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Evaluation of facial alveolar bone thickness and fenestration of the maxillary premolars

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ABSTRACT

Objective: The objective of this study was to retrospectively investigate the facial alveolar bone (FAB) thickness and fenestration rate of maxillary first and second premolars using cone-beam computed tomography (CBCT).
Design: A total of CBCT images of 66 patients were selected and 200 maxillary premolar (100 first and 100 second premolar) were included. The FAB thicknesses were measured at 1,3 and 5 mm apical to the alveolar bone peak. The prevalence of fenestration in maxillary premolars was recorded. The statistical analyses were performed.
Results: The FAB thicknesses of the second premolars (1.39 mm at 1 mm, 1.42 mm at 3 mm, and 1.22 mm at 5 mm) were significantly higher than the first premolars (1.11 mm at 1 mm, 0.70 mm at 3 mm, and 0.48 mm at 5 mm) at 1, 3, and 5 mm levels ($p < 0.05$). The lowest prevalence (1 %) of the thickness of FAB $\geq$ 2 mm was in the first premolar has at 5 mm apical of the alveolar bone peak. The overall prevalence of fenestration in maxillary premolars was found as 30.5 %. There was a statistically significant difference between first and second premolars ($p < 0.05$).
Conclusion: The FAB thicknesses are lower in the first premolar than the second premolar. The lowest FAB thickness was in the first premolar at 5 mm apical of the bone crest as 0.42 mm. The prevalence of fenestration in maxillary premolars was higher in the Turkish subpopulation than in other populations. Fenestration was more common in the maxillary first premolar.

1. Introduction

The facial alveolar bone (FAB) width has a crucial impact on the soft and hard tissue response to extraction, implant placement, periodontal surgery, and orthodontic treatment. The inevitable changes including bone remodeling and resorption observed in the facial alveolar bone affect the results of the treatments involving the esthetic zone (Caiazzo et al., 2013). When the thickness of the FAB is less than 2 mm, significant changes in bone volume are observed due to the resorption (Tomasi et al., 2010). Furthermore, when the thickness of FAB is less than 1 mm, a mean bone loss was 7.5 mm after extraction, while in the case of more than 1 mm, it has been observed to be only 1.1 mm (Chappuis et al., 2013). Besides, the thickness of FAB may contribute to the risk factor of fenestration (Coşkun & Kaya, 2019; Tomasi et al., 2010).

Fenestration is a circumscribed type of alveolar defect that results in exposure of the root surface characterized by the absence of cortical bone, and generally occurs as bilateral defects and can be seen as a window-like aperture (Lindhe & Lang, 2015). Fenestration is also defined as a physiological anatomical variation concerning the health of pulp, periodontium, and oral mucosa as it provides communication pathways to these regions (Boucher et al., 2000). American Association of Endodontists defines fenestration as a window-like aperture exposing a portion of the root and generally located on the buccal aspect of the root (AAE, 2003). In fenestration, the denuded root area does not involve bone margin and is covered only by gingiva and underlying periosteum (Newman et al., 2018). Numerous potential etiological factors for fenestration have been identified, including periodontal or endodontic pathology, bruxism, root position and curvature, thin bone plate, an orthodontic force beyond a normal limit, and occlusal trauma (Jhaveri et al., 2010; Nimigean et al., 2009; Zachrisson & Alnaes, 1973).

Abbreviations: FAB, facial alveolar bone; CBCT, cone-beam computed tomography.

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Owing to the low alveolar support of the tooth, periodontal diseases that already create bone loss induce devastating effects on these teeth and their periodontium (Årtun & Urbye, 1988; Zachrisson & Alnaes, 1973). The alveolar bone should be well examined in terms of the thickness of FAB and the presence of bone defects like fenestration to predict the esthetic results of dental treatments such as periodontal surgery or implant treatment.

Cone-beam computed tomography (CBCT) enables three-dimensional examination of dentoalveolar structures and determination of alveolar bone thickness via multiplanar visualization (Kumar et al., 2015). Numerous studies have used CBCT to investigate the quantity of alveolar bone (Castro et al., 2016; Vera et al., 2012; Wang et al., 2014). Depending on its low radiation dose and compact size equipment, CBCT is routinely used in dentistry and provides high-quality and detailed images of the bone structure (Rojo-Sanchis et al., 2017; Zekry et al., 2014). Therefore, the authors have investigated bone thickness and the presence of fenestration using CBCT.

Previous studies have generally focused on examining the FAB widths and the fenestrations of maxilla incisors and canines (Botticelli et al., 2004; Ghassemian et al., 2012; Nowzari et al., 2012). However, maxillary premolars are displayed in an average smile line and they are considered the esthetic zone variables (Wang et al., 2018). In the literature, there are few studies analyzing the FAB thickness and the fenestration in first and second premolars (Enhos et al., 2012; Nimigean et al., 2009; Vera et al., 2012; Wang et al., 2014). The FAB thickness has been reported 0.60–2.42 mm in maxillary premolars (Braut et al., 2011; Ganji et al., 2019; Rojo-Sanchis et al., 2017; Temple et al., 2016; Vera et al., 2012; Zekry et al., 2014). In addition to this, there are contradictory results in the literature regarding the coronal to apical thickening of the FAB in the maxillary anterior region (Ghassemian et al., 2012; Nowzari et al., 2012; Zekry et al., 2014). The pattern of FAB thickness throughout the root of the tooth is important for the immediate implant placement, or for the movement of the tooth in orthodontic treatment. Nonetheless, no clear data has been stated in the literature regarding the pattern of FAB thickness along the root (Zekry et al., 2014). On the other hand, there is limited data on fenestration rates of maxillary premolars examined with CBCT (Rojo-Sanchis et al., 2021). Most of the studies are focused on the dry skull to examine bone topography. However, there are critical concerns about the investigations using dry skulls, which is the misdirection of the damage or abrasion (Nimigean et al., 2009; Rupprecht et al., 2001). The present retrospective study aimed to investigate the facial bone thickness of maxillary first and second premolars using CBCT and to examine the frequency of fenestration in the maxillary premolar teeth in the Turkish subpopulation. The null hypotheses of this study were that [1] there is no difference between the facial alveolar bone thicknesses of the first and second maxillary premolar and [2] there is no difference between the presence of fenestration among these teeth.

2. Materials and methods

The present study was approved by the local ethics committee (#576). The study was performed in accordance with the Helsinki Declaration of 1975, as revised in 2000. For the study, CBCT images of 101 patients from Turkish subpopulation who attended a university dental clinic between June 2018 and July 2019 were referred for CBCT examination for various indications (implant treatment, removal of an impacted tooth, cyst enucleation) retrospectively examined. Images of the patients were retrospectively evaluated. Inclusion criterion was the non-smoking patient without systemic disease, with periodontal health, and normal occlusion, the presence of at least one maxillary premolar with completion of root formation. Normal occlusion was regarded as Angle Class I occlusion with no crowding and crossbite, a normal overjet, and overbite (between 1 mm and 3 mm), and no facial asymmetry. Teeth with intact enamel were included. In addition, for the study, only the maxillary premolars that have the antagonist and adjacent teeth were included. CBCT images belonging to native Turkish patients were included for the study. Exclusion criteria were patients with previous orthodontic treatment and maxillary premolars with endodontic treatment, decayed, restoration, and undeveloped root with a wide-open apex. Occlusal wear and erosive or traumatic cervical defects were excluded. Besides, patients with a history of trauma were excluded from the study. CBCT images of poor quality and artifacts were also excluded from the study. To determine the sample size, a power analysis was performed with 0.38 effect size, alfa errs 0.05, and power of 0.95, using the software of G*Power 3.1 (Heinrich–Heine–Universität, Düsseldorf, Germany) (Nowzari et al., 2012). A total of 200 first ($n = 100$) and second ($n = 100$) maxillary premolars were selected for the study. All of the first premolars included in the study have two roots, and all of the second premolars have single roots.

For the review of the literature, Scopus, ScienceDirect, Pubmed, and Web of Science databases were researched with the keywords of "maxillary premolar" and "fenestration", selecting only the publication that was pressed in the English language. There was no restriction on the publication date. The data that belonged to different populations and different methodologies were selected.

2.1. Radiographic image analysis

CBCT images were taken from Orthophos (Sirona Dental Systems, Bensheim, Germany). Imaging parameters were set as 85 kVp, 6 mA, 14.1 sn exposure time, 0.2 mm voxel size, and 80 × 40 mm field of view. Imaging parameters were determined according to the “as low as reasonably achievable” (ALARA) principle. The images were constructed and analyzed using Horos 3.0 software (Horos Project, Annapolis, Maryland USA).

The bone thickness measurements were performed at the same magnification and the same slice by two observers (a 10-year experienced periodontist and a 5-year experienced endodontist) independently blind to the patient’s data. Prior to the measurements, two observers were calibrated with the evaluation of 20 of the images, and the kappa score was stated (range from 0.91 to 0.93). Besides, all measurements were performed twice by one observer, and the averages were accepted for statistical analysis. Three subjects were measured at one time, after every three measurements, a break was made to eliminate the eye fatigue of observers. For the interclass and intraclass correlation, all images were measured one week apart.

To locate the slice to be measurements performed, the axial guided navigation method was used (Fig. 1) (Castro et al., 2016). The axial plane was taken as a guide for the coronal plane to achieve an optimal determination of buccal bone thickness. In the axial plane, the buccolingual trace was calibrated to the middle of the root and subsequently, the long axis of the root was detected in the sagittal plane. In the two-rooted premolars, the long axis of the root was determined according to the apex of the buccal root. The measurements of the buccal bone thicknesses were performed in the coronal section at 1 mm, 3 mm, and 5 mm apical to the bone peak point, respectively (Figs. 2 and 3). The buccal bone thickness was defined as the line between the root surface and the outer border of the alveolar bone. Fenestrations detected in two-dimensional axial sections were confirmed by three-dimensional reconstructions (Fig. 4).

2.2. Statistical analysis

Statistical analysis was performed using SPSS version 22.0 for Windows (IBM Corp., Armonk, NY, USA). The mean, maximum, minimum, and standard deviation of the quantitative variables were assessed. The normality distribution of the obtained data was analyzed by the Kolmogorov-Smirnov test. One-way ANOVA was used to compare the numeric data between the bone thicknesses of first and second premolars. To define differences between groups, Dunnett’s test as a post hoc, was used for multiple comparisons. Differences between

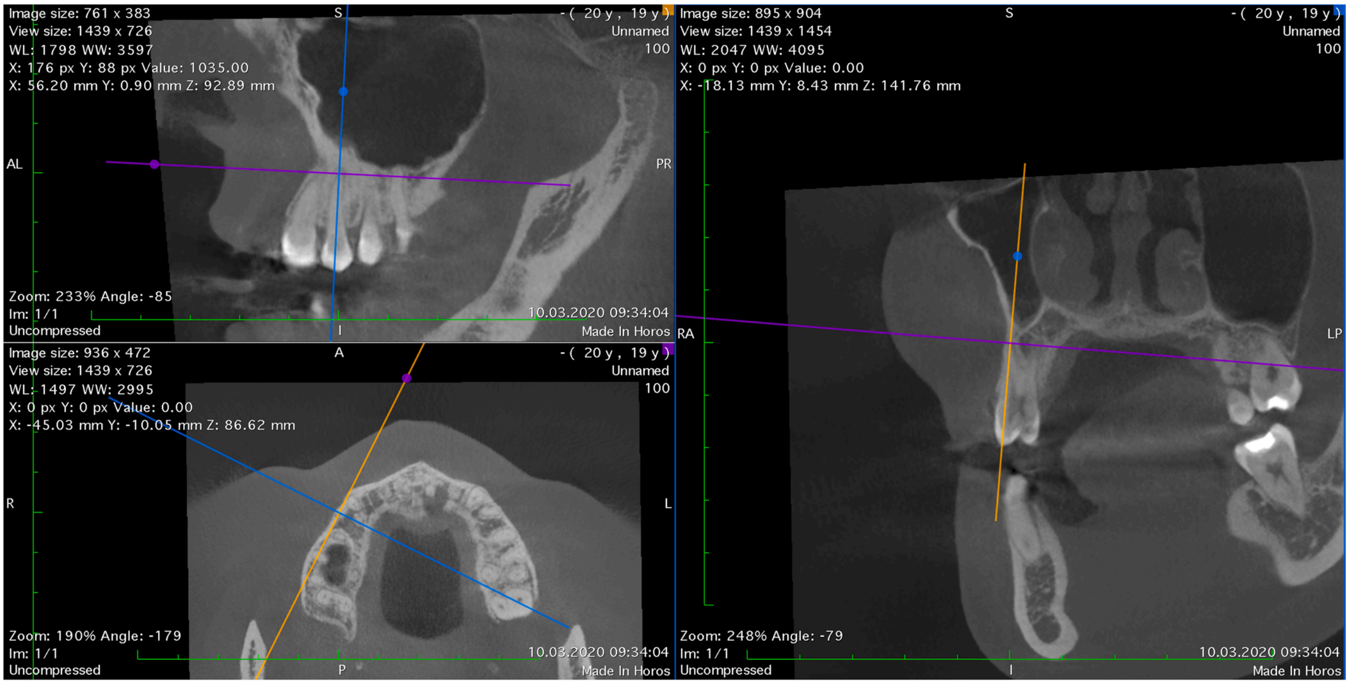

Fig. 1. Cone beam computed tomography (CBCT) images in sagittal, coronal, and axial planes in using the axial navigation method for each premolar tooth individually.

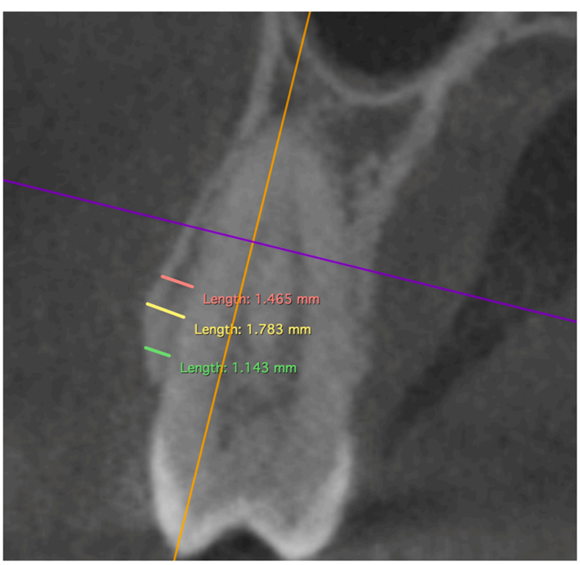

Fig. 2. Facial alveolar bone (FAB) thicknesses of second maxillary premolar at three different bone levels (1 mm, 3 mm, and 5 mm).

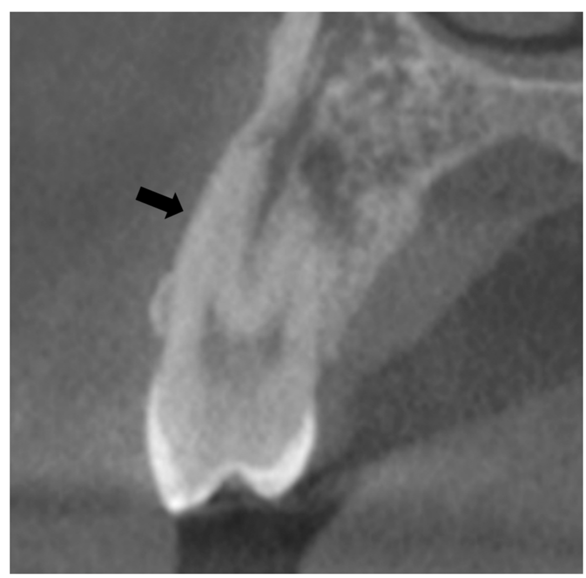

Fig. 3. Cone beam computed tomography (CBCT) image showing fenestrations in maxillary second premolar in coronal planes.

fenestrations were examined using the chi-square test. In statistical tests, differences were considered statistically significant for ($p < 0.05$) with a 95 % confidence interval. Intraclass correlation coefficient (ICC) was used for intra-observer and inter-observer reliability ($p < 0.001$).

3. Results

The study group consisted of 66 patients (36 females and 30 males) aged 25–45 years (mean age: 34 ± 2). The mean thicknesses of FAB in maxillary first premolars at 1 mm, 3 mm, and 5 mm apical to the alveolar bone peak, were found to be 1.11 mm, 0.70 mm, and 0.42 mm, respectively. The mean thickness of FAB in maxillary second premolars at 1 mm, 3 mm, and 5 mm apical to the alveolar bone peak, were found to be 1.39 mm, 1.42 mm, and 1.22 mm, respectively (Table 1). The thickness of FAB in the maxillary first premolar was significantly lower than in the maxillary second premolar at 1 mm, 3 mm, and 5 mm levels ($p < 0.05$). There is no statistical difference in the thickness of FAB between different bone levels in the second premolar ($p > 0.05$), while there is a significant difference in the first premolar ($p < 0.05$). The lowest thickness of FAB was observed in first premolars at 5 mm apical to the alveolar bone peak ($p < 0.05$).

The prevalence of the FAB thickness ≥ 2 mm in maxillary premolars ranged from 1 % to 19 %. The lowest prevalence (1 %) of the thickness of FAB ≥ 2 mm was in the first premolar at 5 mm apical of the alveolar bone peak. The highest prevalence (19 %) of the thickness of FAB

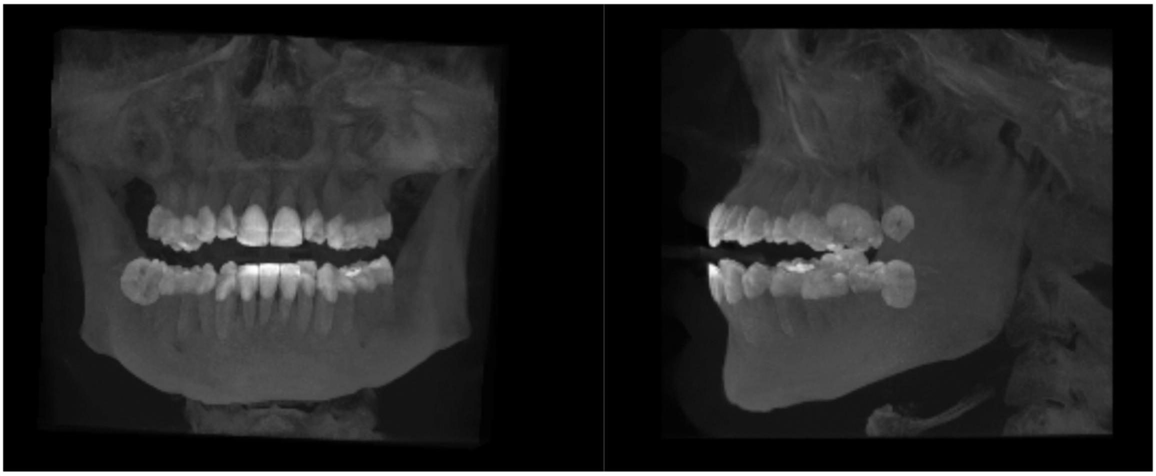

Fig. 4. Three-dimensional reconstruction in cone beam computed tomography (CBCT) for detection of fenestrations (arrow: fenestration).

Table 1
The facial alveolar bone thicknesses of left and right first and second premolars at the level of 1, 3, and 5 mm from bone crest (in mm).

Distance From Bone Crest	Tooth	Total Population				Female				Male			
		Mean	Std (±)	Min.	Max.	Mean	Std (±)	Min.	Max.	Mean	Std (±)	Min.	Max.
1 mm	14	$1,12^{a}$	1,05	0,32	2,99	1,02	0,41	0,21	2,18	1,03	0,53	0,32	2,99
	15	$1,44^{b}$	0,54	0,51	2,67	1,4	0,57	0,51	2,67	1,43	0,47	0,73	2,59
	24	$1,10^{a}$	1,34	0,32	2,99	0,94	0,56	0,33	2,89	0,96	0,42	0,32	2,14
	25	$1,34^{b}$	0,52	0,32	2,67	1,3	0,42	0,57	2,89	1,43	0,61	0,32	2,67
3 mm	14	$0,75^{c}$	0,54	0	2,55	0,79	0,57	0	2,55	0,74	0,59	0	2,06
	15	$1,52^{b}$	0,69	0	3,80	1,5	0,64	0,54	3,01	1,56	0,74	0	3,08
	24	$0,66^{c}$	0,50	0	1,96	0,61	0,46	0,54	1,57	0,64	0,43	0	1,53
	25	$1,33^{b}$	0,68	0	2,78	1,25	0,66	0	2,67	1,52	0,76	0,36	2,85
5 mm	14	$0,47^{d}$	0,51	0	1,71	0,44	0,49	0	1,45	0,53	0,59	0	2,02
	15	$1,31^{b}$	0,80	0	3,07	1,13	0,75	0	2,76	1,4	0,8	0	3,07
	24	$0,38^{d}$	0,51	0	1,74	0,36	0,47	0	1,49	0,36	0,5	0	1,66
	25	$1,14^{b}$	0,73	0	2,92	1,08	0,75	0	2,92	1,28	0,76	0	2,88

Different superscripts in column showed statistical differences according to the one-way ANOVA test ($p < 0.05$). 14,15: first and second right premolar. 24,25: first and second left premolar.

≥ 2 mm was in the second premolar at 3 mm apical of the alveolar bone peak (Table 2).

The overall prevalence of fenestration in maxillary premolars was found as 30.50 % (Table 3) in Turkish subpopulation. The prevalence of fenestration was significantly higher in maxillary first premolar (52 %) than in second premolar (9 %) ($p < 0.05$). The fenestration rate in maxillary first premolars was found as 20 % at 3 mm apical to the alveolar bone peak, and 52 % at 5 mm apical to the alveolar bone peak. For the second premolar, these results were 2 % and 9 % for the 3 mm and 5 mm apical to the bone peak, respectively. Fenestration was not observed in the right and left premolars at 1 mm apical to the vestibular bone. In regards to the location of the fenestration, 76% of the overall recorded fenestrations in all maxillary premolars were observed in the apical half of the root. No statistically significant difference was detected in the prevalence of fenestration between right and left premolars or between males and females ($p > 0.05$).

The ICC for the measurements of the facial bone thickness of maxillary first and second premolars were ICC= 0.983 and ICC= 0.992, respectively. There was no statistical difference between the intra-observer and inter-observer in the measurement values ($p > 0.05$).

Table 2
The frequency distribution of the facial alveolar bone thicknesses ≥ 2 mm in left and right first and second premolars at the level of 1, 3, and 5 mm from bone crest (in mm).

Distance From Bone Crest	Facial Bone > 2 mm (%)			
	14	15	24	25
1 mm	2 (4 %)	7 (14 %)	3 (6 %)	6 (12 %)
3 mm	3 (6 %)	10 (20 %)	0 (0 %)	9 (18 %)
5 mm	1 (2 %)	9 (18 %)	0 (0 %)	9 (18 %)
Total	6 (12 %)	26 (52 %)	3(6 %)	24 (48 %)

14,15: first and second right premolar. 24,25: first and second left premolar.

Table 3
The frequency distribution of fenestrations in left and right first and second premolars at the level of 1, 3, and 5 mm from bone crest (in mm).

			Fenestration (%)			
		Tooth	1 mm	3 mm	5 mm	Total
First Premolar	52 %	14	0 (0 %)	10 (20 %)	24 (48 %)	24 (48 %)^{a}
		24	0 (0 %)	10 (20 %)	28 (56 %)	28 (56 %)^{a}
Second Premolar	9 %	15	0 (0 %)	1 (2 %)	4 (8 %)	4 (8 %)^{b}
		25	0 (0 %)	1 (2 %)	5 (10 %)	5 (10 %)^{b}

Different superscripts in column showed statistical differences according to the chi-square test ($p < 0.05$). 14,15: first and second right premolar. 24,25: first and second left premolar.

4. Discussion

Quantitative data and morphology of the FAB in the maxillary premolar region are substantial parameters for a multi-disciplinary approach and need a detailed examination. Previous studies have generally focused on the maxillary anterior region and there is limited data about the FAB thickness and the presence of fenestration in maxillary premolars, which are a part of the aesthetic zone (Botticelli et al., 2004; Ghassemian et al., 2012; Nowzari et al., 2012; Zekry et al., 2014). In our study, we evaluated the topographic properties of the bone in the maxillary premolar region and used an integrated approach including FAB thickness, the presence of fenestration, location of fenestration, and comparison of the FAB thickness to the threshold of < 2 mm. According to the results of the present study, the first null hypothesis was rejected. The thickness of FAB was greater at the second premolar compared to the first premolar. This result of the present study is consistent with the former studies of Rojo-Sanchis et al. (2017) in Spanish population, Vera et al. (2012), in Dominican population, Zerky et al. (2014) in Chinese population and Temple et al. (2016) in North American population which investigate the FAB width of maxillary premolars. On the contrary, another previous study conducted in the Saudi Arabian population demonstrated lower FAB thickness in second premolar (Ganji et al., 2019). Besides ethnic factors, these findings are explained by the fact the different morphology, number, and inclination of the root of the maxillary premolars. We included the first premolar with only one buccal root and the second premolars with one root and found the FAB thickness is less at the first premolar. Root morphology and width or canal configuration can be affected the FAB thickness. This is important when the presence of endodontic infection. FAB thickness directs the spread of infection. In addition to this, root and bone morphology must be analyzed before orthodontic treatment in terms of understanding the limits of treatment.

In terms of the values of FAB thickness, our results were 0.42–1.11 mm in the first premolar, and 1.22–1.42 in the second premolars. There was no distinct discrepancy between the studies performed in various populations, which reported the range of FAB thickness in the first and second premolar was 0.60–2.43 mm (Braut et al., 2011; Ganji et al., 2019; Rojo-Sanchis et al., 2017; Temple et al., 2016; Vera et al., 2012 Zerky et al., 2014). In a recent meta-analysis, the FAB thickness in the first premolar was shown as 0.65 mm at 5 mm from the alveolar bone peak, and 0.51 mm at mid-root (Rojo-Sanchis et al., 2019). However, contrary to the literature, our study showed a thinner FAB thickness at the 5 mm level as 0.42 mm. In our study, the pattern of the FAB thickness in the first and second premolars from the alveolar bone peak to the apical were also revealed; while there is a more considerable decrease in the FAB width of the first premolars towards the apical, the FAB width is more stable in the second premolars. This result is in agreement with the study of Zekry et al. (2014) in Chinese population reported a more consistent FAB width in second premolars compared to the first premolar.

The thickness of FAB ≥ 2 mm is an essential criterion for implant surgery and concerning the survival rate of the implant. As a part of the biological process after extraction, the diminishment in the horizontal and vertical dimensions of the bone will also affect the esthetic outcomes of the implant treatment (Grunder et al., 2005). Therefore, it is mandatory to identify regions where the bone thickness is less than 2 mm for maxillary premolars. The present study reported that the lowest prevalence (1 %) of the thickness of FAB ≥ 2 mm was in the first premolar has at 5 mm apical of the alveolar bone peak. In addition to this, we found the FAB thickness > 2 mm was 28 % in the Turkish population, similarly, a previous study conducted in the Portuguese population showed the FAB thickness > 2 mm was 22 % (López-Jarana et al., 2018). The ethnic factors affected the different parameters of the topography of FAB, to better understand the influence of racial origin, comprehensive further studies are needed.

The present study reported the prevalence of fenestration as 30.5 % in Turkish population. Root and crown anatomy, root position, the pressure on the tooth during the mastication cycle, properties of occlusion, and morphologically thin bone areas seem to be more prone to resorptive defects like fenestration. Pan et al. (2014) found that the highest fenestration rate in the maxilla was in the maxillary first premolar (10.46 %) instead of the first molar (6.13 %) contrary to most studies (Abdelmalek & Bissada, 1973; Edel, 1981; Rupprecht et al., 2001). The first premolar has clinical importance both because it is in the aesthetic zone and because of the number and location of the roots in the alveolar bone. Previous studies using dry skulls reported the prevalence of fenestrations in maxillary premolar teeth ranging from 0.50 % to 14 % in different ethnic groups and the other studies using CBCT reported the fenestration rate ranging from 1.35 % to 36.78 % in different populations (detailed in Table 4) (Abdelmalek & Bissada, 1973; Davies et al., 1974; Edel, 1981; Grimoud et al., 2017; Jorgić-Srdjak et al., 1998; Larato, 1974; Nimigean et al., 2009; Pan et al., 2014; Volchansky & Vieira, 1981; Yagci et al., 2012). In the present study, the prevalence of fenestrations in first and second premolars was found at 52 % and 9 %, respectively. The results of our study differ from those of previous investigations (detailed in Table 4) (Abdelmalek & Bissada, 1973; Davies et al., 1974; Edel, 1981; Grimoud et al., 2017; Jorgić-Srdjak et al., 1998; Larato, 1974; Nimigean et al., 2009; Pan et al., 2014; Volchansky & Vieira, 1981; Yagci et al., 2012). This inconsistency can be explained by racial origin or the research methodology. However, to confirm the effect of the racial factors, the results of further studies with a larger sample size need to support our retrospective study that has a smaller sample size. Since the etiology of fenestration may be due to hereditary and developmental factors, inconsequently, the prevalence of fenestration may be directly related to racial origin. Yagci et al. (2012) investigated the prevalence of fenestration according to class I, II, and III malocclusions using CBCT and stated that the prevalence of fenestration in first and second premolar, 36.78 %, and 9.19 %, respectively in class I group in the Turkish population (Yagci et al., 2012). The fact that the percentages of this study, compared to other previous studies, are closer to that of our results confirms the influence of racial factors.

Previous studies have shown that the frequency of fenestration in the first premolars is higher than in the second premolars (Abdelmalek & Bissada, 1973; Davies, Downer, Hull, & Lennon, 1974; Edel, 1981; Grimoud, Gibbon, & Ribot, 2017; Larato, 1970; Nimigean et al., 2009;

Table 4
Previous studies about the prevalence of fenestration in first and second maxillary premolars.

Study	Methodology	Racial origin	Sample size (No. of maxilla)	The prevalence of fenestration	
				First premolar	Second premolar
Larato et al. (1970)	Dry skull	Mexican-Indian	108	5.5 %	0.5 %
Abdelmalek & Bissada (1973)	Dry skull	Egyptian	61	5.7 %	1.8 %
Davies et al. (1974)	Dry skull	British	398	7.6 %	4 %
Volchansky & Vieira (1981)	Dry skull	South African	100	4 %	2 %
Edel (1981)	Dry skull	North African	37	10 %	9.8 %
Jorgić-Srdjak et al. (1998)	Dry skull	North-Western Croatian	78	10 %	11 %
Nimigean et al. (2009)	Dry skull	South-East European	138	14 %	6 %
Yagci et al. (2020)	CBCT	Turkish	142	36.78 %	9.19 %
Pan et al. (2014)	CBCT	Chinese	306	10.46 %	1.35 %
Grimoud et al. (2017)	Dry skull	Medieval French	43	15.5 %	5.9 %
Our results	CBCT	Turkish	66	52 %	9 %

Pan et al., 2014; Rupprecht, Horning, Nicoll, & Cohen, 2001; Volchansky & Vieira, 1981; Yagci et al., 2012). This result is consistent with our study, which detected statistically higher fenestration in the first premolars. The second null hypothesis stating that there is no difference between fenestration rates of first and second premolars was also rejected. This conclusion can be attributed mainly to the difference in number and morphology between the roots of the maxillary first and second premolar. The Journal of Periodontology Glossary of Terms (2001), reported that defects such as dehiscence and fenestration generally concern the roots of teeth in prominent positions in the dental arch (American Academy of Periodontology Glossary of Periodontal Terms, 2001). Hence, the high prevalence of fenestrations in the first premolars compared to second premolars may be related to the prominent location of the root in combination with an overlying thin bone plate of the first premolars. This result is also consistent with the present study, which confirmed that the location with the lowest prevalence of bone thickness of more than 2 mm is the location with the highest rate of fenestration.

In the present study, 76 % of the fenestrations in maxillary premolars were observed extending from the middle third to the apical third. The results of distribution with regard to the apical-coronal location of fenestrations in maxillary premolars that were reported in the present study were congruent with that of the literature, where fenestrations were more commonly present in the apical third of the root (Nimigean et al., 2009; Pan et al., 2014; Rupprecht et al., 2001). Edel et al. (1981) reported that 89 % of the fenestrations in the maxilla were at the apical half of the root. Rupprect et al. (2001) reported that while 92 % of the fenestration in the maxilla were at the apical, 72.8 % of the overall fenestrations were at the apical third of the root. As concluded in most studies, although fenestrations were most commonly in the apical region, no apical pathology or clinical symptom was detected involving the fenestration. This result may be related to the nutrition of pulp from periodontal tissues. In our study, the overall prevalence of fenestration in maxillary premolar (%30.50) is higher than in other previous studies. However, there is not enough information on the prevalence of fenestration in the Turkish subpopulation. Further research is needed to investigate the fenestration and dehiscence on skulls to reveal racial characteristics. Even though most studies that investigate fenestration were on skulls, this method does not provide clinical information, the thin extension of alveolar plates may have been physically damaged resulting in a *post-mortem* artifact that interferes with the result of the investigation. Therefore, further studies with larger samples involving clinical data using CBCT are needed.

The accuracy of CBCT to detect bone defects was investigated, and it demonstrated that CBCT can cause false-positive results (Leung et al., 2010; Sun et al., 2015). A previous study reported the prevalence of dehiscence and fenestration defects three times higher in indirect examinations by CBCT than a direct examination by the skull (Leung et al., 2010). However, in the present study, the voxel size was 0.20 mm. Unfortunately, to the literature knowledge, it is not possible to obtain optimal accuracy for the detection of bone defects by a voxel size larger than 0.30 mm (Sun et al., 2015). In our study, the measurements were performed with 0.20 mm voxel size, which provides higher resolution, this means that the rate of bone defect that exists clinically was detected more accurately compared to this study. Nevertheless, in our study, as a limitation, bone thicknesses $\leq$ 0.20 mm are going to go undetected and be assumed a bone defect area.

Limitations of this retrospective study include the low sample size and the use of CBCT to measure the bone thickness and evaluate fenestration. The strength of this study is that it is one of the few studies that examine bone thickness and defects of maxillary premolars, which also belong to the aesthetic region, contrary to numerous previous studies that generally focus on maxilla anterior teeth as an esthetic region. Further research is needed to investigate the bone thickness in the maxillary premolars in larger sample size and using direct measurement methods.

5. Conclusion

Within the limitation of this retrospective study, our results showed that the thickness of FAB is lower at the first premolar than at the second premolar. The lowest prevalence of bone thickness of more than 2 mm (1 %) was observed at 5 mm level of the first premolars. The highest prevalence of bone thickness of more than 2 mm (19 %) was observed at 3 mm to apical of the second premolars. Fenestration was more common in the maxillary first premolar compared to the second premolar. Also, 70 % of fenestration was located in the apical half of the root. Detailed CBCT examination is recommended in periodontal or implant surgery of maxillary premolars for the presence of fenestration defects or bone thickness.

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CRediT authorship contribution statement

Deniz Yanık: Conceptualization, Design, Acquisition of data, Analysis and Interpretation of data, Writing – original draft. **Ahmet Mert Nalbantoğlu:** Conceptualization, Design, Acquisition of data, Analysis and Interpretation of data, Writing – original draft, Visualization.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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