

# Anatomical Landmarks of Maxillary Bifurcated First Premolars and Their Influence on Periodontal Diagnosis and Treatment

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## Abstract

**Objective:** To assess the anatomical landmarks of the roots of bifurcated maxillary first premolars and study their effect on the diagnosis and management of periodontal disease. **Methods:** One hundred sixty-five maxillary first premolars were selected. The frequency of single-, two-rooted, and three-rooted premolars was assessed, but only the dual-rooted were used for the purpose of this study. For each tooth, the following measurements were obtained using a micrometer caliper: buccal and palatal root length, mesial and distal root trunk length, crown length, and width of the furcation entrance. The types of root trunk were classified according to the ratio of root trunk height to root length into types A, B and C. Root trunk types A, B and C are defined as root trunks involving the cervical third or less, up to half of the length of the root, or greater than the apical half of the root, respectively. The presence of any root grooves and concavities, as well as bifurcational ridges, was assessed. The crown to root ratio was calculated. **Results:** Of the 165 maxillary first premolar teeth retrieved, 100 (60.6%) were two-rooted, 62 (37.57%) were single-rooted, and three (1.81%) were triple-rooted. Type A root trunks comprised only 7% of the examined teeth, while types B and C had more or less comparable results (46% and 47% respectively). Type B was more common in distal root trunks while type C was dominant in mesial root trunks. Bifurcation ridges were observed in 37% of the teeth; the mean root trunk length was greater in teeth with bifurcation ridges than in teeth without (7.41 mm vs. 5.96 mm). Root grooves and concavities were found in 96% of the mesial aspects of the root, and in 57% of the palatal aspect of the buccal root. The mean width of the furcation entrance was  $0.89 \pm 0.19$  mm (range 0.39–1.28). The average crown to root ratio was 0.69:1. **Conclusion:** Awareness of root surface anatomical variations may help the practitioner when assessing the diagnosis, treatment plan and prognosis of periodontally involved two-rooted maxillary premolars.

**Key words:** Maxillary bifurcated premolar, root morphology, anatomical risk factor

## Introduction

Periodontal disease is among the most common diseases of the oral cavity, and bacterial plaque is the main local etiological factor for its initiation and progression. Plaque starts to accumulate supragingivally, and if left undisturbed, bacteria begin to migrate subgingivally, changing the environment and allowing Gram-negative anaerobes to flourish, which in turn disturbs the balance between health and disease (Socransky and Haffajee, 1991).

Local etiological or predisposing factors may be present on the crown or the root complex, which is that

part located apically from the cemento-enamel junction (Müller and Eger, 1999). According to Matthews and Tabesh (2004), local factors were defined as anything that influences the oral health status at a particular site or sites with no known systemic influence.

Local plaque retentive factors on the root surface, whether anatomical (e.g., root grooves) or iatrogenic (e.g., subgingival restorative margins), will enhance bacterial adhesion to the pocket epithelium and the tooth surface, thus allowing the growth of subgingival plaque. In the case of multi-rooted teeth, the presence of furcation and several other local anatomical factors on the root surface will aggravate this condition. Grbic and Lamster in 1992 found that multi-rooted mandibular and maxillary molars and maxillary premolars displayed the highest incidence of clinical attachment loss, while maxillary anterior teeth and

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mandibular premolar teeth demonstrated the lowest incidence. These morphological factors related to furcations and roots may contribute to the etiology and compromise the prognosis of periodontally involved teeth. These factors include: furcation entrance width, root trunk length and the presence of root concavities, cervical enamel projections, bifurcation ridges and enamel pearls (Al-Shammari, *et al.*, 2001).

The maxillary first premolar usually has two roots that may either be separated or partially fused. Less frequently, this tooth may have a third root. In this case it is called a “minimolar” because it has one palatal and two buccal roots (mesiobuccal and distobuccal; Rios, 1998). Therefore, this tooth may have two or three furcation entrances that could be affected periodontally.

In the literature, the majority of research regarding furcation morphology and other root surface anatomical factors is concerned with molars (Svärdström and Wennström, 1988; Hou and Tsai, 1997; Paolantonio *et al.*, 1998; Hou *et al.*, 1998; Santana, 2004; Hou *et al.*, 2005). The prevalence of furcation involvement was found to be greater in maxillary than mandibular molars, with a range of 25-52% and 16-35% respectively. Root morphology is a factor that may explain the observed variability (Svärdström and Wennström, 1996).

However, very few studies have investigated this issue with regard to multi-rooted premolars (Joseph *et al.*, 1996; Kerns *et al.*, 1999; Loh, 1998). The bulk of research concerned with multi-rooted premolars was investigated from an endodontic point of view (Vertucci *et al.*, 1979; Chaparro *et al.*, 1999; Mattuella *et al.*, 2005; Awawdeh *et al.*, 2008).

The diagnosis, treatment, and prognosis of furcation involvement are still tricky issues in the field of periodontal therapy. This is even more challenging in the case of furcation-involved premolars. The examination of proximal furcations is more difficult than it is in the buccal and lingual furcations, particularly when neighboring teeth are present. This is often more difficult in the case of long root trunks. Therefore, such teeth may not be identified as furcationally involved without surgical exposure (Carnevale *et al.*, 2003). The presence of proximal furcation was also considered a risk factor for the adjacent site of the neighboring tooth because it can negatively influence the periodontal status and healing after non-surgical treatment in proximal sites (Ehnevid and Jansson, 2001). In addition, the least favorable responses to periodontal treatment were found in maxillary molars and bicusps that have proximal furcations (Ramfjord *et al.*, 1980).

Several concerns need to be addressed and taken into consideration while evaluating the prognosis of a furcation-involved premolar in order to decide to whether to keep or extract the tooth. Extraction of teeth and replacement with implants are becoming

increasingly frequent in the management of periodontally compromised patients.

The anatomic variations of multi-rooted maxillary first premolars that have been investigated include: root trunk dimension (Kerns *et al.*, 1999), furcation entrance diameter (Bower, 1979; Ward *et al.*, 1999), root grooves on the proximal aspects (Booker and Loughlin, 1985), and concavities on the palatal aspect of the buccal root (Tamse *et al.*, 2000; Lammertyn *et al.*, 2009). Various anatomical landmarks of maxillary multi-rooted premolars predispose these teeth to weakening during different types of treatment in dental practice, where 56% of vertical root fractures are related to premolars (Testori *et al.*, 1993; Kishen, 2006).

The purpose of this study was to assess the anatomical landmarks of the roots of two-rooted maxillary first premolars and to discuss their effect on the diagnosis and management of periodontal disease.

## Materials and methods

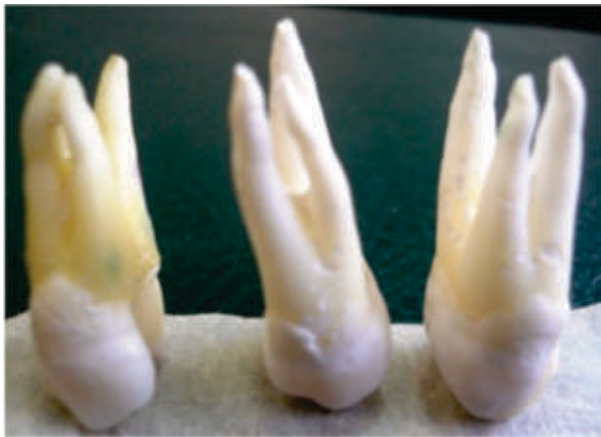
For the purpose of this study, 165 maxillary first premolars were selected from an extracted teeth collection of a dental practice disposal from the out-patient clinics of King Hussein Medical Center. All teeth were extracted for orthodontic reasons and selected on the basis of having: 1) intact roots and furcation regions; 2) a preserved cemento-enamel junction unaltered by loss of tooth substance due to dental caries, fractures or tooth wear; 3) the presence of intact crowns to facilitate sorting of teeth according to general anatomical characteristics. Maxillary first premolars were identified by the following coronal morphological features: having two cusps, with the buccal cusp prominently larger than the palatal, clearly visible mesiodistal (central) developmental groove on the occlusal surface, distinctive marginal groove which often cuts across the mesial ridge, and the presence of a marked concavity (canine fossa) situated on the cervical two thirds of the crown and extending across the cervical line towards the root(s) as a shallow groove (Ash, 1994).

To remove any attached soft tissue, all teeth were immersed in 5.25% sodium hypochlorite for 30 minutes. Any calculus obscuring the furcation entrance or root trunk was removed gently using a manual curette scaler. Prior to root surface measurement, all teeth were assigned an identification number.

Using a micrometer caliper, the following measurements were obtained for each tooth: vertical dimensions of the root trunk at the mesial and distal aspects; buccal and palatal root length; crown length; and the distance between the cemento-enamel junction and mesial root concavity. In addition, each root was inspected for the presence of bifurcational ridges and any concavity or depression on any aspect of the root surfaces.

The width of the furcational entrance was assessed using endodontic reamers with different sizes. Reamers

**Figure 1. Three maxillary first premolars with three roots.**



**Figure 2. Bifurcation ridges appeared at different levels along the vertical dimension of the furcation.**



**Table 1: The mean and range of the crown and root lengths and the ratio of the means.**

	Crown length (n = 100)	Root length (n = 200)	
		Buccal (n = 100)	Palatal (n = 100)
Mean $\pm$ SD (mm)	8.56 $\pm$ 0.73	12.61 $\pm$ 1.21	12.34 $\pm$ 1.20
Range	6.71 - 10.77	10.12 - 15.38	9.67 - 15.57
CL:RL ratio	0.69:1.00		

CL, crown length; RL, root length

were inserted horizontally into the most coronal entrance of the furcation, then a stopper was used to locate the exact point where the reamer could not penetrate any further. The reamer was then removed and the diameter was measured using a micrometer caliper.

Based on the ratio of root trunk height to root length, the types of root trunk were classified according to Hou and Tasi (1997) into types A, B and C. Types A, B and C are defined as root trunks involving the cervical third of the root length or less, the cervical third to one half the root length, and more than the cervical half of the root's length, respectively.

## Results

Of the 165 maxillary first premolar teeth retrieved, 100 (60.6%) were two-rooted, 62 (37.57%) were single-rooted, and three (1.81%) were triple-rooted. The third root of the three-rooted maxillary first premolars appears as a separation of the buccal root into mesiobuccal and distobuccal roots (Figure 1).

Table 1 presents the means and ranges of the crown and root dimensions of the two-rooted maxillary first premolars. The crown length was found to be greater than half of the root length with a ratio of 0.69:1 mm (range 1:1.1 – 1:2).

Table 2 presents the percentage of each type of root

trunk (based on the ratio of root trunk height to root length) found in the teeth examined in this study. The table shows that the majority of root trunk dimensions involved more than the cervical third of the root length. Type A root trunks comprised only 7% of the examined teeth, while types B and C had more or less comparable results (46% and 47% respectively), with type C slightly greater than B.

Variation in root trunk types at the mesial and distal aspects of the teeth is showed in Table 3. It can be seen that while type B is more frequently the distal root trunk, type C is more dominant on the mesial root trunk.

Bifurcation ridges were observed in 37% of the teeth. It can be seen that the mean root trunk length is greater in teeth with bifurcation ridges than in teeth without (7.41 vs. 5.96; Table 4). It is also noted that bifurcation ridges appeared with different extensions along the vertical dimension of the furcation (Figure 2).

In 96% of teeth, root grooves and concavities were found on the mesial aspect of the root, and in 57% they were found on the palatal aspect of the buccal root. The average distance from the cemento-enamel junction to the mesial root groove was 1.63 mm with a range of 0 - 2.45 mm. No grooves were observed on the distal aspects of the roots.

The mean width of the furcation entrance was

**Table 2. Types of root trunk (based on the ratio of root trunk height to root length) and the percentage of each type found in the teeth examined. Types A, B and C are defined as root trunks involving the cervical third of the root length or less, the cervical third to one half the root length, and more than the cervical half of the root's length, respectively.**

Type of root trunk	% of total	Trunk length (mm) Mean $\pm$ SD Range	Root length (mm) Mean $\pm$ SD Range	TL/RL
A	7%	3.47 $\pm$ 1.07 (2.75 - 3.95)	12.1 $\pm$ 0.31 (11.47 - 12.96)	0.24:1
B	46%	5.12 $\pm$ 0.28 (4.25 - 7.36)	12.66 $\pm$ 3.46 (10.04 - 14.74)	0.404:1
C	47%	8.29 $\pm$ 1.2 (5.57 - 12.54)	12.34 $\pm$ 0.08 (9.67 - 15.05)	0.67:1
Total	100%	6.49 $\pm$ 2.16 (2.75 - 11.8)	12.47 $\pm$ 1.13 (10.01 - 14.74)	0.52:1

SD, standard deviation; TL, trunk length; RL, root length

**Table 3. Types of root trunk (based on the ratio of root trunk height to root length) and the percentage of each type found in mesial versus distal roots.**

Trunk Type	Mesial root trunk (n = 100) Mean $\pm$ SD (6.61 $\pm$ 2.45 mm)	Distal root trunk (n = 100) Mean $\pm$ SD (6.38 $\pm$ 2.29 mm)
A	9%	9%
B	45%	50.8%
C	46%	41%

**Table 4. The average mesial and distal root trunk and root length dimensions (mm) in the presence or absence of bifurcation ridges.**

Bifurcation ridge	%	BRL	PRL	Mean RL	MRT	DRT	Mean RT
Presence	37%	12.53	12.40	12.47	7.61	7.19	7.41
Absence	63%	12.65	12.29	12.47	6.02	5.90	5.96

BRL, buccal root length; PRL, palatal root length; MRT, mesial root trunk, DRT, distal root trunk

0.89  $\pm$  0.19 mm with a range of 0.39 - 1.28 mm. Three teeth (3%) had a furcation entrance of less than 0.55 mm, 29% ranged from 0.55 - 0.75 mm, and 68% were more than 0.75 mm.

## Discussion

The majority of maxillary first premolars frequently show dual roots, and even when the teeth are single-rooted, longitudinal grooves are often observed on both the mesial and distal surfaces of the root, suggesting an incomplete separation of the root (Loh, 1998). The results of this study showed that 62 (37.57%) of the maxillary first premolars were single-

rooted, 100 (60.6%) were two-rooted, and three (1.81%) were triple-rooted. Kartal *et al.* (1998) have the most comparable results to our study: they found that the frequency of single-rooted, two-rooted and three-rooted premolars was 37.3%, 61.3% and 1.3%, respectively. Two roots is the most common form, not only in the present study (60.6%) but also in previous reports, varying from 50.6% (Loh, 1998) to 85% (Walton and Torabinejad, 1996).

One of the anatomic variations of multi-rooted maxillary first premolars is the presence of a furcal groove or concavity on the palatal aspect of the buccal root. This groove is described by Lammertyn *et al.*



(2009) as a developmental depression or furcal concavity that starts at a point just apical to the bifurcation and disappears toward the apex. However, Tamse *et al.* (2000) stated that this furcal groove is a morphological and not a developmental entity, as no depression could be found on the buccal aspect of the root. In the present study, we found that 57% of bifurcated maxillary first premolars had a furcal groove on the palatal aspect of the buccal root; this percentage is, however, less than that reported in the literature, which ranged from 62-97% (Gher and Vernino, 1980; Joseph *et al.*, 1996; Tamse *et al.*, 2000; Lammertyn *et al.*, 2009). Although the depth of the groove was not assessed in this study, the mean depth of this groove is reported in the literature to range from 0.36 - 0.46 mm (Joseph, 1996; Tamse *et al.*, 2000; Lammertyn *et al.*, 2009). Therefore, if attachment loss approaches these external root grooves and concavities, they are often difficult to diagnose, and if diagnosed they are difficult to access and debride using either surgical or non-surgical methods. This in turn may affect the progression of attachment loss by harboring bacterial plaque (Matthews and Tabash, 2004). Gher and Vernino (1980) reported that once this groove becomes periodontally involved it presents a major therapeutic problem. It is important to consider the presence of this groove when assessing the prognosis of maxillary first premolars, especially if it had been root canal treated, because its depth has an inverse relation with the palatal dentin thickness (Lammertyn *et al.*, 2009). Therefore, root perforation leading to periodontic-endodontic communication or vertical root fracture is a possibility (Tamse *et al.*, 2000). Vertical root fracture was found to be responsible for 4.3% of endodontic failures, and in 56% of cases it occurred in premolars (Kishen, 2006).

Maxillary first bicuspid also display a groove on the proximal surfaces. These often persist toward the apical region and are associated with a greater loss of attachment than that found around non-grooved teeth (Leknes *et al.*, 1994). In this study, 96% of investigated teeth had proximal root concavities at their mesial aspect, while none of the distal aspects had concavities. In their morphological study of the mesial roots of maxillary first bicuspid, Booker and Loughlin (1985) found that 100% of teeth had mesial root concavities. The mean distance from the cemento-enamel junction to the mesial concavity in the present research was  $1.62 \pm 0.33$  mm, with a range of 0 - 2.45 mm. Lu (1992) investigated the topographical characteristics of root trunk length related to guided tissue regeneration and reported that developmental concavities on the root trunks at the entrances of furcations may prevent complete adaptation of the coronal microstructure of the membrane along their root surfaces. They suggested that subgingival application of guided tissue membranes 1-2 mm below the cemento-enamel junction cannot ensure complete adaptation of

furcation defects with their coronal microstructures in the majority of molars. This needs to be taken into consideration when treating periodontal defects of maxillary bicuspid using guided tissue regeneration. Guided tissue regeneration attempts have been reported to be less successful in maxillary than in mandibular furcations, and least effective at proximal sites of maxillary molars (Pontoriero *et al.*, 1989; Pontoriero and Lindhe, 1995) and premolars (Proestakis *et al.*, 1992).

Another anatomical variation is the dimension of the root trunk, which can be defined as that part of the root complex that extends between the cemento-enamel junction and the furcation entrance. The mean dimension of the root trunk in this study was  $6.49 \pm 2.16$  mm. It was found that type A root trunks comprised only 7% of the examined teeth, while type B and C were more dominant, comprising 46% and 47% respectively. Based on this, it can be noted that the entrance of the furcation in more than 90% of teeth is located further apically than the cervical third of the root. The dimensions of the root trunk should be taken into consideration in the diagnosis, treatment planning and assessment of the prognosis of multi-rooted maxillary first premolars.

Some reports indicate that the mandibular first molars are the most common sites for furcation involvement and the maxillary premolars are the least common (Larato, 1970). While this may be true, furcation diagnosis of maxillary premolars seems to be difficult because of many factors that limit access to the furcation, such as root trunk length and the presence of bifurcational ridges. In addition to difficulty in radiographic detection of maxillary furcations because of superimposition of the palatal root, Pepelassi *et al.* (2000) compared the size and appearance of osseous defects when evaluated radiographically (from both panoramic and periapical radiographs) and upon surgical exposure. They reported that the mean surgical depth of the osseous defects was statistically significantly different from the mean depth assessed radiographically, and that the defect depth was greatest in maxillary premolars and least in lower anterior teeth.

Because of the reasons mentioned above, the clinical assessment of a furcation involvement in maxillary premolars is often difficult even after elevation of a soft tissue flap. Therefore, it is recommended to apply all possible clinical and radiographic diagnostic tests to identify the configuration of the roots and furcation of maxillary premolars. It might be necessary to probe mesially and distally with a furcation probe, both from the buccal and palatal aspect, and take more than one periapical X-ray with different angulations.

Root resection of premolars is possible only in rare instances because of the anatomy of the root complex (Joseph *et al.*, 1996). This could be in case of a short root trunk, long roots and a wide furcation entrance

with no evidence of bifurcational ridges, and the feasibility of endodontic treatment. For this tooth (maxillary first premolar), the furcation is often located at such an apical level that the maintenance of one root serves no significant purpose. The length and the shape of the root cones are among the factors considered prior to root resection. Short, small roots should consequently be regarded as poor abutments for prosthetic restorations. In this investigation, the buccal root appeared slightly longer than the palatal root (12.6 mm vs. 12.3 mm). A case of traumatic non-deliberate hemi-section was described by Rapoport and Deep in 2003 as the first documented report to detail the restoration of a hemi-sectioned maxillary first premolar.

Furcation entrance dimension is of paramount importance for successful therapy, as it affects the feasibility of gaining access to the inter-radicular area with mechanical instruments. The results of this study revealed that the mean width of the furcation entrance was  $0.89 \pm 0.19$  mm, with a range of 0.39 - 1.28 mm. Joseph *et al.* (1996) reported the mean width of the furcation entrance of maxillary first bicuspids to be 0.71 mm, and that 57% of the furcation entrance widths were less than 0.75 mm. Dos Santos *et al.* (2009) measured the blade width of different curettes (McCall 17–18, Gracey 5–6 and Gracey 5–6 mini-five) and found that the mean blade widths for these curettes ranges from 0.63 - 1.02 mm. This research revealed that 3% of the examined teeth had a furcation entrance of less than 0.55 mm, 29% range between 0.55 - 0.75, and 68% were greater than 0.75 mm, compared to molars, where the width of the furcation entrance is less than 0.75 mm in 63% of upper and 50% of lower molars (Bower, 1979). Therefore, with regard to the diameter of the furcation entrance, maxillary first premolars furcations are more accessible to debridement than maxillary and mandibular molars. Gracey 13/14 and 11/12 curettes are particularly well suited for multi-rooted premolars as well as in furcations and depressions (Rateitschak *et al.*, 1989). Ultrasonic inserts may then have easier access to furcation areas than curette blades, especially in deep furcation involvements. Matia *et al.* (1986) found that the width of the furcation entrance influences the efficacy of scaling and root planing after flap reflection, and that the use of ultrasonics gives better results in narrow furcation areas.

Little is described in the literature about bifurcation ridges; most information is obtained from a study done by Everett *et al.* (1958), who studied the morphology of the bifurcation of mandibular first molars. Bifurcation ridges are described as anatomical structures that run across the bifurcation between the roots, and they are of two types: intermediate bifurcational ridges (distinct ridges running across the bifurcation in a mesiodistal direction), and bucco-lingual bifurcational ridges (run across the buccal and lingual roots (Everett *et al.*, 1958).

These ridges, found in 70-73% of mandibular molars, create niches for plaque accumulation and affect the ease of access to the exposed bifurcation (Everett *et al.*, 1958; Novaes Jr *et al.*, 2005). Intermediate bifurcational ridges are formed primarily by cementum; however, some sections have a basis of dentine on which the extensive cementum deposition occurs. Bucco-lingual ridges, on the other hand, are mainly composed of dentine covered by a small amount of cementum. Odontoplasty should be considered in the presence of severe bifurcation ridges to ensure proper root surface preparation (Mardam-Bey *et al.*, 1991). The use of rotary diamond instrumentation has been proposed to overcome the problem of accessibility in concavities and ridges (Rateitschak *et al.*, 1989).

In the present study bifurcation ridges (bucco-palatal) were observed in 37% of the teeth and appeared at different levels along the vertical dimension of the furcation. Once periodontitis involves the furcation, the presence of these ridges may affect the diagnosis, treatment planning, and prognosis of the furcation defect. Misdiagnosis of the furcation degree is possible in case of the presence of bifurcation ridges. The shape of the bifurcation ridge between the buccal and palatal roots may resemble a three-walled space that may be helpful for regenerative therapy. Further research is advised in this aspect: first, to confirm whether these ridges are composed of dentine or cementum; and second, to determine if regeneration is possible in such cases.

Therefore, the decision to try to save or to extract periodontitis-affected maxillary first premolars requires clinical decision-making and treatment strategies. In most cases, the presence of a deep furcation involvement to the second or third degree in a maxillary first premolar calls for tooth extraction (Carnevale *et al.*, 2003). However, with advanced magnification, there are exciting new possibilities as novel techniques and instruments are developed to meet the needs of this growing segment of dental treatment (Shourie *et al.*, 2011).

In addition to the anatomical features of the teeth that were investigated in the present study, it is worth mentioning other features that were noted. First, displayed gingiva around the first premolars during smiling was found in 44% of subjects (Kapagiannidis *et al.*, 2005). Second, the maxillary sinus was radiographically evident in about 50% of first premolar sites (Pramstraller *et al.*, 2011). Third, the extent of gingival recession was greatest for midbuccal sites on mandibular and maxillary premolars (Thomson *et al.*, 2000). Fourth, the average width of the attached gingiva at the maxillary first premolar area was 1.9 mm (Ainamo and Löe, 1996).

Clinical research is the best way to assess the effect of root morphology on the diagnosis and management of periodontal disease. However, knowledge gained from this study may provide an insight to the

configuration of the root complex that might predict the course of the disease or modify our treatment plan. Previous research has been mainly concerned with the root surface anatomy of molars, with very few reports published concerning premolars. This was the reason for conducting this study.

In conclusion, most of the anatomical features investigated in this study are not favorable to achieving a good prognosis for periodontal defects associated with maxillary first premolars. However, knowledge about the anatomical and morphological variations of roots may help in achieving better clinical practice in the field of periodontal therapy.

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