Original Article

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Morphometric Analysis of the Foramen Palatinum Majus by Cone-beam Computed Tomography

Foramen Palatinum Majus'un Konik Işınlı Bilgisayarlı Tomografi ile Morfometrik Analizi

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ABSTRACT

Objective: The aim of this study was to detect possible variations of the foramen palatinum majus (FPM), by imaging with cone-beam computed tomography (CBCT), and to make a morphometric comparison of FPM in dentate and edentulous individuals.

Methods: In the study, CBCT recordings of 250 individuals, 125 dentate and 125 edentulous individuals, in the archive of the Faculty of Dentistry, Oral and Maxillofacial Radiology were retrospectively analyzed. The diameter of the FPM, its position relative to the molar teeth, its shape (round, ovoid, slit), its distance from the mid-maxillary suture (MMS), and its distance from the incisive foramen (IF) were evaluated. The SPSS V.21 software (IBM Corp., Armonk, NY, USA) was used for the analysis of the data and it was considered significant at the $p<0.05$ level.

Results: The records of 122 female and 128 male patients aged between 18 and 86 years (52±16) were examined. In dentate individuals, FPM was most frequently located in the region between the second and third molars, 54.4% on the right and 56.8% on the left. The most common FPM shape was ovoid, with 80% on the right and 74.4% on the left. The diameter of FPM, FPM-MMS, and FPM-IF distance showed a statistically significant difference between dentate and edentulous individuals, and the values of edentulous individuals were higher ($p<0.05$).

Conclusion: Since the position of the FPM in the maxilla changes with tooth loss, dentists should be careful in surgical and anesthesia procedures in this region.

Keywords: Greater palatine foramen, maxilla, cone-beam computed tomography

ÖZ

Amaç: Bu çalışmanın amacı, foramen palatinum majusun (FPM) konik ışınlı bilgisayarlı tomografi (KIBT) ile görüntülenerek olası varyasyonlarının tespiti, dişli ve dişsiz bireylerde FPM'nin morfometrik karşılaştırmasının yapılmasıdır.

Yöntemler: Çalışmada Diş Hekimliği Fakültesi Ağız, Diş ve Çene Radyolojisi arşivinde bulunan 125 dişli ve 125 dişsiz toplam 250 bireye ait KIBT kayıtları retrospektif olarak incelenmiştir. FPM'nin çapı, molar dişlere göre konumu, şekli (yuvarlak, ovoid, yarık), mid-maksiller sütur (MMS) ve insiziv foramene (İF) olan mesafesi değerlendirilmiştir. Verilerin analizi için SPSS V.21 yazılımı (IBM Corp., Armonk, NY, USA) kullanılmış olup $p<0,05$ seviyesinde anlamlı kabul edilmiştir.

Bulgular: Çalışmada 18-86 yaş aralığında (52±16), 122 kadın ve 128 erkek hastaya ait kayıtlar incelenmiştir. Dişli bireylerde FPM sağda %54,4, solda %56,8 oranında olmak üzere en sık ikinci ve üçüncü molarlar arasındaki bölgede yerleşim göstermiştir. En sık gözlemlenen FPM şekli sağda %80, solda %74,4 oranında olmak üzere ovoiddir. FPM'nin çapı, FPM-MMS ve FPM-İF mesafesi dişli ve dişsiz bireylerde istatistiksel olarak anlamlı fark göstermiş olup, dişsiz bireylerde bu değerler daha yüksektir ($p<0,05$).

Sonuç: Diş kaybı ile birlikte FPM'nin maksilladaki konumunun değişim göstermesi nedeni ile diş hekimleri bu bölgedeki cerrahi işlemler ve anestezi prosedürlerinde dikkatli davranmalıdır.

Anahtar Sözcükler: Foramen palatinum majus, maksilla, konik ışınlı bilgisayarlı tomografi

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Introduction

The foramen palatinum majus (FPM) carries the greater palatine vessels extending from the maxillary artery and the greater palatine nerve, a branch of the maxillary division of the trigeminal nerve (1). The greater palatine nerve leaves the pterygopalatine ganglion and passes through the greater palatine canal to reach the FPM in the hard palate (2). Accurate determination of the anatomical location of the FPM is very important in dentistry in procedures such as posterior palatal block anesthesia, cleft palate treatment (palatorraphy), periodontal surgery, palatal tumor resection, and palatal abscess incision (3). Maxillary nerve block anesthesia is used in the presence of odontogenic infection where infiltration anesthesia is contraindicated, and in maxillary sinus surgeries, and surgical applications where general anesthesia is contraindicated (4). With this technique, the entire hemimaxilla including the teeth, palatal and gingival mucosa, midface skin, maxillary sinus, and nasal cavity are anesthetized (5).

In a meta-analysis including 23 studies conducted by Tomaszewska et al. (6), it was stated that FPM was most frequently located opposite the maxillary third molar. It was stated that the mid-maxillary suture (MMS), posterior nasal spine (PNS), and alveolar bone were the most important points in determining the position of the FPM in edentulous patients.

In studies conducted to date, it has been reported that the position of FPM may vary according to age, gender, and racial differences (4), but the effect of tooth loss has not been sufficiently discussed. The aim of this study was to detect possible variations of FPM by imaging with cone-beam computed tomography (CBCT), and to make a morphometric comparison of FPM in dentate and edentulous individuals.

Methods

Sample and Study Design

This study was carried out retrospectively using CBCT records obtained between 2014 and 2021 at the Faculty of Dentistry, Department of Oral and Maxillofacial Radiology. The study protocol was approved by the Faculty of Dentistry Non-Pharmaceutical and Medical Device Research Ethics Committee (no: 09-79, date: 06.09.2021) and was conducted in accordance with the principles defined in the Declaration of Helsinki, including all revisions.

In the study, CBCT records of individuals over the age of 18 were examined. Artifact-free images with optimal image quality where the maxilla could be clearly examined, and CBCT recordings obtained with 100x100 mm, 140x100 mm, 170x120 mm imaging volume (field of view size) where both FPMs could be fully observed, were included in the study. CBCT records of patients with severe malocclusion and craniofacial anomalies, cleft lip-palate, orthognathic surgery, and maxillofacial trauma were excluded from the study.

Individuals without maxillary molar tooth loss were evaluated in the "dentate" group and individuals without maxillary molar teeth in the "edentulous" group.

Radiological Assessment

1. Transverse diameter of right-left FPM in axial sections (Figure 1),

2. The distance from the center of the FPM to the incisive foramen (FPM-IF), the distance from the center of the FPM to the posterior nasal spine (FPM-PNS), the closest perpendicular distance of the center of the FPM to the mid-maxillary suture in axial sections (FPM-MMS) (Figure 2),

3. The relationship of FPM to the upper molars [2nd molar level (M2), between the 2nd-3rd molars (M2-M3), at the level of the 3rd molar (M3), at the distal of the 3rd molar (D-M3)],

4. The shape of right-left FPM: round (Figure 3), ovoid (Figure 4), slit (Figure 5)

Image Acquisition

All scanning parameters were obtained with the Morita 3D Accuitomo 170 (J Morita MFG Corp. Kyoto, Japan) CBCT device according to the manufacturer's recommended protocol. Studies were conducted using i-Dixel software (J Morita MFG Corp., Kyoto, Japan). A 2.66 GHz Intel Xeon PC with 3.25 Gb RAM, Windows XPTM Professional operating system, and a 27-inch flat-panel color display (Dell U2711HTM) with a resolution of 2,560×1,600 pixels was used to analyze the CBCT images.

Statistical Analysis

The SPSS V.21 software (IBM Corp., Armonk, NY, USA) was used for data analysis. The same researchers took the measurements and repeated them twice to ensure measurement reliability and

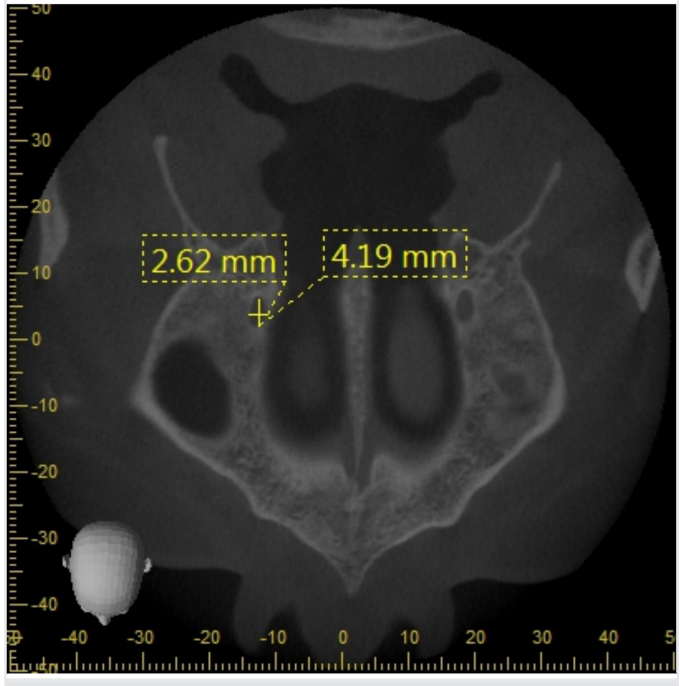

Figure 1. Transverse diameter of right-left FPM in axial sections

FPM: Foramen palatinum majus

minimize individual variability. In this study, descriptive statistics (mean, standard deviation) were calculated for all parameters. Before performing descriptive and quantitative analysis for morphometric measurements and morphological evaluations, it was checked whether the data were normally distributed. Kolmogorov-Smirnov and Shapiro-Wilk tests were used for normality analysis. The means of two independent groups with parameters showing normal distribution were compared with

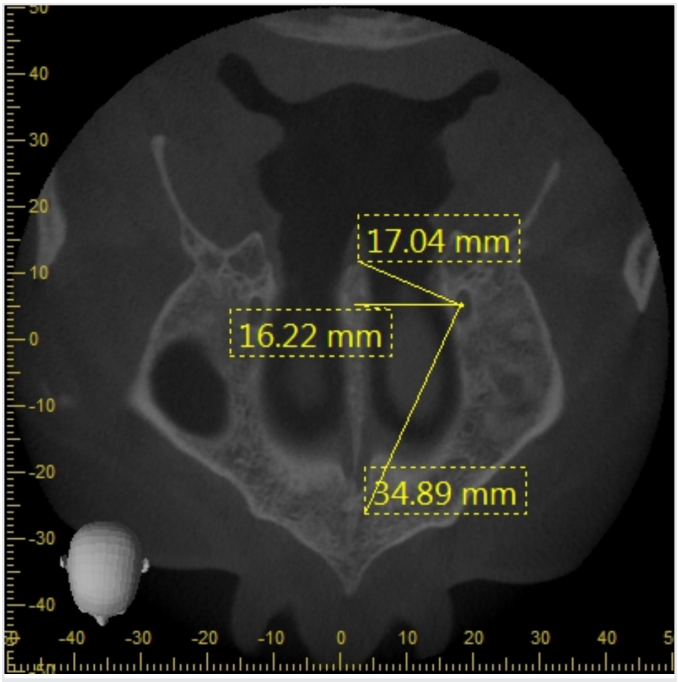

Figure 2. The distance from the center of the Foramen palatinum majus (FPM) to the incisive foramen (FPM-IF), the distance from the center of the FPM to the posterior nasal spine (FPM-PNS), the distance of the center of the FPM to the mid-maxillary suture (FPM-MMS)

Figure 3. Round shape of FPM on an axial CBCT slice

FPM: Foramen palatinum majus, CBCT: Cone-beam computed tomography

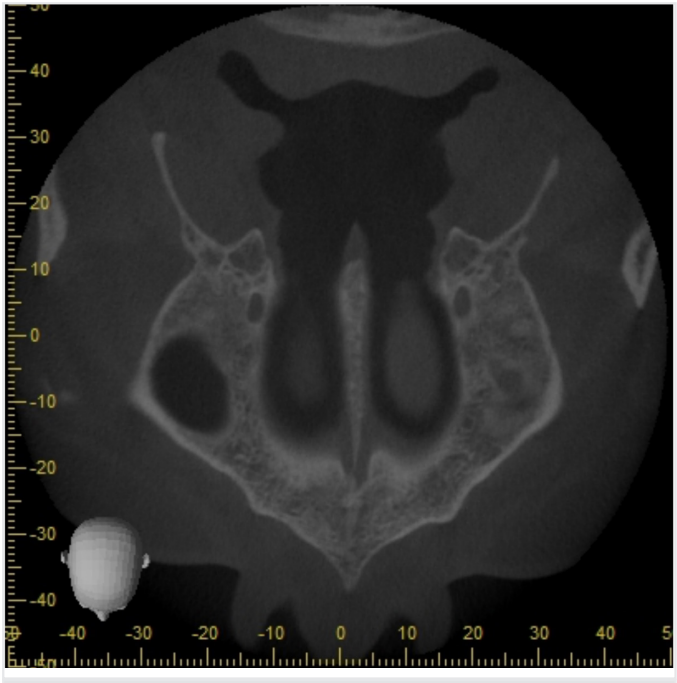

Figure 4. Ovoid shape of FPM on an axial CBCT slice

FPM: Foramen palatinum majus, CBCT: Cone-beam computed tomography

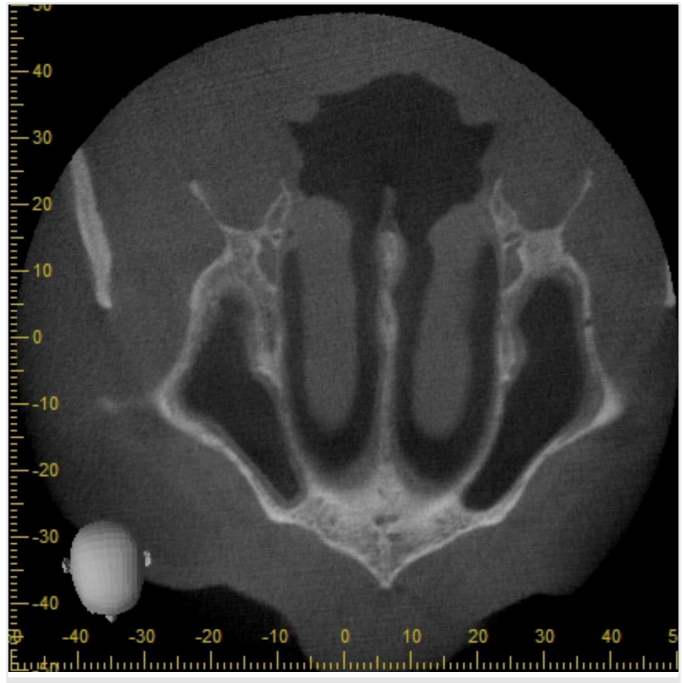

Figure 5. Slit shape of FPM on an axial CBCT slice

FPM: Foramen palatinum majus, CBCT: Cone-beam computed tomography

the independent t-test. The mean of two independent groups with the parameters that did not show normal distribution was compared with the Mann-Whitney U test. The chi-square test was used to determine the relationships between categorical variables and was considered significant at the $p<0.05$ level.

Power analysis

To find significant difference between female and male individuals in terms of left vertical diameter with large effect size (cohen d=1.0) (5), minimum required sample size was calculated as 22 for each group (α=0.05, 1-β=0.90). G-power version 3.1.9 was used for sample size calculation.

Results

In this study, 250 individuals (122 female and 128 male) aged between 18 and 86 were examined. In addition, 125 of the 250 individuals in the study were dentate and 125 were edentulous individuals.

The mean vertical diameter and transverse diameter of FPM were found 4.62±1.33 mm and 1.72±0.56 mm in female dentate individuals. In female edentulous individuals, these values were determined as 5.06±1.70 mm and 2.21±0.7 mm, respectively. The mean distance between FPM and MMS, IF and PNS were 15.82±2.35 mm, 35.8±3.53 mm, and 16.68±1.32 mm in female dentate individuals, respectively. In female edentulous individuals, these values were determined as 16.30±2.37 mm, 36.16±3.58 mm, and 16.91±1.36 mm, respectively.

The mean vertical diameter and transverse diameter of FPM were found 5.33±1.46 mm and 2.28±0.7 mm in male dentate individuals. In male edentulous individuals, these values were determined as 5.22±1.50 mm and 2.56±0.67 mm, respectively. The mean distance between FPM and MMS, IF and PNS were 16.65±2.28 mm, 36.66±3.60 mm, and 17.57±1.54 mm in male dentate individuals, respectively. In male edentulous individuals, these values were determined as 17.70±3.06 mm, 37.60±4.66 mm, and 18.37±1.40 mm, respectively. In Table 1, right and left measurement values of all parameters in dentate and edentulous male and female individuals are given separately. When the measured parameters were compared between dentate and edentulous female and male individuals, a statistically significant difference was found between the genders. Furthermore, it was determined that the values of these parameters were higher in male individuals than in female individuals ($p<0.05$).

When the measurement values of the individuals according to their dentate and edentulous were examined, there was a statistically significant difference in right vertical diameter, right-left transverse diameter, right-left FPM MMS, right-left

Table 1. Minimum, maximum, mean and standard deviation values of the parameters in dentate and edentulous female and male individuals. Comparison between gender in dentate and edentulous individuals ($p<0.05$)

		Female					Male					
Dentition status	**Parameters**	**n**	**min.**	**max.**	**mean**	**SD**	**n**	**min.**	**max.**	**mean**	**SD**	**p**
Dentate	**Right vertical diameter**	69	1.93	10.71	4.45	1.33	56	2.66	9.07	4.92	1.36	>0.05
	Left vertical diameter	69	2.37	10.98	4.79	1.33	56	3.44	10.33	5.74	1.56	<0.001
	Right transverse diameter	69	0.55	3.18	1.67	0.52	56	0.94	3.31	2.09	0.56	<0.001
	Left transverse diameter	69	0.70	3.49	1.78	0.60	56	1.05	4.63	2.46	0.77	<0.001
	Right FPM MMS	69	12.56	19.54	15.75	1.36	56	13.56	19.71	16.56	1.40	<0.01
	Left FPM MMS	69	12.56	35.60	15.89	3.04	56	13.32	34.73	16.75	2.92	<0.01
	Right FPM IF	69	18.14	43.53	35.69	3.87	56	16.05	46.00	36.92	4.12	<0.05
	Left FPM IF	69	30.23	44.91	35.91	3.17	56	30.09	44.46	36.40	3.02	>0.05
	Right FPM PNS	69	13.50	20.56	16.70	1.33	56	14.31	20.06	17.39	1.39	<0.01
	Left FPM PNS	69	13.14	20.15	16.66	1.32	56	14.83	22.56	17.75	1.68	<0.001
Edentulous	**Right vertical diameter**	53	1.72	10.84	4.75	1.60	72	1.22	9.89	5.11	1.48	<0.05
	Left vertical diameter	53	2.45	9.07	5.00	1.66	72	2.62	11.53	5.33	1.51	>0.05
	Right transverse diameter	53	0.89	4.15	2.12	0.67	72	1.10	3.85	2.46	0.57	<0.01
	Left transverse diameter	53	1.22	5.76	2.31	0.72	72	1.06	5.78	2.67	0.76	<0.01
	Right FPM MMS	53	13.43	19.36	16.32	1.35	72	14.30	20.06	17.24	1.40	<0.001
	Left FPM MMS	53	13.08	35.53	16.29	3.08	72	13.78	38.85	18.16	4.06	<0.001
	Right FPM IF	53	16.05	41.69	35.99	3.95	72	15.35	46.65	37.16	5.57	<0.05
	Left FPM IF	53	28.47	42.24	36.33	3.20	72	32.16	49.29	38.04	3.52	<0.05
	Right FPM PNS	53	14.52	19.80	17.06	1.31	72	15.52	20.90	18.23	1.33	<0.001
	Left FPM PNS	53	13.38	21.02	16.76	1.40	72	15.10	21.66	18.50	1.47	<0.001

n: Number of sample, min: Minimum value, max: Maximum value, mean: Mean value, SD: Standard deviation value, p: Significance value, FPM: Foramen palatinum majus, MMS: Mid-maxillary suture, IF: Incisive foramen, PNS: Posterior nasal spine

FPM PNS, and left FPM IF, and these values were higher in edentulous individuals ($p<0.05$) (Table 2).

When the localization of the FPM according to the molar teeth was examined, it was determined that FPM was frequently localized in the interdental region of M2-M3 molars (n=139, 56%). Following this, it was determined that the FPM were localized relative to the molar teeth in the form of M3 (n=77, 31%), D-M3 (n=27, 10%), and M2 (n=7, 3%), respectively.

Although the shape of FPM was statistically significantly associated with the dentition status ($p<0.05$), It was determined that the shape of FPM did not show a statistically significant difference between genders ($p>0.05$) (Table 3).

The round-shaped of FPM (3.6%) in dentate individuals and slit-shaped FPM (26%) in edentulous individuals were the least common forms of FPM. In our study, the most common form of FPM in both dentate (76.8%) and edentulous (77.6%) individuals were determined as ovoid (Table 4).

Table 2. Minimum. maximum. mean. standard deviation and p values of the parameters in dentate and edentulous individuals ($p<0.05$)

	Dentate individuals					Edentulous individuals					
Parameters	n	min.	max.	mean	SD	n	min.	max.	mean	SD	p
Right vertical diameter	125	1.93	10.71	4.66	1.36	125	1.22	10.84	4.95	1.53	<0.05
Left vertical diameter	125	2.37	10.98	5.22	1.51	125	2.45	11.53	5.18	1.57	>0.05
Right transverse diameter	125	0.55	3.31	1.86	0.58	125	0.89	4.15	2.31	0.63	<0.001
Left transverse diameter	125	0.70	4.63	2.08	0.76	125	1.06	5.78	2.51	0.75	<0.001
Right FPM MMS	125	12.56	19.71	16.11	1.43	125	13.43	20.06	16.85	1.44	<0.001
Left FPM MMS	125	12.56	35.60	16.27	3.00	125	13.08	38.85	17.36	3.77	<0.001
Right FPM IF	125	16.05	46.00	36.24	4.01	125	15.35	46.65	36.66	4.96	>0.05
Left FPM IF	125	30.09	44.91	36.13	3.10	125	28.47	49.29	37.31	3.47	<0.01
Right FPM PNS	125	13.50	20.56	17.01	1.39	125	14.52	20.90	17.73	1.43	<0.001
Left FPM PNS	125	13.14	22.56	17.15	1.58	125	13.38	21.66	17.76	1.67	<0.01

n: Number of sample, min: Minimum value, max: Maximum value, mean: Mean value, SD: Standard deviation value, p: Significance value, FPM: Foramen palatinum majus, MMS: Mid-maxillary suture, IF: Incisive foramen, PNS: Posterior nasal spine

Table 3. The opening shape of FPM according to the gender (%)

		Gender					
		Female		Male			
Parameter	**Shape**	**n**	**%**	**n**	**%**	**p**	**X^2**
Right FPM shape	**Round**	6	4.9%	10	7.8%	>0.05	2.236
	Ovoid	96	78.7%	104	81.3%		
	Slit	20	16.4%	14	10.9%		
Left FPM shape	**Round**	7	5.7%	16	12.5%	>0.05	3.490
	Ovoid	95	77.9%	91	71.1%		
	Slit	20	16.4%	21	16.4%		

n: Number of sample, p: Significance value, X^2: Chi-square value, FPM: Foramen palatinum majus

Table 4. The opening shape of FPM according to the dentition satatus (%)

		Dentition status					
		Dentate		Edentulous			
Parameters	Shape	n	%	n	%	p	X^2
Right FPM shape	**Round**	4	3.2%	12	9.6%	<0.05	6.961
	Ovoid	99	79.2%	101	80.8%		
	Slit	22	17.6%	12	9.6%		
Left FPM shape	**Round**	5	4.0%	18	14.4%	<0.01	11.470
	Ovoid	93	74.4%	93	74.4%		
	Slit	27	21.6%	14	11.2%		

n: Number of sample, p: Significance value, X^2: Chi-square value, FPM: Foramen palatinum majus

Discussion

A subepithelial connective tissue graft is the ideal soft tissue graft in the treatment of gingival recessions and its use is increasing day by day. Since the great palatine artery and nerve are located in the palatal donor area, surgeons should work carefully in this area to prevent hemorrhage and paresthesia (7). In addition, it is important to determine the location of the FPM in nerve block anesthesia before palatal surgical procedures. The anesthesia block of the greater palatine is recommended for surgical procedures in the upper molars, maxillary sinus, and nose area (8). The location of FPM in different populations has been investigated in the literature to date, and it has been reported that it may be affected by gender and racial differences (6). However, there is insufficient data on the localization of FPM in edentulous and edentulous individuals. Therefore, in this study, it was aimed to determine the possible variations of FPM and to make a morphometric comparison of FPM using CBCT in dentate and edentulous individuals.

Although FPM has been mostly studied on dry skulls (3,4) in the researches carried out to date, there are also studies conducted with medical CT (9,10) and CBCT (1,5,11-13). CBCT, which provides three-dimensional evaluation with high image quality in addition to low radiation dose, shorter image acquisition time, low cost and easy access compared to medical CT, has become a popular imaging method in maxillofacial region examinations (7,11,14).

Considering it as a guide in determining the FPM position of teeth for dentate individuals, it was determined in this study that FPM was frequently localized at the level of M2-M3 molars (n=139, 56%). Following this, it was determined that the FPM was positioned relative to the molar teeth as M3 (n=77, 31%), D-M3 (n=27, 10%), and M2 (n=7, 3%), respectively. Since there was no such guide in edentulous individuals, according to our results, FPM was located 16.85 on the right and 17.36 mm on the left from the MMS ($p<0.01$), 37.31 mm on the left from the IF ($p<0.01$), and 17.73 mm on the right ($p<0.001$) and 17.76 mm on the left from the PNS ($p<0.01$). These measurement values seem to be higher in edentulous individuals than in dentate individuals. Median maxillary suture and posterior nasal spina are the most important landmarks for locating FPM in edentulous individuals (6). The fact that the parameters measured in edentulous individuals are higher than those in dentate individuals may be related to alveolar bone resorption that occurs with tooth loss (12). In the human cadaver study conducted by Miwa et al. (13) it was stated that the great palatine artery and nerve showed different patterns in edentulous and dentate individuals. When females and males were compared, the measurement values in males were found to be higher. It can be thought that the skull size in males causes this situation (6). When the FPM diameters of the dentate and edentulous individuals were compared, diameter values were found to be higher in edentulous individuals. The mean right vertical diameter of the edentulous individuals was 4.95 mm ($p<0.05$), the right transverse diameter was 2.31 mm ($p<0.001$) and the left transverse diameter was 2.51 mm ($p<0.001$). The larger diameter values in edentulous individuals may be related to the fact that these individuals are older and that the foramen can be seen more easily in osteoporotic boneswith advancing age.

In a meta-analysis by Tomaszewska et al. (6) which included 27 studies, it was reported that FPM was most frequently located at the M3 level with a rate of 63.9%. It has been stated that racial and genetic differences are effective on the change of FPM position. In addition, the application of different methodologies for the measurements seems to be effective on the results (6).

The morphological character of FPM is important as it is the area where the anesthetic solution will be discharged in the anesthetic procedures to be applied, and its different variations may limit the positioning of the injector (15). In our study, the most common form of FPM in all individuals was determined as ovoid. Similarly, in the study conducted by Rapado-González et al. (16) with 110 CBCT images and Lopes et al. (17) on 94 dry skulls, the dominant FPM shape was found to be ovoid.

In a recent study conducted by Lacerda-Santos et al. (18), 60 patients were separated according to three different skeletal face types [brachyfacial (low-angle), dolichofacial (high-angle) and mesofacial (average)], and the position of FPM in different face types was investigated. Although the morphology of FPM is similar in different face types, it has been determined that the FPM is located more distant from the alveolar crest in individuals with dolichofacial face type. Since it can change according to craniofacial development, masticatory system, muscle activity, occlusion, and genetic facial type (18), it should be considered that FPM may have an effect on its position.

Conclusion

Measurements of FPM differ significantly in dentate and edentulous individuals and between male and female genders. FPM is often ovoid and located in the interdental region of M2-M3 molars in toothed patients. Care should be taken in surgical procedures to be performed in this area.

Ethics

Ethics Committee Approval: The study protocol was approved by the Faculty of Dentistry Non-Pharmaceutical and Medical Device Research Ethics Committee (no: 09-79, date: 06.09.2021).

Informed Consent: Retrospective study.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: M.T., Design: M.T., Data Collection or Processing: D.A., Analysis or Interpretation: M.T., D.A., A.D.A.K., Literature Search: M.T., A.D.A.K., Writing: M.T., A.D.A.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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