

## Article

# A Microcomputed Tomographic Evaluation of Root Canal Morphology of Maxillary Second Premolars in a Pakistani Cohort

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**Abstract:** This study aimed to investigate variations in the root canal morphology of maxillary second premolar (MSP) teeth using microcomputed tomography (micro-CT). Sixty (N = 60) human extracted MSPs were collected and prepared for micro-CT scanning. The duration for scanning a single sample ranged between 30 and 40 min and a three-dimensional (3-D) image was obtained for all the MSPs. The images were evaluated by a single observer who recorded the canal morphology type, number of roots, canal orifices, apical foramina(s), apical delta(s), and accessory canals. The root canal configuration was categorized in agreement with Vertucci's classification, and any configuration not in agreement with Vertucci's classification was reported as an "additional canal configuration". Descriptive statistics (such as mean percentages) were calculated using SPSS software. The most common types agreeing with Vertucci's classification (in order of highest to lowest incidence) were types I, III, V, VII, II, and VI. The teeth also exhibited four additional configurations that were different from Vertucci's classification: types 2-3, 1-2-3, 2-1-2-1, and 1-2-1-3. A single root was found in 96.7% and the majority of the samples demonstrated two canals (73.3%). Further, 80% of the teeth showed one canal orifice. The number of apical foramina's in the teeth was variable, with 56.7% having solitary apical foramen. The accessory canal was found in 33.3%, and apical delta was found in only 20% of the samples. Variable morphology of the MSPs was detected in our study. The canal configuration most prevalent was type 1; however, the results also revealed some additional canal types.

**Keywords:** root canal; maxillary second premolar; micro-CT; tomography; dentistry

## 1. Introduction

Dental caries is a multifactorial disease that initiates with demineralization of the teeth [1]. Untreated caries progress to involve the pulp [2], a condition that requires root canal treatment (RCT). The outcome of a successful RCT depends on knowledge of the morphology of a tooth, which can affect cleaning, shaping, and obturation of the root canals

in three-dimension (3-D) [3]. The incapability to detect, debride, and shape root canals is one of the most common reasons for the failure of endodontic treatment [4]. The occurrence of anatomic deviations in the root canal morphology offers a significant challenge to dental practitioners [5]. Improper endodontic treatment eventually gives space to microorganisms that can enter the canal and cause endodontic failure [6]. Henceforth, appropriate skills are required to properly treat teeth with complex root canal systems [7]. Researchers have used various techniques to observe the inner and outer anatomy of the tooth, such as conventional radiographs, modified radiographic techniques, cone beam computed tomography (CBCT), and microcomputed tomography (micro-CT) [8]. Among these techniques, the use of micro-CT to study the tooth morphology gives high-quality details in 3-D and can be used for quantitative as well as qualitative analysis (3). Additionally, scan thickness of micro-CT is less than computed tomography (CT); therefore, it could produce high-definition (HD) images with minimum destruction of the samples [9].

The morphology of the root canal could be different in people with different racial backgrounds [9]. The knowledge obtained from various racial regions could help in locating and negotiating root canals in an ideal way [3]. The maxillary second premolar (MSP) is one of the most challenging teeth for endodontic treatment as it has shown significant variations in its root canal configuration, as shown in previous studies [5,10,11]. This tooth usually presents with one or two root canals, but occasionally, a third canal is also found [12]. However, the majority of the studies in the literature have reported a higher incidence of two root canals [13,14]. The MSPs mostly have a single root; however, two roots and three roots are also observed. Maxillary premolars (first or second) having three roots are regarded as “ridiculous premolars” or “small molars” [15,16]. Concerning the root canal configuration of MSPs, its incidence varies among different populations. An earlier study from Turkey [17] reported Vertucci’s type-I canal configuration [18] to be most prevalent in MSPs as it was found in 77.6% of the teeth. Another study reported type-II Vertucci’s canal configuration to be most commonly found in their study (present in 43.3% MSPs) [19]. It should also be noted that MSPs also present with dilacerated canals (merged or independent) [20]. Therefore, in the light of the abovementioned evidence, it can be said that MSPs pose anatomical challenges in root canal navigation and treatment. Knowledge on MSP anatomy could prove to be valuable, as it would aid dental practitioners in performing successful endodontic treatments, reducing the incidence of endodontic failures.

There is a deficit of studies in the literature from Pakistan that have studied the morphology of MSPs root canals. Three previous studies that were reported from this region studying the morphology of the same tooth have used clinical examination aided by conventional radiography and CBCT [14,21,22]. To the best of our understanding, no studies in the literature from this region exist that have utilized micro-CT to appraise the root canal morphology of MSPs. Therefore, the current study was aimed at evaluating the morphology of the MSPs root canal and to compare it with an already established root canal morphology classification system.

## 2. Materials and Methods

The study was conducted after obtaining approval from the ethics committee of the institute. Our study followed all the ethical etiquettes outlined in the Helsinki declaration (1964) and its later revisions.

### 2.1. Collection of Teeth and Inclusion Criteria

Sixty permanent MSPs (N = 60) from a subpopulation of Pakistan that were extracted for orthodontic reasons were collected. The teeth were collected from general dental practices in the city of Peshawar, Pakistan. These teeth were collected irrespective of any age or gender predilection. Teeth with fully developed clinical crowns and completely formed root apices were included in the study. In addition, teeth that had caries, restorations, and other observable defects were excluded from this study.

## 2.2. Preparation of Teeth and Initial Radiographic Scanning

The extracted teeth were cleaned of any debris or soft tissues with an ultrasonic scaler (Superior Instruments Co., New York, NY, USA). The teeth were kept in 500 mL of distilled water contained in glass beakers and were used within 30 days post-storage. The distilled water was replenished in the beakers every day. All the teeth were initially evaluated using periapical radiography. Teeth exhibiting resorption, fractures, and/or calcification were omitted from this study.

## 2.3. Micro-CT Scanning

The teeth were positioned perpendicularly on the scanning platform after mounting the roots in sticky Wax. A sealed X-ray tube operated at 90 kV, and 112  $\mu$ A was used for the scanning procedure. The duration for scanning a single sample ranged between 30 and 40 min. The transmission X-ray images were set for 360° rotation with a camera pixel size of 27.4  $\mu$ m. The teeth were stored in distilled water again once the scanning was complete to facilitate a re-scan (in case the scan was not appropriate). All tooth samples were analyzed using a SkyScan 1172 X-ray micro-CT scanner (Bruker Corp., Antwerp, Belgium).

## 2.4. Evaluation

A 3-D image was obtained for all the scanned MSPs with SkyScan CT-Volume v2.2 software (Bruker Corp., Antwerp, Belgium). The images were evaluated by a single observer (trained endodontist) who recorded the number of roots, canals, orifices, and apical foramina(s). Furthermore, the images were observed for the incidence of apical deltas and accessory canals. The root canal configuration was categorized in agreement with Vertucci's classification (1974) [18], and any configuration that was not previously included in Vertucci's classification was reported as an "additional canal configuration".

## 2.5. Statistical Analysis

As our study was only designed to observe the morphology of the MSPs root canal, descriptive statistics (such as mean percentages) were calculated using SPSS software (version 20.0, IBM, Chicago, IL, USA). Vertucci's classification [18] was considered a gold standard for comparison.

## 3. Results

### 3.1. Number of Roots and Canals

The micro-CT assessment of the root canal morphology and canal systems of MSPs revealed that 96.7% of teeth had a single root, 3.3% were two-rooted, and no tooth had three roots. Additionally, 73.3% teeth had two root canals, while 26.7% had one canal. In our study, no MSP tooth had the third root or possessed a third canal.

### 3.2. Canal Configuration Types

The canal configuration types observed in our study are presented in Table 1. Comparing our results with Vertucci's classification, type-I was most frequently detected (26.7%) shadowed closely by type-III (23.4%). The lowest percentage (3.3%) of canal type was observed for types-II, IV, and VI, whereas no type-VIII canals were found. Among the additional canals appreciated in our study, the most common had pattern 1-2-1-3 (6.7%) followed equally by patterns 2-3, 1-2-3, and 2-1-2-1 (Table 1). The representative micro-CT images (that were in line with Vertucci's classification) showed the variation in different morphological patterns and canal configurations observed for MSPs in the present study are demonstrated in Figures 1–7. The representative micro-CT images that represented additional canal configurations are presented in Figures 8–11.

**Table 1.** Distribution of the canal configuration of MSPs observed in the study.

Vertucci's Canal Type	Pattern	Percentage %
I	1-1	26.7
II	2-1	3.3
III	1-2-1	23.4
IV	2-2	3.3
V	1-2	16.7
VI	2-1-2	3.3
VII	1-2-1-2	6.7
VIII	3-3	0
Additional	2-3	3.3
Additional	1-2-3	3.3
Additional	2-1-2-1	3.3
Additional	1-2-1-3	6.7

**Figure 1.** Micro-CT image showing Vertucci's type I (1-1) canal configuration.**Figure 2.** Micro-CT image showing Vertucci's type II (2-1) canal configuration.



**Figure 3.** Micro-CT image showing Vertucci's type III (1-2-1) canal configuration.



**Figure 4.** Micro-CT image showing Vertucci's type IV (2-2) canal configuration.



**Figure 5.** Micro-CT image showing Vertucci's type V (1-2) canal configuration.



Figure 6. Micro-CT image showing Vertucci's type VI (2-1-2) canal configuration.



Figure 7. Micro-CT image showing Vertucci's type VII (1-2-1-2) canal configuration.

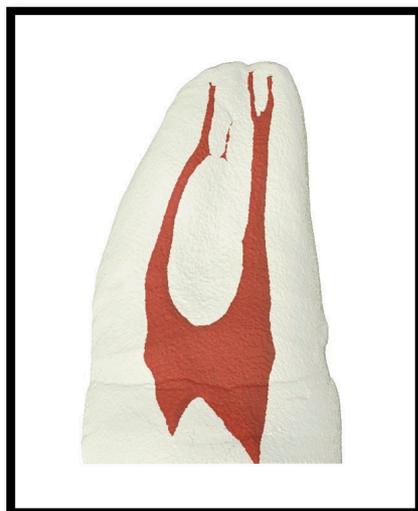


Figure 8. Micro-CT image showing the additional canal configuration (2-3).



Figure 9. Micro-CT image showing the additional canal configuration (1-2-3).



Figure 10. Micro-CT image showing the additional canal configuration (2-1-2-1).



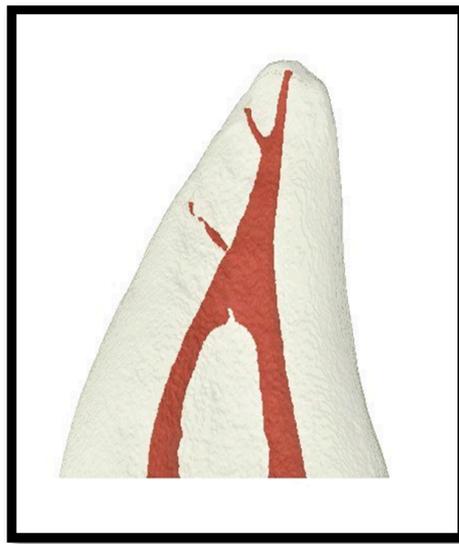
Figure 11. Micro-CT image showing the additional canal configuration (1-2-1-3).

### 3.3. Root Canal Orifices, Apical Foramina, and Apical Deltas

Single canal orifice was witnessed in 80% of the teeth, whereas 20% of the teeth revealed two canal orifices. The apical foramina's incidence was inconsistent, with a single apical foramen perceived in 56.7% of teeth, two apical foramina's found in 30%, and three apical foramina's were seen in 13.3% of the teeth. The apical delta was only appreciated in 20% of the teeth.

### 3.4. Accessory Canals and Isthmuses

The accessory canals were found in 33.3% of teeth, 30% were located in the apical third (Figure 12), and 3.3% were located in the middle third of the roots (Figure 13). Isthmuses were noticed in the middle third (6.7%) (Figure 14) and coronal third (6.7%) of the teeth (Figure 15).



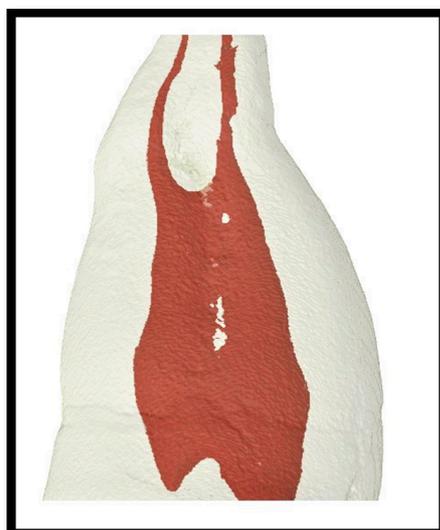
**Figure 12.** Micro-CT image showing the apical third location of the accessory canal.



**Figure 13.** Micro-CT image showing the middle third location of the accessory canal.



**Figure 14.** Micro-CT image showing the middle third location of the isthmus.



**Figure 15.** Micro-CT image showing the coronal third location of the isthmus.

#### 4. Discussion

The results of our study revealed many canal types in conformity with Vertucci's classification, while some additional canal types were also detected. Thorough awareness of the root canal system and its anatomic deviations is mandatory for a positive endodontic treatment. This study determined the root canal morphology of MSPs in a Pakistani subpopulation. Previously, MSPs internal configuration has been testified to be highly variable [23–27]. According to a study by Pecora et al., single-rooted MSPs were found in 93% of the study sample, while the remaining study sample had two roots [28]. Another study on MSPs in China reported single roots in 92.5% of the samples while the remaining 7.5% of teeth had two roots, and no three-rooted MSPs were found in that study [19]. The outcomes of our study are in harmony with these former studies as 96.7% of MSPs had a single root whereas the remaining 3.3% had two roots. Additionally, no three-rooted MSP were found in our study.

The canal numbers reported in the literature are variable for MSPs and various studies have reported different frequencies of the canals. Kartal et al. and Weng et al. found a single canal in 27.7% and 48.66% of the samples, respectively, while 72.3% and 50.64% of the remaining samples had two canals, respectively [29,30]. In our study, 73.3% of the samples had two canals while the remaining teeth had one canal. This finding is in accordance with these previous studies.

Canal configurations are also different, as reported by studies from other parts of the world. In a Saudi population, the canal configuration of type V was most predominant in MSPs, trailed by types IV, I, III, and II [9]. From Pakistan, a previous CBCT study reported that type I was the commonest root canal configuration, shadowed by type II [22]. In another study, about 39.93% of MSPs in a Spanish population had type I canal configuration trailed by type IV [31]. A previous study on the Turkish population also found the type I canal configuration to be most prevailing in MSPs [17]. In our study, the canal configuration of type 1 was most rampant, and this finding is in agreement with the outcomes of Bulut et al. [17], Nazeer et al. [22], and Abella et al. [31].

An accessory canal is a term used for small canals, which are found few millimeters apically [9]. It is believed that they are developed from breakage of the Hertwig epithelial root sheath (HERS), or during development, HERS grows around the prevailing blood vessels [32]. The number of accessory canals could be different, and their incidence does not follow a specific ethnicity pattern. In a previous similar study from Saudi Arabia, the incidence of accessory canals was 8% [9]. In contrast, our study revealed that 33.3% of the teeth had accessory root canals.

An isthmus is an intercanal connection or crosswise anastomosis, which is a narrow ribbon-shaped communication containing pulp or pulpal derivative tissue between two root canals [3]. Its importance lies in the fact that it can act as a reservoir for bacteria, and roots that have two or more canals are highly likely to have an isthmus [23]. Our results showed that 13.3% of the samples had isthmuses, which is higher than 2%, reported in a study from Saudi Arabia [9]. On the other hand, it was lower than that reported by other studies conducted by Jayasimha et al. [23], Sert and Bayirli [24], and Vertucci et al. [18], reporting isthmuses in 19%, 20.5%, and 30.8% of the samples, respectively.

Apical delta is another important measure for successful endodontic treatment because of its ability to harbor microorganisms and difficulty getting debrided [23]. Our results revealed a higher number of apical delta (20%) compared to the study conducted by Elnour et al., who reported it to be 7% [9]. In an earlier study, Caliskan et al. reported an apical delta prevalence of 26% in the MSPs in a Turkish population, and our findings are almost similar to their results [33]. These variations between different studies support the fact that MSPs internal and external morphology varies according to various attributes, such as age, gender, sample sizes, racial, ethnicity, and genetic factors [34].

Multiple approaches have been suggested to report the root canal morphology in the literature comprehensively. One of them is the classification proposed by Sert and Bayirli [24], which proposed 14 supplemental types of root canal configuration in addition to Vertucci's classification. However, no classification can accurately describe the root canal configuration of the teeth despite the systematic efforts of researchers due to its complexity. More recently, a classification by Ahmed et al. has been proposed to simplify the reported information related to roots and root canal morphology [35]. In this classification, instead of using Roman numbers (types), the authors have suggested using a code based on the number of roots, number of orifices, and root canal morphology. Therefore, according to this classification [35], our study showed the following morphological prevalence in the MSPs:  $^1\text{MSPs}^1$  (26.7%),  $^1\text{MSP}^{1-2-1}$  (23.4%),  $^1\text{MSP}^{1-2}$  (16.7%),  $^1\text{MSP}^{1-2-1-2}$  (6.7%),  $^1\text{MSP}^{1-2-1-3}$  (6.7%),  $^1\text{MSP}^{2-1}$  (3.3%),  $^1\text{MSP}^2$  (3.3%),  $^1\text{MSP}^{2-1-2}$  (3.3%),  $^1\text{MSP}^{2-3}$  (3.3%),  $^1\text{MSP}^{1-2-3}$  (3.3%), and  $^1\text{MSP}^{2-1-2-1}$  (3.3%) (*a numeric superscript before the MSP indicates the number of roots whereas, superscripted numbers after MSP represent the number of orifices, canals, and foraminas*). However, the Vertucci classification was preferred in the present study as it has been used in multiple previous studies [3,5,6,9,11,13,14], allowing a direct comparison to be made with other studies. Nevertheless, it is worth mentioning that the classification proposed by Ahmed et al. [35] is a viable attempt to simplify the reporting of root canal morphology, and researchers are encouraged to use it in for comparisons in future studies.

The main limitation of our study was its sample size. However, collecting sound MSPs that are extracted for orthodontic reasons is challenging. Our study can provide a baseline to understand root canal morphology in this subpopulation from Pakistan. Prospective

studies with a bigger sample size are recommended to create a clear image of the variations of root canal morphology in MSPs from the same subpopulation.

## 5. Conclusions

In conclusion, 96.7% of MSPs had a single root and 73.3% had two canals. The predominant canal configuration was type 1 (26.7%) followed by type III (23.4%). A variable morphology of the MSPs was detected with a high incidence of different root canal systems. Clinicians should be mindful of differences in the root canal morphology of MSPs and should give weightage to the patient's ethnic origin while planning appropriate root treatment.

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**Institutional Review Board Statement:** The study was conducted after obtaining approval from the ethics committee of the Gandhara University, Peshawar Pakistan, with approval number, EA-2019021. Our study followed all the ethical etiquettes outlined in the Helsinki declaration (1964) and its later revisions.

**Informed Consent Statement:** All participants consented for the use of their extracted teeth due to orthodontics reasons to be used in the study.

**Data Availability Statement:** The data of the study presented is available from the authors of the article on individual request.

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