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ORIGINAL ARTICLE

Three-rooted maxillary first premolars incidentally detected on cone beam CT: an in vivo study

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Abstract

Purpose To explore the incidence and analyze the morphology of three-rooted maxillary first premolars (MFPs) incidentally detected on cone beam computed tomography (CBCT) scans.

Methods Of 1328 patients who underwent CBCT scans of the maxilla, only patients with three-rooted MFPs were selected. Morphological features, including the lengths and diameters of palatal, mesiobuccal (MB) and distobuccal (DB) roots, the positions of bucco-palatal (B-P) bifurcations, the distances between root canal bifurcations and cementoenamel junctions (CEJs) and the distances between the apical thirds of the roots, were measured. The canal configuration and the visibility of root canals were also evaluated.

Results A total of 16/1328 (1.2%) patients had one or two three-rooted MFPs, and a total of 22/2656 (0.8%) three-rooted MFPs were enrolled. The lengths and diameters of palatal roots were significantly greater than those of other roots. The positions of B-P bifurcations were located mainly at the middle third of the root. The median distances between root canal bifurcations and CEJs were 3 mm for B-P bifurcations and 5.2 mm for MB–DB bifurcations. The distance between MB and DB roots was significantly shorter than the distances between other root pairs. All teeth had a type VIII canal configuration. Palatal roots exhibited the best visibility of root canals, whereas the worst visibility was observed within DB roots. A gender-related relationship was observed only for the lengths of the roots.

Conclusions The occurrence of three-rooted MFPs is not unusual; therefore, preoperative CBCT evaluation could be suggested whenever endodontic procedures are planned on an MFP.

Keywords Bicuspid · Tooth root · Anatomic variation · Cone-beam computed tomography

Introduction

The maxillary first premolar (MFP) is one of the most difficult teeth to treat endodontically because of anatomic variability in its root morphology. Therefore, an adequate knowledge of the complexity of root morphology is critical to ensure proper treatment and avoid complications.

Most MFPs have two separate roots with two root canals [2]; however, in some cases, their root anatomy is complex due to variation in canal configuration and the number of roots. The occurrence of MFPs with three roots is the most common anatomic variation, with a reported incidence ranging from 0.4 to 9.2% [2, 6, 11].

In clinical practice, periapical radiography is commonly used to assess radicular anatomy in the diagnosis and treatment of endodontic disease. However, this radiographic technique provides a two-dimensional view of a three-dimensional structure with magnification, geometric distortion, and overlapping with adjacent anatomic structures. In fact, in a previous ex vivo study, Matherne et al. [13] found that radiography failed to identify at least one root canal in 40% of teeth. Thus, to overcome the limitations of radiography, a three-dimensional imaging modality is required to provide a more detailed assessment of root morphology.

Two main CT techniques are used in the literature to evaluate the morphology of three-rooted MFPs: high-resolution computed tomography (μCT) and cone beam computed

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tomography (CBCT) [4, 7, 12, 19]. Both of these CT modalities provide a non-invasive three-dimensional view of the tooth and are considered adequate for anatomical analysis of root morphology.

The main advantage that makes µCT a particularly attractive technique for evaluating root morphology is that its spatial resolution is higher than that achieved by CBCT (voxel sizes of approximately 30–40 µm for µCT vs. 150–200 µm for CBCT) [14, 19]. Conversely, the main disadvantage of µCT compared with CBCT scans is its high radiation dose, which makes it less suitable for clinical use [12]. Therefore, we consider CBCT to be the best non-invasive technique for assessing root morphology during routine clinical practice due to its high spatial resolution and low radiation dose delivered to patients.

Few anatomical studies have explored three-rooted MFPs, and the available literature is limited to the presentation of analyses of extracted teeth performed using µCT or CBCT [4, 7, 12, 19]. Thus, to the best of our knowledge, no published studies have evaluated the anatomy of MFPs with three distinct roots using CBCT in living subjects.

Therefore, in this study, we aimed to investigate the incidence and analyze the morphology of three-rooted MFPs incidentally detected on routine CBCT scans in a sample of European (Italian) patients.

Materials and methods

Patient selection

From January 2012 to July 2018, 1387 patients were referred to our radiology department to undergo a CBCT scan of the maxilla as part of a routine dental examination. A total of 59/1387 patients, in whom one or both MFPs were missing, were excluded because only patients with both MFPs were considered in the study. In the final group of 1328 patients, a retrospective search was performed in the department RIS/PACS to retrieve all CBCT reports containing findings indicative of three-rooted MFP. The images contained in these CBCT reports were reviewed by an experienced radiologist (A.B., who has more than 10 years of experience in dental imaging and 6 years of experience in using CBCT), and only those patients with one or two MFPs with three distinct roots were enrolled in the study.

Image acquisition

All examinations were performed with a CBCT scanner (NewTom 5G®, QR, Verona, Italy) at a tube voltage of 110 kVp; exposure time and mA were variable and based on the selected FOV (12 × 8 or 15 × 12 cm). The acquisition volume was reconstructed as axial sections with an isotropic voxel size of 200 µm. In addition, the high-resolution dataset produced by CBCT was further processed in multiplanar (MPR) images that were either parallel (panoramic) or perpendicular (cross-sectional) to the curvature of the superior dental arch.

Image analysis

Image analysis was performed using advanced and interactive MPR software (CT Viewer application; Philips IntelliSpace Portal) by the same experienced radiologist (A.B.).

The following parameters were measured on CBCT images:

- The length of the palatal root from the bucco-palatal (B-P) bifurcation.
- The length of the mesiobuccal (MB) and distobuccal (DB) roots from their bifurcation.
- The maximum diameter of the palatal, MB and DB roots at their cervical thirds.
- The position of the B-P bifurcation.
- The distances between the bifurcation of the B-P and MB–DB root canals and the cementoenamel junction (CEJ).
- The distances between palatal, MB and DB roots at their apical thirds.

The internal root canal configuration (defined using Vertucci's criteria) [18] and the visibility of palatal, MB and DB root canals at their cervical, middle and apical thirds were also evaluated (Fig. 1).

This was a retrospective analysis, and it did not alter the management of the patients; thus, no specific consent was required. However, informed consent for the use of personal data was obtained from all patients.

Statistical analysis

The data are presented as the number (%) or the mean ± standard deviation for normally distributed data or as the median and the interquartile range (IQR) for non-normally distributed data. One-way ANOVA was used to compare the lengths and maximum diameters of palatal, MB and DB roots. One-way ANOVA was also used to compare the distances between palatal, MB and DB roots at their apical thirds. To analyze gender differences in root measurements, Student's *t* test for independent groups (for normally distributed data) and the Mann–Whitney *U* test (for non-normally distributed data) were applied.

Statistical analyses were performed using dedicated software (MedCalc Software Version 18.2.1). p values of < 0.05 were considered statistically significant.

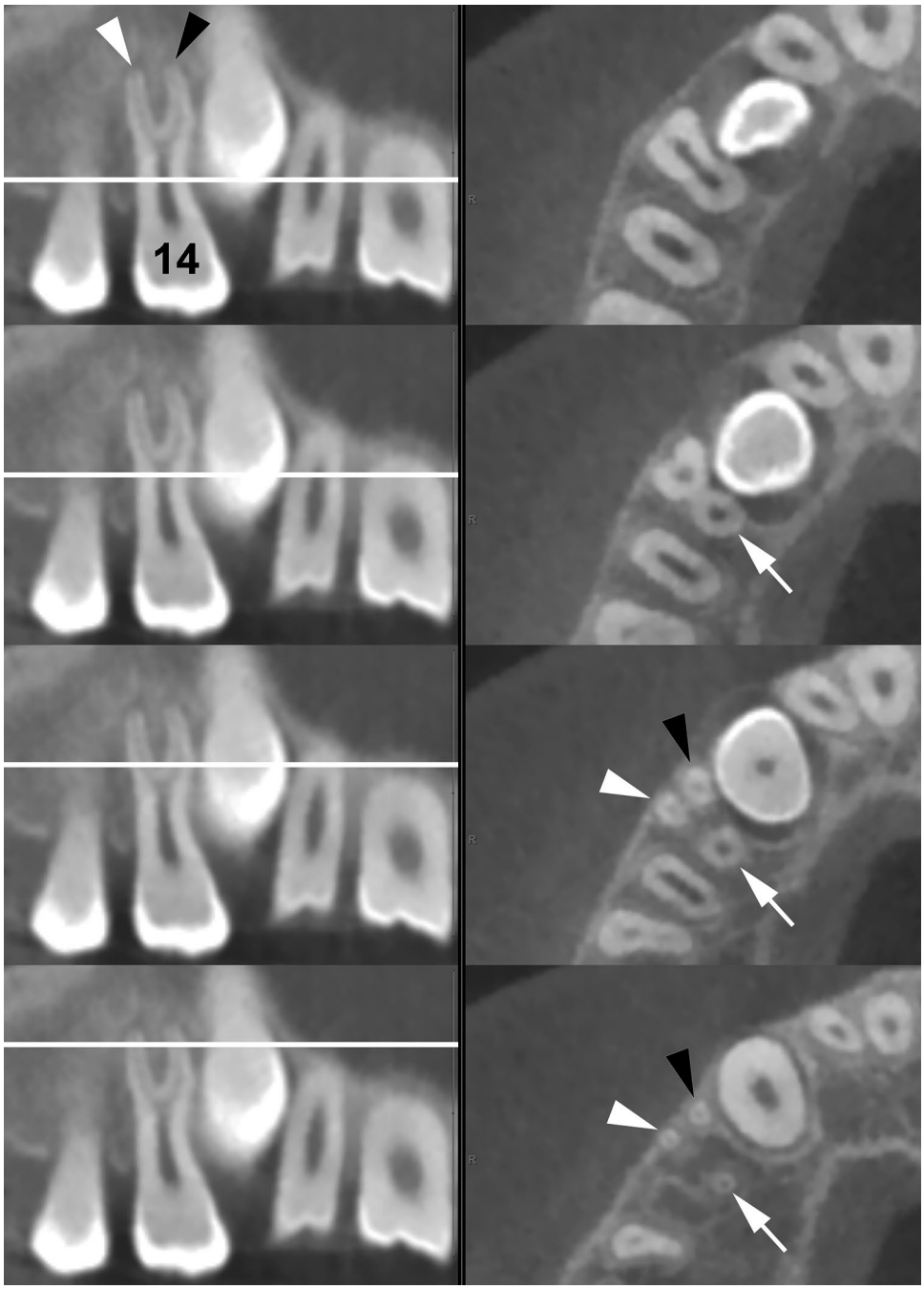

Fig. 1 Panoramic CBCT images (on the left side) and corresponding axial CBCT images (on the right side) showing external and internal root morphologies in the cervical third, at the B-P bifurcation, at the MB–DB bifurcation and in the apical third, respectively (see the white reference lines on panoramic images). 14 right MFP; black arrowhead MB root; white arrowhead DB root; white arrow P root

Results

The search identified a total of 16/1328 (1.2%) patients (nine males and seven females) with one or two MFPs with three distinct roots (Table 1). The 16 patients were aged 11–75-year-old (mean 30.8 ± 18.6-year-old) and were of European (Italian) origin.

Of the included patients, ten (five males and five females) had a unilateral three-rooted MFP (Fig. 2), while six (four males and two females) had a bilateral

Table 1 Incidence of three-rooted MFPs in the study sample (1328 patients)

	No. of patients (%)
Presence	16 (1.2)
Unilateral	10 (0.8)
Bilateral	6 (0.5)
Right	13 (1.0)
Left	9 (0.7)

Data are presented as numbers (%)

MFP maxillary first premolar

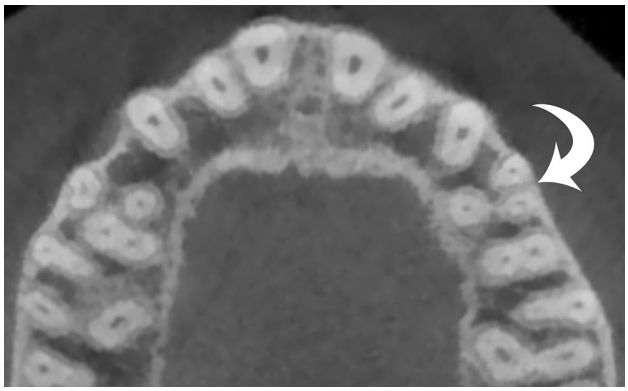

Fig. 2 Axial CBCT image showing a unilateral three-rooted MFP on the left side (curved arrow) in an 18-year-old male patient

three-rooted MFP (Fig. 3; Table 1). Therefore, we found a total of 22/2656 (0.8%) MFPs with three distinct roots.

Three-rooted MFPs were found on the right side in 13 patients and on the left side in nine (Table 1). Two female patients had a unilateral three-rooted MFP (one on the right side and one on the left side) that was endodontically treated. Two male patients with bilateral three-rooted MFPs had one MFP that was endodontically treated (one patient on the right and the other on the left) (Fig. 3). These endodontically treated teeth were excluded from the anatomical study.

Therefore, a total of 18 three-rooted MFPs (11 on the right side and seven on the left side) were enrolled in the anatomical study.

The lengths of palatal roots ranged from 5.4 to 10.5 mm (mean 8.4 ± 1.6 mm). The lengths of MB roots ranged from 4.4 to 9.2 mm (mean 6.5 ± 1.5 mm), whereas the lengths of DB roots ranged from 4 to 8.8 mm (mean 5.7 ± 1.3 mm) (Table 2). The palatal roots were significantly longer than the MB and DB roots ($p < 0.05$). No significant difference was observed between the lengths of MB roots and DB roots.

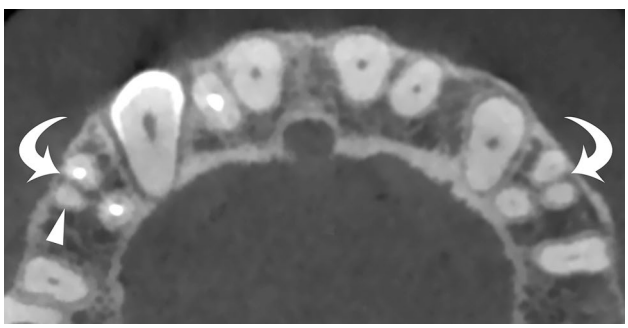

Fig. 3 Axial CBCT image showing bilateral three-rooted MFPs (curved arrows) in a 32-year-old male patient. An incomplete endodontic treatment is visible in the DB canal of the right three-rooted MFP (arrowhead)

Table 2 Lengths and diameters of the palatal, mesiobuccal and distobuccal roots

Parameter	Root		
	P	MB	DB
Length (mm)			
Male	9.5 ± 1.0	7.4 ± 1.2	6.3 ± 1.3
Female	6.9 ± 1.0	5.3 ± 0.6	4.8 ± 0.6
Total	8.4 ± 1.6	6.5 ± 1.5	5.7 ± 1.3
Diameter[a] (mm)			
Male	3.7 ± 0.5	2.9 ± 0.5	2.6 ± 0.5
Female	3.5 ± 0.4	2.6 ± 0.3	2.5 ± 0.3
Total	3.6 ± 0.4	2.7 ± 0.4	2.6 ± 0.4

Data are presented as mean ± standard deviation

P palatal, *MB* mesiobuccal, *DB* distobuccal

[a]Maximum diameter of the roots at their cervical thirds

The maximum diameters of palatal roots in the cervical third ranged from 2.8 to 4.3 mm (mean 3.6 ± 0.4 mm). The maximum diameters of MB roots in the cervical third ranged from 1.8 to 3.5 mm (mean 2.7 ± 0.4 mm). The maximum diameters of DB roots in the cervical third ranged from 2 to 3.3 mm (mean 2.6 ± 0.4 mm) (Table 2). The maximum diameters of palatal roots in the cervical third were significantly higher than those of MB and DB roots ($p < 0.05$). No significant difference was observed in the maximum diameters of MB roots and DB roots.

Fourteen of the three-rooted MFPs included in the anatomical study (77.8%) had a B-P bifurcation in the middle third of the root (Fig. 4b). In the remaining 4/18 (22.2%) teeth, the B-P bifurcation occurred in the cervical third of the root (Fig. 4a). This latter type of bifurcation was observed in three male patients (two with unilateral and one with bilateral three-rooted MFPs). The distance between the bifurcation of the B-P root canals and the CEJ ranged from 2.4 to 4.9 mm (median 3 mm, IOR 2.9–3.5 mm). The distance between the bifurcation of the MB–DB root canals and the CEJ ranged from 4.5 to 7.5 mm (median 5.2 mm; IOR 4.7–6.2 mm).

The distances between the apical thirds of palatal and MB roots ranged from 2 to 4 mm (mean 3.3 ± 0.5 mm). The distance between the apical thirds of palatal and DB roots ranged from 1.9 to 4.4 mm (mean 3.3 ± 0.8 mm). The distance between the apical thirds of MB and DB roots ranged from 0.6 to 2.8 mm (mean 1.4 ± 0.6 mm) (Table 3). The distance between the apical thirds of MB and DB roots was significantly shorter than that between palatal and MB or DB roots ($p < 0.05$). No significant difference was observed in the distances between the apical thirds of palatal and other roots.

All three-rooted MFPs included in the anatomical study had a type VIII canal configuration (Fig. 1) [18]. The

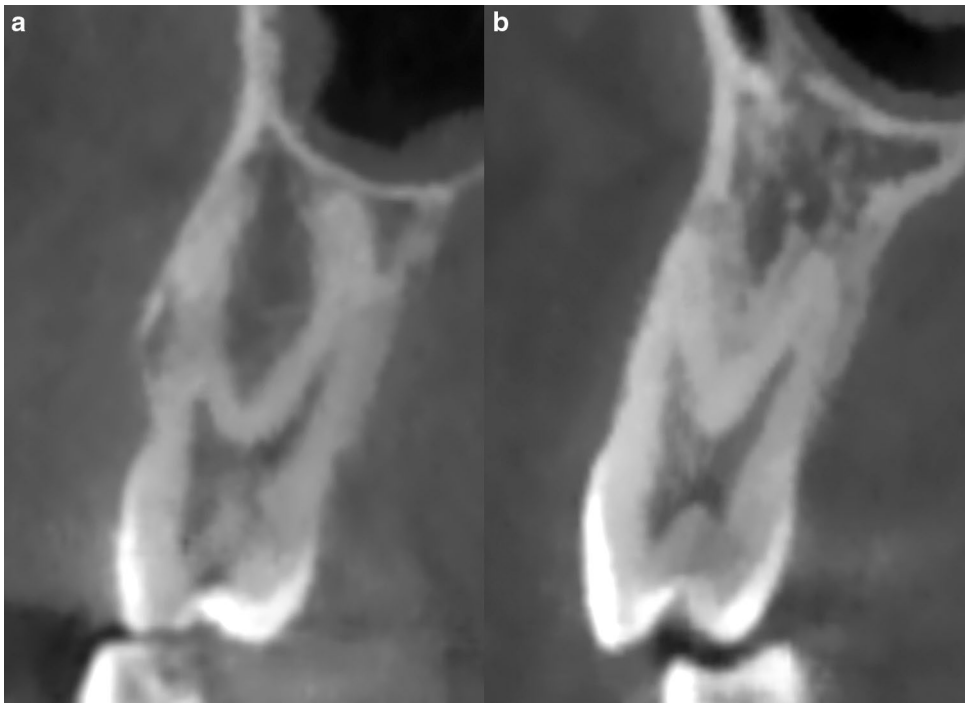

Fig. 4 Cross-sectional CBCT images showing the different positions of B-P bifurcations in two patients: in the cervical third in a male patient (**a**) and in the middle third in a female patient (**b**)

Table 3 Distances between palatal, MB and DB roots at their apical thirds

Parameter	Root		
	P–MB	P–DB	MB–DB
Distance between roots (mm)			
Male	3.5 ± 0.5	3.5 ± 0.9	1.6 ± 0.6
Female	3.1 ± 0.5	3.1 ± 0.6	1.1 ± 0.4
Total	3.3 ± 0.5	3.3 ± 0.8	1.4 ± 0.6

Data are presented as mean ± standard deviation

P palatal, *MB* mesiobuccal, *DB* distobuccal

visibility of root canals within palatal roots was 100% in the cervical third, 100% in the middle third and 38.9% in the apical third. The visibility of root canals within MB roots was 100% in the cervical third, 77.8% in the middle third and 5.6% in the apical third. The visibility of root canals within DB roots was 94.4% in the cervical third, 33.3% in the middle third and 5.6% in the apical third (Fig. 5; Table 4).

The lengths of palatal, MB and DB roots were significantly greater in males than in females ($p < 0.02$) (Table 2). There were no significant differences between the genders in root bifurcation–CEJ distances ($p > 0.63$) or the maximum diameters of roots in their cervical thirds ($p > 0.18$) (Table 2). There were also no significant differences between the genders in the distances between roots at their apical thirds ($p > 0.07$) (Table 3).

The four three-rooted MFPs that were excluded from the anatomical study had undergone incomplete endodontic treatment, with untreated root canals located within MB roots in two cases and within DB roots in the remaining two cases (Fig. 3).

Discussion

Most MFPs show one (41.7%) or two (56.6%) roots [2]. The most frequent type of anatomical variation observed in these teeth is the presence of three roots, which has a reported incidence ranging from 0.4 to 9.2% [2, 6, 11]. The frequency of three-rooted MFPs varies among ethnic groups and has a low incidence in Asian populations [5, 6, 9, 17]. Three-rooted MFPs typically have two buccal roots and one palatal root. The presence of a three-rooted MFP can be evaluated using various radiological methods, such as periapical radiography, CBCT and μCT.

Periapical radiograph is commonly used to assess radicular anatomy in the diagnosis and treatment of endodontic disease. However, its two-dimensional nature limits the usefulness of this examination for obtaining a detailed assessment of root morphology.

Currently, μCT is considered the best imaging modality for analyzing anatomical variation in MFPs [12, 19]. Marca et al. [12] found that μCT provided images with a spatial resolution higher than that obtained in CBCT. In their series of 16 three-rooted MFPs, μCT imaging was more accurate for demonstrating root canals, especially those of small size.

However, the high radiation dose required to perform μCT is not suitable for clinical use. Therefore, CBCT is

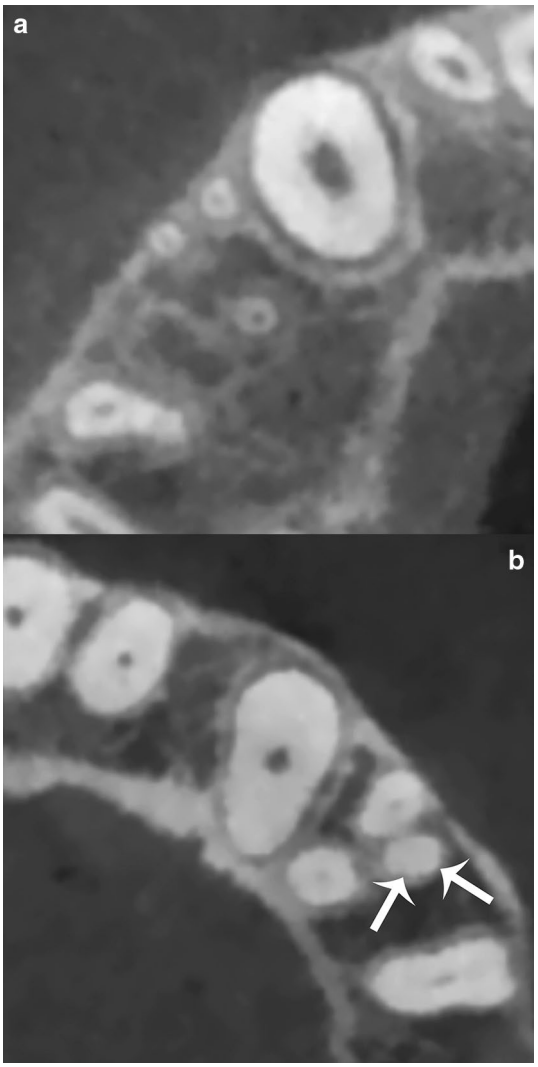

Fig. 5 Axial CBCT images showing the visibility of root canals in two different patients. **a** All root canals are detectable in the apical third. **b** The DB canal is not detectable in the cervical third (arrows)

Table 4 Visibility of the palatal, mesiobuccal and distobuccal root canals at their cervical, middle and apical thirds

Parameter	Root canal		
	P	MB	DB
Visibility			
Cervical	18 (100)	18 (100)	17 (94.4)
Middle	18 (100)	14 (77.8)	6 (33.3)
Apical	7 (38.9)	1 (5.6)	1 (5.6)

Data are presented as numbers (%)

P palatal, *MB* mesiobuccal, *DB* distobuccal

currently regarded as the best non-invasive imaging modality for preoperative assessment of the external and internal morphology of teeth in clinical practice [10, 16].

In the present study, we report the incidence and analyze the morphology of three-rooted MFPs incidentally detected on routine CBCT scans. To the best of our knowledge, this CBCT study is the first in vivo analysis to report on incidence, morphology and gender-related relationships in a group of three-rooted MFPs.

In the present study, we found that the incidences of three-rooted MFPs per patient and per tooth were 1.2% and 0.8%, respectively. In a previous European (Spanish) in vivo CBCT study, Abella et al. [1] found that the incidence per tooth of three-rooted MFPs on routine CBCT scans was 2.6%. The lower incidence observed in our study could be related to the fact that we only considered teeth with three distinct roots. A comparison of the incidence of the three-rooted MFPs between the present and previous in vivo CBCT studies is shown in Table 5.

In our study, we found that three-rooted MFPs were more frequent on the right side than on the left side and that bilateral three-rooted MFPs had a male predominance (Fig. 3). Conversely, no gender or side predilection was observed by Abella et al. and Tian et al. [1, 17]. However, in a recent study, Alqedairi et al. identified three-rooted MFPs only in male patients [3].

In the present study, we found that all three-rooted MFPs exhibited one palatal root and two buccal roots (MB and DB), consistent with previous CBCT studies [4, 9].

With regard for the lengths of the roots of three-rooted MFPs, we observed that the palatal roots were significantly longer than the MB and DB roots. We also found that the maximum diameters of the cervical third of palatal roots were significantly greater than those of other roots. There were no significant differences in the lengths and diameters between MB and DB roots. Conversely, Marca et al. reported that MB roots had larger size than was found in DB roots.

In the present study, we found that the B-P bifurcations of three-rooted MFPs occurred mainly in the middle third of the root (77.8%) (Fig. 4b). Moreover, we also found that

Table 5 Number and incidence of three-rooted MFPs in the present study and previous in vivo CBCT studies

Study	Country	No. of MFPs	No. of three-rooted MFPs (%)
Tian et al. [17]	China	300	2 (0.7)
Abella et al. [1]	Spain	430	11 (2.6)
Li et al. [9]	China	1387	7 (0.5)
Alqedairi et al. [3]	Saudi Arabia	334	4 (1.2)
Saber et al. [15]	Egypt	358	4 (1.1)
Present study	Italy	2656	22 (0.8)

Data are presented as numbers (%)

MFP maxillary first premolar

B-P bifurcations occurring in the cervical third of the root were observed only in men (Fig. 4a).

With regard for the distances between the bifurcation of the B-P and MB–DB root canals and the CEJ, our measurements showed that they were greater than those reported by Beltes et al. [4] in their ex vivo CBCT study. These differences may be related to the different type of study (in vivo vs. ex vivo) and the different methods used to acquire measurements (interactive MPR views vs. axial views).

In our study, we also found that the distance between MB and DB roots was significantly shorter than those between palatal and MB or DB roots.

With regard for the internal root canal configuration, all teeth in the current study presented three separate root canals (type VIII canal configuration) (Fig. 1). This finding is similar to what was observed in the CBCT studies reported by Abella et al. and Tian et al. [1, 17]. In their study populations, the authors also found that only three-rooted teeth exhibited a type VIII canal configuration [1, 17]. In contrast with this latter observation, Li et al. and Alqedairi et al. [3, 9] found that even MFPs with two roots can possess a type VIII canal configuration.

In the present study, we also assessed the visibility of root canals. In all cases, the visibility of root canals decreased from the cervical to the apical third of the root. Palatal root canals had the best visibility, with a percentage detection ranging from 100% in the cervical and middle thirds to 38.9% in the apical third. Visibility was better in MB root canals than in DB root canals in the cervical and middle thirds of the root. The worst root canal visibility was observed in the apical thirds of MB and DB roots, in which visibility was 5.6% (Fig. 5). This latter observation is probably related to the small size of the root canal in the apical third of the root. A similar finding was reported in a study by Marca et al. [12].

With regard for the relationships between gender and root measurements, we found that only the lengths of roots were significantly greater in males than in females. No other gender-related relationship was observed.

Three-rooted MFPs are not an unusual anatomical variant, especially in European populations [8, 11]. Hence, certain authors believe that this anatomical variant is a Caucasian trait [1, 11].

From a clinical point of view, the literature indicates that patients with three-rooted MFPs have an increased risk of incomplete root canal treatment. Similar to these studies, we found that all four three-rooted MFPs that underwent endodontic procedure had an incomplete treatment (Fig. 3). Therefore, to avoid incomplete treatment or complications, such as periapical lesions of inflammatory origin and radicular fractures, in the maxillary premolar region, an accurate morphological analysis of the anatomical variations of MFPs is essential for preoperative endodontic planning. Moreover, to avoid future problems, the occurrence of three-rooted MFPs should be reported even when a CBCT scan is performed for a dental procedure involving a region outside the premolar area, especially in younger patients.

This study has some limitations. First, only a small number of three-rooted MFPs were included; however, to our knowledge, the present sample is the largest among the available CBCT in vivo studies [1, 3, 9, 15, 17]. Second, we included only three-rooted MFPs with three distinct roots, but the literature does indicate that this is the most frequent subtype. Third, while the image analysis was performed by one observer, his lengthy experience may have improved the accuracy of morphological analysis.

In conclusion, in the present in vivo CBCT study, we report the incidence, morphology and gender-related relationship of three-rooted MFPs in a European (Italian) population. Improving our knowledge about the presence and characteristics of this anatomical variant can help to increase the success rates of root canal treatments. Therefore, given that three-rooted MFPs are not unusual in Europeans, a preoperative CBCT evaluation could be suggested whenever a dental endodontic procedure is planned on an MFP. In addition, to avoid future misdiagnosis and complications, we recommend reporting the number of roots and the canal configuration of any MFP detected on CBCT images.

Author contributions AB: Project development, Data collection and data analysis, Manuscript writing and editing; SM: Data analysis, Literature research, Manuscript editing; AZ: Data collection, Manuscript editing; IT: Literature research, Manuscript editing; RM: Manuscript editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent This study was retrospective, and it did not alter the management of the patients; thus, no specific consent was required.

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