third (1%).

4. Discussion

This study investigated the root canal morphology of maxillary second premolars in a Saudi Arabian population. Previous studies on maxillary second premolars have reported varia-

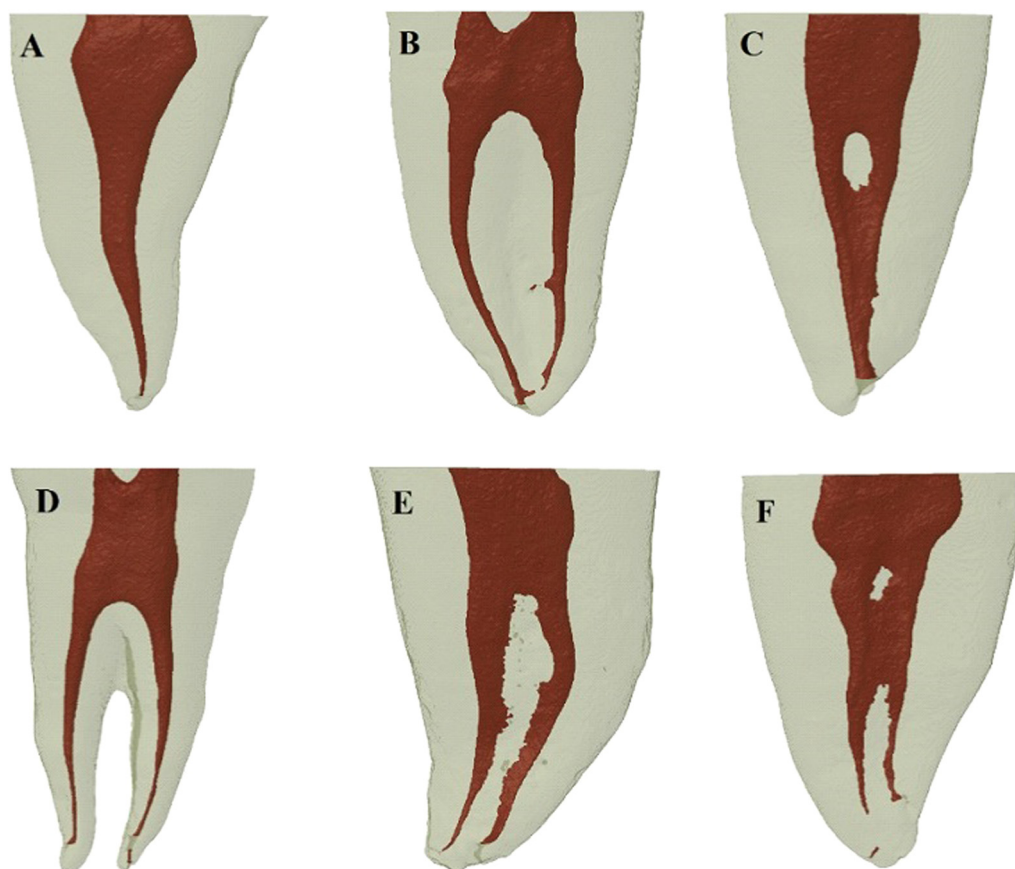


Figure 1 Morphologic patterns of root canal systems in maxillary second premolars. (A) Vertucci type I. (B) Vertucci type II (2-1 configuration). (C) Vertucci type III (1-2-1 configuration). (D) Vertucci type IV (2-2 configuration). (E) Vertucci type V (1-2 configuration). (F) Vertucci type VII (1-2-1-2 configuration).

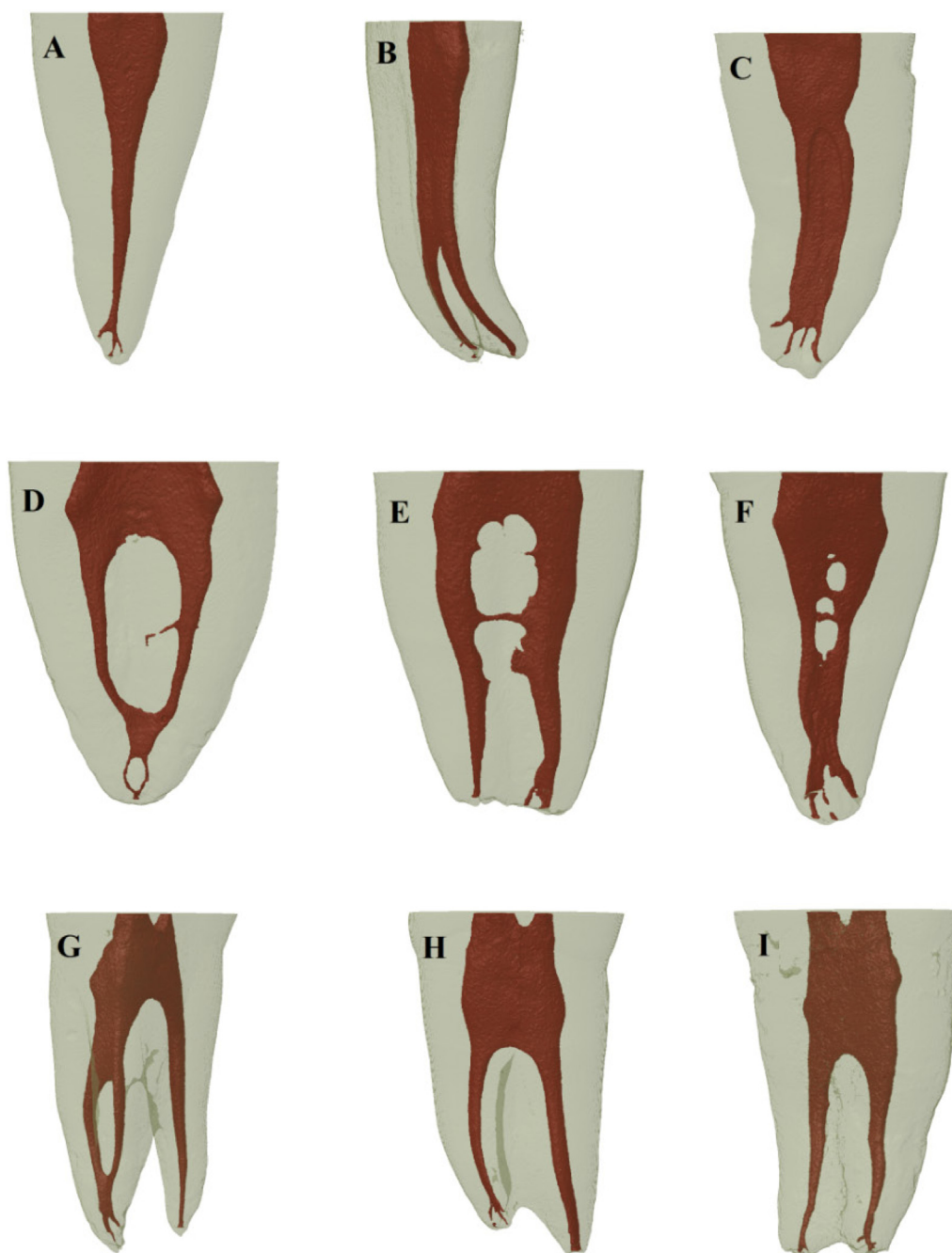


Figure 2 Additional canal configurations. (A) 1–3 configuration. (B) 1–2–3 configuration. (C) 1–4 configuration. (D) 2–1–2–1 configuration. (E) 2–3 configuration. (F) 1–2–1–3 configuration. (G) 2–3–2–3 configuration. (H) 2–4 configuration. (I) 2–5 configuration.

tions in the numbers and patterns of roots and canals. In 1993, Pecora et al. found that 90.3% of maxillary second premolars ($n = 435$) exhibited single roots, whereas 9.7% possessed two roots. This result differs from our finding that 67% of teeth have one root, and 30% have two roots.

According to previous studies, the frequency of a single canal in maxillary second premolars varies between 27.70% and 48.66%, and the occurrence of two canals varies between 50.64% and 72.30% (Kartal et al., 1998; Weng et al., 2009). Other studies reported a high incidence (64.1% and 67.3%) of single canals at the apex of maxillary second premolars

and a relatively lower incidence (35.4% and 32.4%) of two canals in this region (Jayasimha Raj and Mylswamy, 2010; Pecora et al., 1993). In 2012, Al-nazhan et al. found that 59.4% of maxillary second premolars had two root canals, and this result is slightly lower than the present study (65%). Our results were in agreement with a previous study showing that 64% of maxillary second premolars contained two canals (Elkady and Allouba, 2013).

A number of studies have reported on the absence or presence of three canals in maxillary second premolars, with incidences ranging from 0% to 2% of teeth (Vertucci et al.,

Table 2 Comparison of maxillary second premolar roots between studies.

Study	Technique	Patient nationality (sample size)	One root (%)	Two roots (%)	Three roots (%)
Pecora et al. (1993)	Clearing	Brazilian (<i>n</i> = 435)	90.3	9.7	-
Kartal et al. (1998)	Clearing	Turkish (<i>n</i> = 300)	69.6	29.7	0.7
Yang et al. (2014)	CBCT	Chinese (<i>n</i> = 392)	86.5	13.5	-
Abella et al. (2015)	CBCT	Spanish (<i>n</i> = 374)	82.9	15.5	1.6
Present study	Micro-CT	Saudi Arabian (<i>n</i> = 100)	67	30	3

CBCT: Cone beam computed tomography; CT: Computerized tomography.

Table 3 Comparison of maxillary second premolar canals between studies.

Study	Technique	Patient nationality (sample size)	One canal (%)	Two canals (%)	Three canals (%)
Pecora et al. (1993)	Clearing	Brazilian (<i>n</i> = 300)	67.3	32.4	0.3
Kartal et al. (1998)	Clearing	Turkish (<i>n</i> = 300)	48.66	50.64	0.66
Weng et al. (2009)	Modified root canal staining	Chinese (<i>n</i> = 65)	27.7	72.3	-
Jayasimha Raj and Mylswamy (2010)	Staining and clearing	Indian (<i>n</i> = 200)	64.1	35.4	0.5
Al-Nazhan et al. (2012)	Periapical Radiograph	Saudi Arabian (<i>n</i> = 431)	39.7	59.4	0.9
Elkady and Allouba, 2013	CBCT	Saudi Arabian (<i>n</i> = 110)	36.3	63.7	-
Yang et al. (2014)	CBCT	Chinese (<i>n</i> = 374)	39.3	59.1	1.6
Abella et al. (2015)	CBCT	Spanish (<i>n</i> = 392)	45.4	54.3	0.3
Present study	Micro-CT	Saudi Arabian (<i>n</i> = 100)	30	65	5

CBCT: Cone beam computed tomography; CT: Computerized tomography.



Figure 3 Accessory canals located in the (a) bifurcation and (b) middle third of the root. Intercanal communication in the (c) coronal (d) middle, and (e) apical third of the root.

1974; Pecora et al., 1993; Weng et al., 2009; Jayasimha Raj and Mylswamy, 2010). In the present study, three canals were observed in 5% of the total sample, which is a higher frequency than that reported in previous studies. This difference may be attributed to the application of micro-CT

in this study because it is a more advanced technique for specimen analysis than tooth clearing and staining techniques, which were used in previous studies (Vertucci et al., 1974; Pecora et al., 1993; Weng et al., 2009; Jayasimha Raj and Mylswamy, 2010).

The most common canal configuration observed in this study was type V, occurring in 29% of maxillary second premolars, followed by types IV, I, III, and II (23%, 21%, 9%, and 6%, respectively). Tables 2 and 3 present comparisons of the numbers of roots and canals in maxillary second premolars between different studies. Discrepancies in these findings may be explained by the differences in sample size, ethnic population, and analysis technique among the different studies.

In the present study, one canal orifice was recorded in 55% of teeth, and two canal orifices were observed in 45% of teeth. An isthmus, which is a narrow ribbon-shaped communication between two root canals that may contain pulp or necrotic tissues, was only found in 2% of teeth. This result is low compared to previous studies, which have reported the incidence of isthmuses to vary between 19% and 65% (Vertucci, 2005; Weng et al., 2009; Jayasimha Raj and Mylswamy, 2010). An isthmus may affect the success rate of endodontic treatment because it is generally difficult to clean during root canal treatment, and it can act as a reservoir for microorganisms (Burlleson et al., 2007).

Apical deltas were observed in 7% of teeth in this study. This result is comparable to the findings of Kartal et al. (1998) and Jayasimha Raj and Mylswamy (2010); however, it is lower than that reported by other studies (Sert and Bayirli, 2004; Vertucci, 2005; Weng et al., 2009). For example, Weng et al. reported apical deltas in 43% of second premolars (Weng et al., 2009). Similar to isthmuses, the apical delta region is another important consideration during root resection and endodontic surgery because it can harbor microorganisms (Leonardo et al., 1994).

Intercanal communication was observed in 8% of teeth, with the highest incidence recorded in the middle third, followed by the coronal and apical thirds.

5. Conclusions

There was a high occurrence of single roots and two canals among the evaluated maxillary second premolars. The root canal morphology of maxillary second premolars in Saudi Arabian patients is complex and variable. Additional types of canal configurations that were inconsistent with the Vertucci classification were recorded in 19% of teeth. Therefore, the external and internal morphology of maxillary second premolars requires cautious evaluation prior to endodontic treatment.

Ethical statement

The authors confirm that this study has been conducted with the ethical approval of all relevant bodies and approvals are acknowledged within the manuscript.

Conflict of interest

None declared.

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