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ORIGINAL ARTICLE

Incidence of three roots and/or four root canals in the permanent mandibular first molars in a Korean sub-population

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Abstract
Objectives The purpose of this study was to evaluate the prevalence of three-rooted permanent mandibular first molars (PMFMs) with four canals and their morphological characteristics among a Korean population from using cone-beam computed tomography scans (CBCTs).
Materials and methods Among the 705 CBCTs screened, 472 patient cases possessing at least one PMFM were identified. A total of 780 PMFMs were evaluated in axial section series to determine the number of roots and canals. The incidences of three-rooted PMFMs were compared with regard to gender and location. For distal root(s) with two canals, inter-orifice distances (IOD) between distobuccal and distolingual canals were measured at pulpal floor and furcation levels. The difference of IOD between males and females was also analyzed using chi-square tests.
Results Among the 472 CBCTs of 225 females and 247 males, 84 females and 107 males were found to have at least one three-rooted PMFM. Among the 780 PMFMs, 191 PMFMs (24.5%, 89 of 397 left and 102 of 383 right) were found to have three roots. The prevalence of distal root(s) with two canals was 34.2% (267 of 780). From the molars with two distal canals, the mean IOD between distobuccal and distolingual canals at the pulpal floor level was 3.1 mm in males and 2.9 mm in females (p=0.0428).
Conclusions The occurrence of three-rooted PMFMs among a Korean population was 24.5% and was higher than other countries and ethnicities. Understanding the prevalence of PMFMs with a distolingual root and/or canal in a Korean population and the IOD between distobuccal and distolingual canals may be useful for successful endodontic treatments.
Clinical relevance Acknowledgment of potential incidence of three-rooted permanent mandibular first molars with four canals and the distance between two distal canals may increase the success rate of root canal treatment by reducing the missing canal untreated.

Keywords CBCT · Distolingual canal · Distolingual root · Inter-orifice distance · Radix entomolaris · Three-rooted mandibular molars

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Introduction

One of the main objectives of root canal treatment is the thorough chemomechanical shaping and cleaning of the entire root canal system [1, 2]. For successful root canal treatment, it is important for a clinician to understand tooth and root canal anatomy. Although most of the permanent mandibular first molars (PMFMs) have two roots located mesially and distally, in some patients, they have an additional root, requiring special attention. Variations in root canal morphology of the PMFM have been frequently reported [3]; the additional third root in those PMFMs is

typically distributed distolingually or, less frequently, distobuccally. The coronal part of the distolingual supernumerary root, the radix entomolaris, is completely or partially fixed to the distal root and smaller than the distobuccal (DB) and mesial roots [1, 4].

Several reports suggest that the morphology of PMFMs varies according to ethnicity [5–10]. In populations with mongoloid traits, PMFMs with an additional root located distolingually are a most common variant [5, 7, 9]. In fact, the prevalence in Asian populations is as high as 17.8% to 24.5% when it is compared to those of Caucasian heritage (0.7% to 4.2%) [5–7, 9, 10].

In previous studies, the two main methods to assess the prevalence of three-rooted PMFMs have been microscopic analysis of extracted teeth and clinical radiographic assessment. Although several authors have studied this anomaly directly from extracted teeth [8, 11–14], the possibility of root fracture during extraction exists, due to its curved and slender root shape [1, 2, 4], as well as the difficulty in collecting a sufficient amount of samples. Moreover, conventional intraoral periapical radiographs are not completely reliable because of limitations such as distortion and superimposition [5–7, 15].

The recent introduction of cone-beam computed tomography (CBCT) potentially provides dentists with a practical tool for three-dimensional reconstruction imaging for use in endodontic applications and morphologic analyses when indicated [15–18]. CBCT scans can be used for the comparative assessment of morphology and to determine the exact position of the distolingual (DL) root of PMFMs. Studies that used CBCTs instead of extracted teeth allowed expanding the range and number of the sample [19–21]. However, little information is available regarding specific anatomic characteristics such as canal location besides the incidence of the three-rooted PMFMs.

Therefore, the purposes of this study were not only to determine the incidence (frequency of the occurrence) of three-rooted PMFMs but also, in case of having a DL canal, measure the distance between DB canal and DL canal using the CBCT database.

Materials and methods

The protocol for this study was approved by the Institutional Review Board at the Pusan National University Hospital (E-2011039). Among the CBCT images taken of patients who visited the St. Bennedict Dental Hospital (Busan, Korea) from May 2008 to April 2011 for implant surgery and surgical removal of deeply impacted teeth (including third molars and supernumerary teeth), high-quality CBCTs from 705 patients (361 male and 342 female) were screened, and 780 PMFMs were evaluated retrospectively. The scans were obtained using the Implagraphy system (Vatech, Seoul, Korea) at 200-μm resolution (pixel size) and a 144-mm (width) by 121-mm (height) field of view. The criterions for case selection from the existing CBCT data sets were as follows: each case had to have fully erupted PMFM(s) without any root canal fillings.

All PMFMs were anatomically analyzed in detail by using image viewer software (EasyDent; Vatech). CT images were reconstructed to have three planes (sagittal, coronal, and axial), and three-dimensional images were generated. PMFMs were evaluated in the axial plane by moving the toolbar from pulpal floor to apex in the sagittal plane to investigate the number of roots and canals. The PMFMs were classified into four types according to the number of roots and root canals (number of roots in upper case + number of canals in lower case); type I=M1D1+m1d1 (two roots, two canals), type II=M1D1+m2d1 (two roots, three canals), type III=M1D1+m2d2 (two roots, four canals), type IV=M1D2+m2d2 (three roots, four canals) (Fig. 1).

From all of the reviewed PMFMs having two distal canals and orifices (type III and type IV), the inter-orifice distance (IOD) between the DL canal orifice and the DB canal orifice was measured at the pulpal floor level and furcation level using the axial plane, which was parallel to the occlusal plane (Fig. 2a). At each level of measurement, two kinds of IODs were measured; one was between the center of the orifice of the DL and DB canals, and another was between the peripheral boundaries (the farthest distance). When a tooth had one oval-shaped canal orifice of the distal canal at the pulpal floor level and it separated into two canals apically, the tooth was excluded from IOD measurements.

The total incidence, gender ratio, bilateral and unilateral appearance, and the correlation between right-side and left-side occurrences of these PMFMs were computed and compared statistically using the chi-square test. The IOD data were normally distributed (by Kolmogorov–Smirnov test), and therefore, the distances between two distal canals were compared for the gender differences using the *t* test.

Results

Out of 705 scans initially included, 232 patients were excluded from this study. One hundred eighty-three patients had no PMFM, and 47 had a CT image of the maxillary area only. One patient had a distorted CBCT image, and one had immature PMFMs. There were 472 patients (225 females and 247 males) aged between 8 and 88 years, with a mean age of 45.8±15.6 years.

A total of 780 PMFMs were evaluated; among the 397 left molars and 383 right molars, 89 left and 102 right

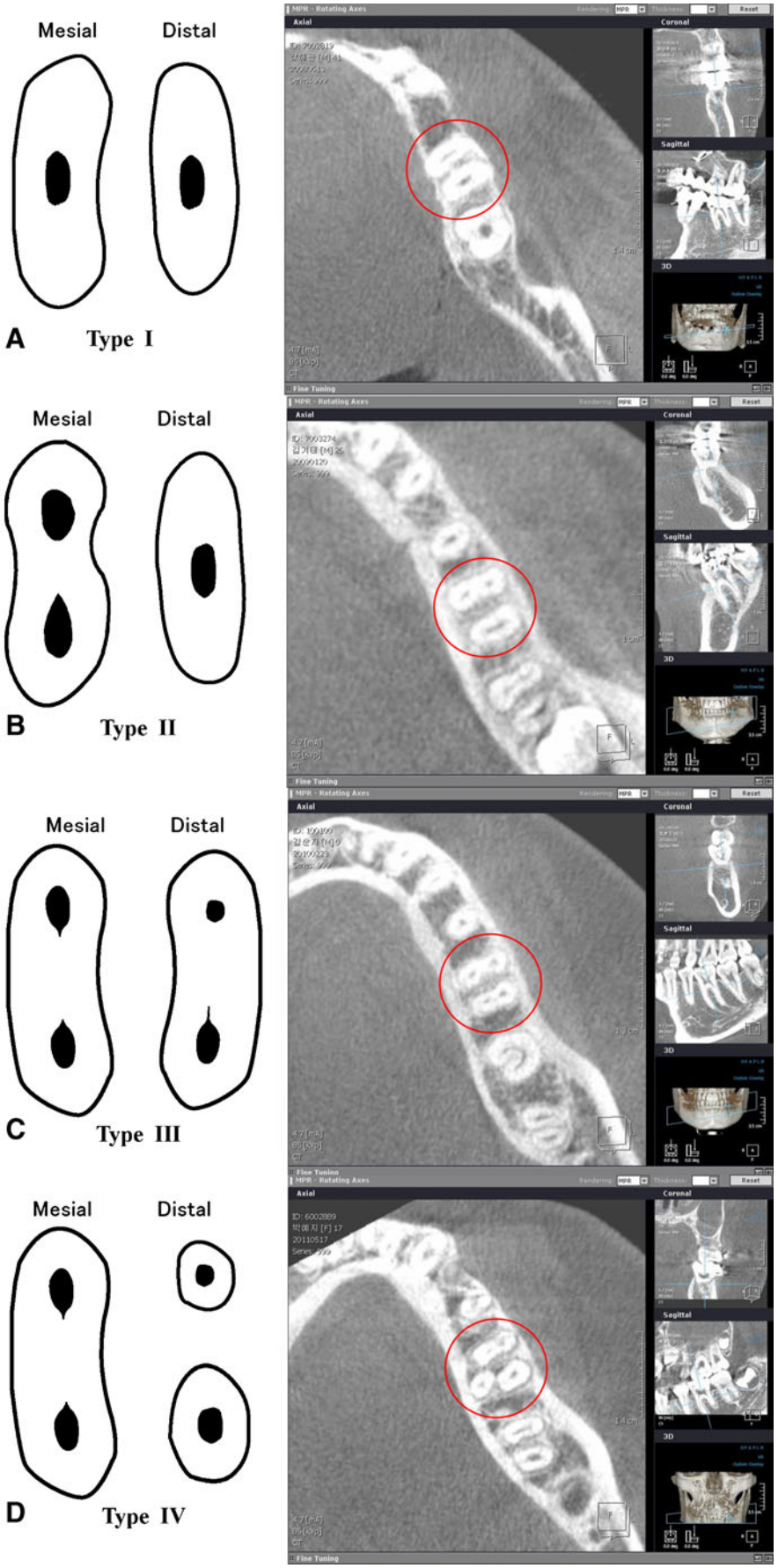

Fig. 1 Classifications of mandibular permanent first molars according to the number of roots and root canals and the examples (in *circles*) from CBCT data (**a** type I with two roots and two canals, **b** type II with two roots and three canals, **c** type III with two roots and four canals, and **d** type IV with three roots and four canals)

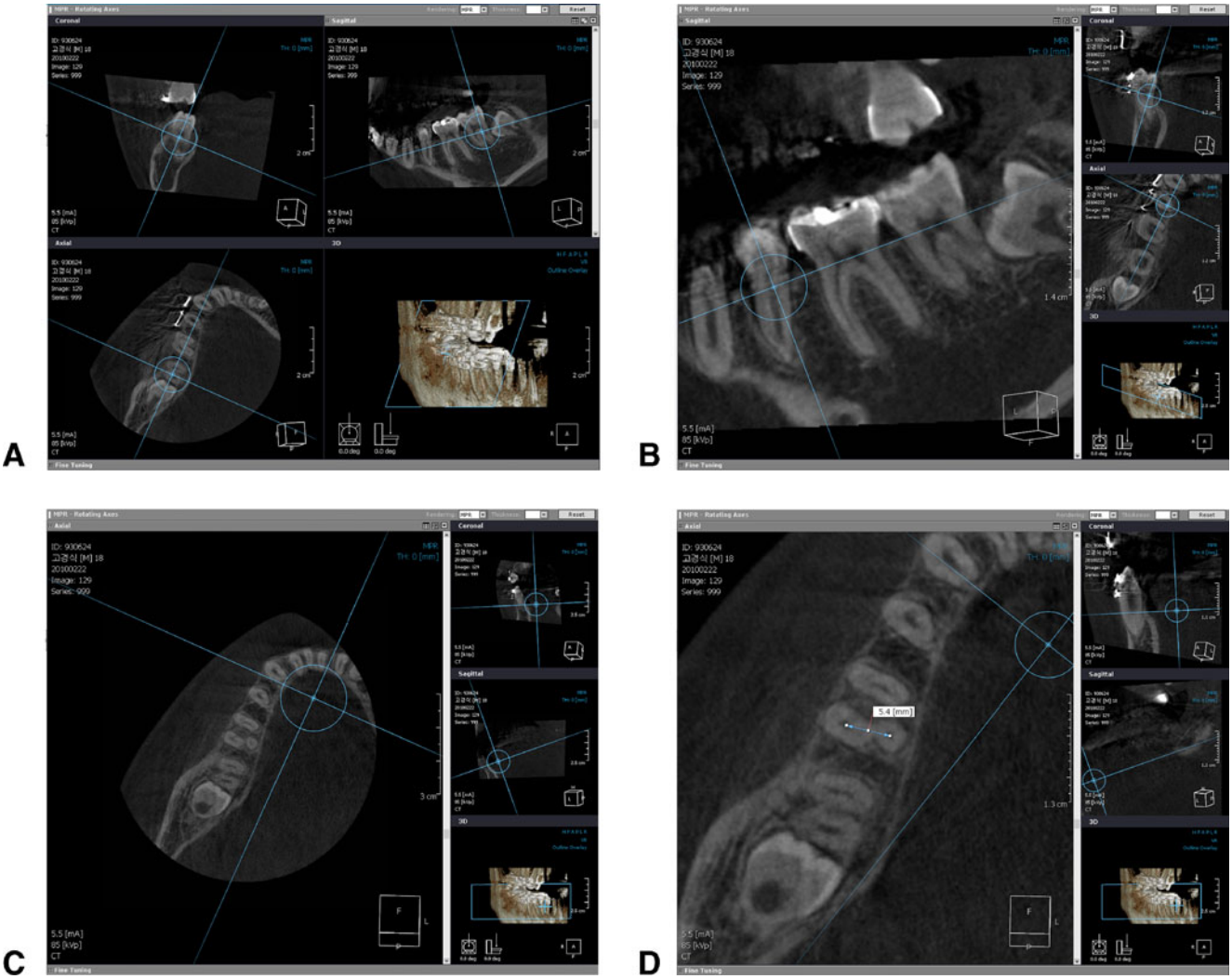

Fig. 2 Representative CBCT images from a right permanent mandibular first molar. **a** Basic composition of reconstructed images with coronal, sagittal, and axial views and three-dimensional images. **b** Sagittal view to control the level of the coronal plane. The horizontal guide line was set at the pulpal floor and parallel to the occlusal plane. **c** Axial plane to evaluate the number of roots and canals. **d** Measurement of the distance between distobuccal and distolingual canals

PMFMs were found to have three roots (type IV). The incidence of the DL root of PMFM was 24.5% (191 of 780 teeth, Table 1). The incidences did not differ between women (84 of 366 teeth, 23.0%) and men (107 of 414 teeth, 25.9%) (p=0.9740). The occurrence of such PMFM neither differed significantly between the left side (89 of 397 teeth, 26.6%) and the right side (102 of 383 teeth, 22.4%) (p=0.4011, Table 1). From the patients who have both left and right PMFMs (310 patients), 20.7% (64 of 310 patients) of patients had three-rooted PMFMs bilaterally. The overall incidence of type III (9.7%) and type IV (24.5%) (both with two distal canals) was 34.2% (267 of 780 teeth) (Table 1).

From the samples measured for distal IOD (type III and type IV, n=262), the DL root canal orifice was separated from the DB canal orifice by 3.1±0.7 mm in the center of male molar canals, 2.9±0.6 mm in females at pulpal floor level with a significant difference (p=0.0428). Males had a distance of 4.6±3.8 mm between the peripheral boundaries, and females had 4.0±0.7 mm (p=0.1390). At the furcation level, the distance for male subjects was 4.5±1.2 mm, and the one for females was 4.2±1.0 mm (p=0.0365), relative to the canal centers. Regarding peripheral boundaries, the distances for males and females, respectively, were 5.5±1.3 and 5.2±1.0 mm (p=0.0261, Table 2).

Discussion

The knowledge of variations in root canal morphology in multi-rooted teeth is indispensable for successful endodontic therapy because missing canals may result in treatment failure via the persistence of intracanal microorganisms

Table 1 Classifications of permanent mandibular first molars according to gender and location

	Type I (%) M1D1+m1d1[a]	Type II (%) M1D1+m2d1[a]	Type III (%) M1D1+m2d2[a]	Type IV (%) M1D2+m2d2[a]
Male (n=414)	1 (0.24)	266 (64.25)	40 (9.66)	107 (25.85)
Female (n=366)	8 (2.18)	238 (65.03)	36 (9.84)	84 (22.95)
Left (n=397)	6 (1.51)	266 (67.00)	36 (9.07)	89 (22.42)
Right (n=383)	3 (0.78)	238 (62.14)	40 (10.45)	102 (26.63)
Total (n=780)	9 (1.15)	504 (64.62)	76 (9.74)	191 (24.49)

Type I=M1D1+m1d1 (two roots, two canals), type II=M1D1+m2d1 (two roots, three canals), type III=M1D1+m2d2 (two roots, four canals), type IV=M1D2+m2d2 (three roots, four canals)

[a] Number of roots in upper case + number of canals in lower case (M and m, mesial; D and d, distal)

[22–25]. The aim of this study was to provide useful information about the number of roots and canals, as well as the distance between the DB canal and DL canal for PMFMs, if two distal canals were present.

According to the present results, the occurrence of three-rooted PMFMs in the Korean population was 24.5% of all teeth examined. This finding was in agreement with a recent paper [9] and previous reports on Mongolians [5, 7–9, 14, 26, 27] but was considerably higher compared with data reported for non-Mongolian races [6, 8, 10, 13]. On the other hand, in Caucasian populations, the prevalence of PMFMs with three roots was 2.2% [8] to 4.2% [6]. It was 3.4% for the UK [13] and 0.7% for Germany [10]. The prevalence in a Taiwanese population was estimated to be 17.8% [5]; in a Chinese population, it was 21.7% [7], 13.4% [26], and finally 14.6% for Hong Kong Chinese [27]. Song et al. [9] reported the prevalence for Koreans as 24.5%, which is essentially the same as in the present study. These reports indicate that the prevalence of three-rooted PMFMs differs significantly with race, and the additional root is found mostly in races of mongoloid origin.

Gender predilection for an additional root in the PMFM has been also reported by several studies [5, 14, 28–30]. Some studies have found males to have a higher percentage of this anomaly [28–30]. However, others reported the prevalence of a three-rooted PMFM was similar in both genders or rather higher in females [5, 14]. In the present study, there was neither a significant difference according to the gender (p=0.9740), which is similar to a recent report from Tu et al. [5], nor the side of occurrence (left vs right side, p=0.4011). However, other studies reported that three-rooted PMFMs occurred more frequently on the right side than on the left side [5], whereas there are also studies showing that these teeth occurred more frequently on the left side [14, 31]. These contradictory findings may be explained by marked differences in the sample size and in the methods used. Some studies reported a bilateral occurrence of three-rooted PMFMs from 50% to 69% [5, 27], although these figures were obtained from Hispanic children and Asians. In the present study, bilateral occurrence of three-rooted PMFMs was 20.7%.

Table 2 Inter-canal distance between the distal two canals of permanent first mandibular molars

	Pulpal floor level (mm)		Furcation level (mm)	
	Central	Peripheral	Central	Peripheral
Male (n=145)	3.1±0.7	4.6±3.8	4.5±1.2	5.5±1.3
Female (n=117)	2.9±0.6	4.0±0.7	4.2±1.0	5.2±1.0
p value	0.0428	0.1390	0.0365	0.0261

The IOD between DB and DL canals was measured, and this kind of information had not yet been reported. At the pulpal floor level, the IOD was 3.1±0.7 mm in males and 2.9±0.6 mm in females. After access cavity preparation during clinical procedure, these data may be consulted to accomplish the radicular access, specifically for the DL canal orifice. Access opening would be extended as much as the maximum distance shown here (approx. 3 mm); clinicians need to explore the DL canal after locating the DB (distal) canal with the file angled to the lingual side.

Regarding the IOD between DB and DL canals, the difference between males and females was also assessed. The central IOD at pulpal floor level and the central and peripheral distances at furcation level in males were significantly greater than in females (p<0.05). The results appear to confirm that males had a larger skeleton and teeth compared to females as shown earlier [32, 33]. They also indicate that the access cavity should be prepared wider when finding the DL canal in males.

The reported variation in the occurrence of four-canaled PMFMs, regardless of the number of roots, was between 26.0% and 57.7% [34–37]. In the present study, the prevalence of four canals was 34.2%. It is important to recognize that 9.7% of Koreans had two distal root canals even in one

distal root (type III in this study) similar to a mesial root with two canals.

In the present study, the IODs between DB and DL canals were measured using a novel method. First, the measuring levels were standardized, namely pulpal floor level and furcation level. The distance at the pulpal floor level would be more valuable than the distance at the furcation level during the clinical procedure for exploring a supernumerary root canal orifice. The distance between DL and DB canals was measured at the center of canals and boundary of canals. At the level of the pulpal floor, the information about the two distances between the DB and DL canal centers and between the peripheral boundaries of the canals would help clinicians to determine the size of an access cavity. Considering a supernumerary root in the PMFM, the conventional triangular access cavity should be modified to a trapezoidal form with DL extension [1]. Even if preoperative examination indicated the presence of a single distal root canal, it would be helpful to consider the distance between the peripheral boundaries (IOD) of the distal canals not to miss the possible existence of a supernumerary root canal.

The number of canals is more important than number of roots for successful root canal treatment. This study was designed to examine the root canal system using the CBCT images without tooth destruction. The prevalence of three-rooted PMFMs was almost 25% while the prevalence of two-rooted PMFMs with definitely separated two canals was almost 10%. This additive occurrence in the two-rooted PMFM may have a higher risk of missing through the conventional radiographs or extracted root evaluation.

Meanwhile, if the middle mesial canal which occurs occasionally in the mesial root of PMFMs were searched in the present research using the same CBCT data, it would also be valuable information for the successful root canal treatment. However, this information was not investigated at this time for the main purpose of seeing the distal root and distal canals and the limited resolution of 200 μm of the CBCT to see the finite middle mesial canals.

Clearly, CBCT is not indicated in routine cases. However, when indicated, CBCTs facilitate endodontic procedures and will help to avoid "missed" canals. The presence of the distolingual root in the PMFM may be a contributing factor to localized periodontal destruction, especially in teeth with advanced periodontitis [7]. Currently, technology has advanced allowing a study that is accurate, nondestructive, and feasible. CBCT is an accurate and detective tool for examining the morphology of the root canal [15–18]. CBCT systems might be a valuable tool for morphologic analysis of the root canal system [5]. Although the CBCT image is more reliable than extracted tooth evaluation or periapical radiographic method, further study would be needed to verify the accuracy of CT using other modalities. In clinical situations, CT scans are frequently not available for root canal treatment; therefore, shift scan and a careful interpretation of conventional radiographs would be important. Generating comparison data from existing CBCTs has provided an understanding of the prevalence of PMFMs with a distolingual root and/or canal and data regarding IOD between distobuccal and distolingual canals that both may be useful for successful endodontic treatments.

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