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Investigation of the Relatıonshıp of Palatal Arch Morphometry with Maxillary Sinus Volume: CBCT Study

SUMMARY

Background/Aim*: The maxillofacial region is a complex of anatomical structures that are in close proximity and connection with each other. The aim of this study was to determine the shape, depth, width, length and palatal vault angle of the palatal arch on cone beam computed tomography (CBCT) images taken for various reasons and to determine the relationship between these factors and maxillary sinus volume.* ***Material and Methods:*** *CBCT images of a total of 150 male and female patients over the age of 18, taken for different diagnostic purposes, were evaluated by an oral radiologist with two years of experience. The shape of the palatal arch was determined on each image, and palatal depth, width, length and palatal vault angle were measured. ITK-SNAP (version 3.8.0) software was used for maxillary sinus measurement. Statistical analysis of the study was performed using SPSS v.21 software.* ***Results:*** *All of the measured parameters were found to be statistically significant between genders, except for the palatal vault angle. As a result of the correlation analysis, it was shown that palatal length was 0.4% (R2=0.004), palatal depth was 42.3% (R2=0.423), and palatal width was 2%(R2=0.020) effective in explaining the palatal vault angle. A high level of correlation was detected between the right (1) and left (2) sinus maxillaris volumes and total sinus maxillaris volumes (r1=0.959, r2=0.961).* ***Conclusions:*** *There is a significant difference in palatal arch parameters between different genders. In addition, these dimensions also play a role on maxillary sinus volumes.*

Keywords: Cone Beam Computed Tomography, Hard Palate, Maxillary Sinus, Palatal Vault

Melek Tassoker[1], Büşra Öztürk[1], Anil Didem Aydin Kabakçi[2]

[1] Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Necmettin Erbakan University, Turkey
[2] Department of Anatomy, Meram Medicine Faculty, Necmettin Erbakan University, Turkey

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Introduction

Dental arch morphology is of great importance in many disciplines of dentistry such as prosthodontics, orthodontics, forensic odontology, maxillofacial surgery and anthropology. Understanding the morphology provides an understanding of the relationship between anatomical structures and increases the accuracy and reliability of diagnoses and treatments for these structures. The hard palate in the maxillofacial structure is composed of the palatal process of the maxillary bone and the horizontal lamina of the palatine bone. It has anatomical and clinical importance in orofacial functions such as chewing, swallowing, phonation and breathing[1]. Its morphology varies depending on the skeletal structure, facial type and breathing pattern of the person[2-4].

The hard palate is analyzed in three different categories according to its shape: oval-shaped, V-shaped and U-shaped[5]. Palatal width is defined as the mesiodistal distance between the mesiobuccal tubercle tips of the right and left maxillary 1st molars. Palatal length is the distance from the most labial point of the central teeth perpendicular to the line drawn for palatal width. Palatal depth or height is the vertical distance from the line drawn for palatal

width at the level of the occlusal plane to the hard palate[6]. The palatal vault angle is the angle between the horizontal plane passing through the enamel-cementum junction of the maxillary first molar and the line drawn through the midpalatal suture. According to the palatal vault angle, 3 groups are determined for the palatal structure: the shallow group where the angle is less than 30 degrees, the intermediate group between 30 and 40 degrees and the deep group where the angle is greater than 40 degrees[7]. Considering the central location of the hard palate and its close relationship with the adjacent nasal cavity, oral cavity and maxillary sinuses, changes in its morphology are likely to affect other structures of the stomatognathic system[8-10].

The maxillary sinuses, the largest of the paranasal sinuses, are epithelium-covered pyramid-shaped air-filled cavities located in the right and left maxilla[11]. At birth, its volume is approximately 6-8 cm^3, reaching its adult size at 10-12 years of age[12-14]. The average volume of the maxillary sinus[15] in an adult is approximately 15 cm^3. Maxillary sinus volume, which increases until early adulthood, gradually decreases with aging. It has been shown that the increase in maxillary sinus volume is positively correlated with the increase in height and weight in individuals[16]. Miranda-Viana *et al*.[4] found that hard palate structure varied according to gender and face type, maxillary sinus volume decreased as palatal height increased and maxillary sinus volume increased as palatal width increased.

In the literature, various methods such as cadaver, stereology, two-dimensional conventional radiographs, computed tomography (CT), magnetic resonance imaging (MRI) have been used to measure maxillary sinus volume[17]. Increasingly used in dental practice, cone beam CT (CBCT) provides multiplanar images with sagittal, coronal and axial slices[18]. The low cost, high resolution and lower radiation dose compared to CT are among the advantages of the technique and provide accurate three-dimensional analysis of the maxillary sinus[19-21].

The aim of this study was to determine the shape of the palatal arch on CBCT images and to correlate palatal depth, width, length and palatal vault angle measurements with maxillary sinus volume.

Material and Methods

Sample and Study Design

The present study was approved by the Research Ethics Committee of Necmettin Erbakan University Dentistry Faculty (nm.2023/256) and was conducted in accordance with ethical regulations and relevant guidelines. Between February 2019 and April 2023, CBCT images with 500x500 resolution of a total of 150 male and female (84 female-66 male) patients taken for different diagnostic purposes at Necmettin Erbakan University Faculty of Dentistry, Department of Oral and Maxillofacial Radiology were used. CBCT images were acquired using Morita 3D Accuitomo 170 (J Morita MFG Corp., Kyoto, Japan, operating at 90 kVp and 5 mA, 17.5 second rotation time, voxel 0.25 mm, 140m x100 mm field of view, 360° data acquisition, and no additional filtering) and NewTom GiANO cone beam 3D imaging (distributed by Verona, Italy, operating at 90 kVp and 10 mA, 18 second rotation time, voxel 0.15 mm, 140m x100 mm field of view, 360° data acquisition, and no additional filtering). Each patient was positioned parallel to the ground and the median line was standardized according to the equipments' procedure.

Some criteria were considered when selecting CBCT images. The inclusion criteria were as follows; patient's age ≥ 18 years, patients without missing teeth, images with FOV size where the maxillary sinus volume can be completely measured and with optimal diagnostic capability. The exclusion criteria were as follows; patients younger than 18 years old, patients with missing teeth, patients with systemic diseases affecting growth and development, patients with skeletal and dental malocclusion, patients with head and neck trauma or surgery, patients with cleft lip-palate, presence of impacted and/or supernumerary teeth, patients with maxillary sinus and jaw pathologies and recordings with artifacts in which the maxillary sinus cannot be clearly measured.

Radiological examination

All assessments were done by an oral radiologist with two years of experience. The palatal vault angle was classified according to the figure below, in accordance with the classification specified by Kim *et al.*[22] on coronal CBCT sections. The palatal vault angle was determined by measuring the angle between the horizontal plane and the imaginary plane drawn from the cemento-enamel junction of the first molar to the midpalatal suture (Figure 1). Angle (>40): the deep group, Angle (30-40): the intermediate group, Angle (<30): the shallow group[22].

Palatal width, length and depth were measured according to the following landmarks:

Palatal width: mesiodistal distance between the mesiobuccal tubercle tips of the right and left maxillary 1st molars (in axial section) (Figure 2).

Palatal length: the distance from the most labial point of the central teeth perpendicular to the line drawn for palatal width (in axial section) (Figure 2).

Palatal depth: vertical distance from the line drawn for palatal width at the level of the occlusal plane to the hard palate (in coronal section) (Figure 2).

Palatal arch shape: oval, U, V shape (in axial section)

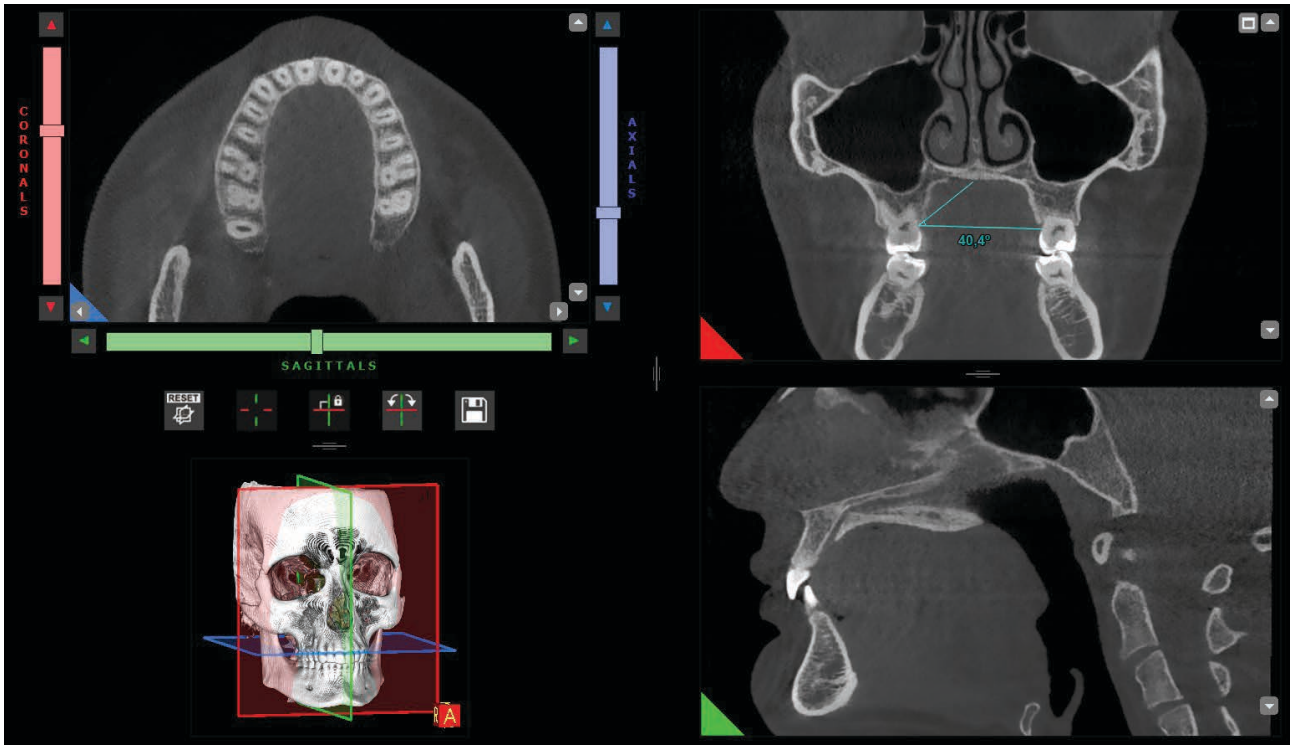

Figure 1. Palatal vault angle in the frontal plane

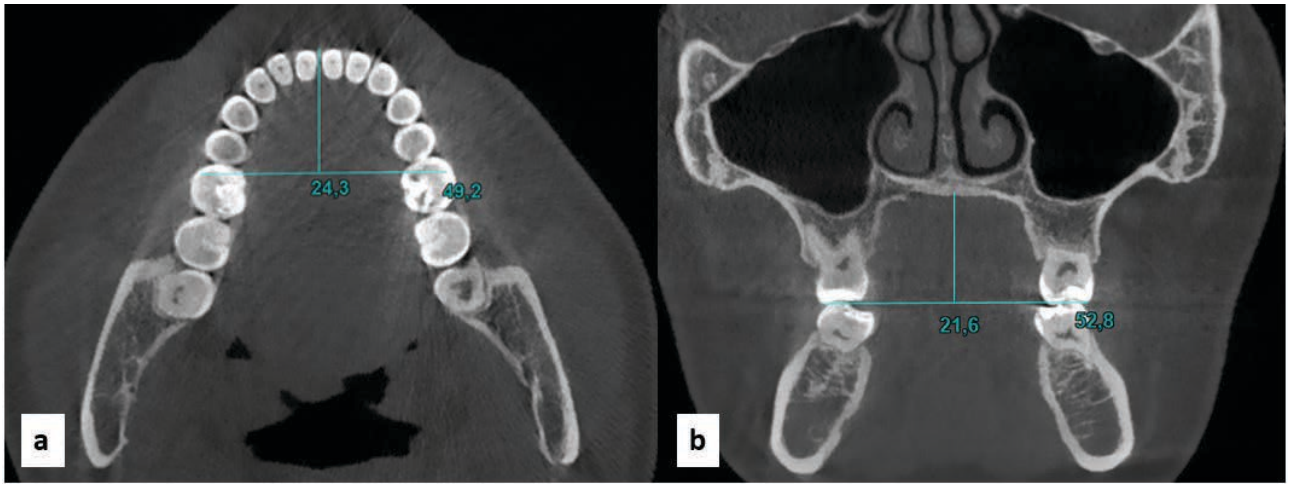

Figure 2. Palatal width and length in axial plane (a) Palatal depth in coronal plane (b)

Volume measurement

Maxillary sinus volume measurements were performed with the open access ITK-SNAP (version 3.8.0) software (Cognitica, Philadelphia, PA, USA) (https://www. itksnap.org). Volume measurements were repeated by a single observer at 1-week intervals. The anterior, posterior, lateral, medial, superior and inferior walls of the maxillary sinus were delineated to define the region of interest (ROI) for segmentation by the observer in multiplanar reconstructions. After the ROI was delimited, the maxillary sinus was segmented and the volume of the maxillary sinus was displayed in the 3D reconstruction window of the software and the volume was given in cubic millimeters. The volume of the right and left maxillary sinus was calculated separately and the total maxillary sinus volume of each patient was determined (Figure 3).

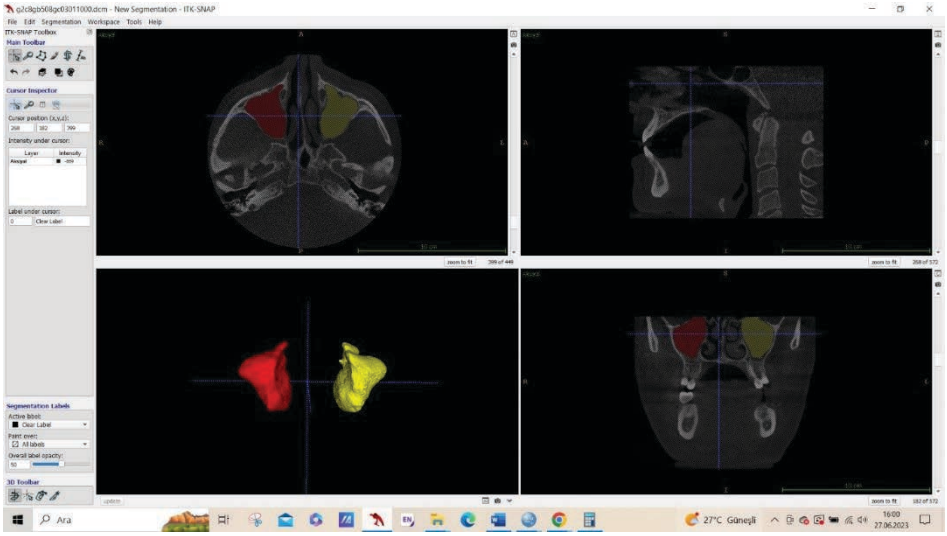

Figure 3. Volumetric analysis of maxillary sinuses in ITK-SNAP software (version 3.8.0)

Statistical analyses

Statistical analysis of the study was performed using SPSS v.21 software (IBM, Chicago, IL, USA). Normal distribution suitability of the parameters was evaluated by Kolmogorov-Smirnov test and Skewness and Kurtosis Values[23]. The obtained data were evaluated with both descriptive (mean value, standard deviation, maximum and minimum values, percentages) and quantitative (Independent Student t-test was used to compare continuous variables, paired sample t-test was used to compare bilateral maxillary sinus volumes, Pearson correlation test was used to analyze the relationship between parameters, and Chi-square test was used to analyze the relationship between variables.) statistical methods. The 95% confidence intervals were calculated and a $p<0.05$ was considered statistically significant.

Results

In our study, CBCT images of 84 female and 66 male individuals were scanned retrospectively. The ages of male patients participating in the study ranged between 18 and 58 (mean 29.12), and the ages of female patients ranged between 18 and 60 (mean 27.85). The average palatal width, length, depth, right maxillary sinus volume, left maxillary sinus volume, total maxillary sinus volume and palatal vault angle were found to be 55.08±3.84 mm, 27.04±2.35 mm, 21.53±2.80 mm, 15.20±5.09 mm, 15.45±5.24 mm, 30.65±9.91, and 38.38±5.16 mm, respectively (Table 1). All of the measured parameters were found to be statistically significant between genders, except for the palatal vault angle (Table 2). The most common palatal arch shape was determined to be U-shaped in both female and male patients (n=50, 59.52% for female, n=31, 46.97% for male) (Table 3). The least common palatal arch shape was V-shaped in both genders (Table 3). In our study, it was determined that gender caused a significant difference in the shape of the palatal arch (X^2=8.384, p=0.015) (Table 3). While V-shaped arches are more common in males, U-shaped and oval arches are more common in females.

Table 1. The mean, maximum, minimum and standart of parameters (N: the number of patient, Min:Minumum, Max.:Maximum, SD: Standart deviation)

Parameters	N	Min.	Max.	Mean	SD
Palatal Width	150	45.38	65.67	55.08	3.85
Palatal Length	150	20.95	33.26	27.04	2.36
Palatal Depth	150	13.77	29.44	21.52	2.81
Right Maxillary Sinus Volume	150	4.94	25.99	15.20	5.09
Left Maxillary Sinus Volume	150	5.26	31.39	15.45	5.24
Total Maxillary Sinus Volume	150	12.94	50.36	30.65	9.91
Palatal Vault Angle	150	23.90	50.50	38.38	5.16

No statistically significant difference was observed between the sides of the right and left maxillary sinus volume measurements of the patients(p=0.292). In addition, no statistically significant difference was observed between the right and left maxillary sinus volume measurements of both male and female patients (Table 4). As a result of the correlation analysis, it was shown that palatal length was 0.4% (R^2=0.004), palatal depth was 42.3% (R^2=0.423), and palatal width was 2% (R^2=0.020) effective in explaining the palatal vault angle (Figure 4, 5 and 6).

Table 2. The mean, standart deviation and p values of parameters according to the gender (N: the number of patient, SD: Standart deviation, p: significance value)

Parameters	Gender	N	Mean	SD	p
Palatal Width	Female	84	53.7	3.23	
	Male	66	56.83	3.88	0.000*
Palatal Length	Female	84	26.7	2.37	
	Male	66	27.48	2.28	0.044*
Palatal Depth	Female	84	20.42	2.48	
	Male	66	22.93	2.59	0.000*
Right Maxillary Sinus Volume	Female	84	13.86	4.75	
	Male	66	16.9	5.03	0.000*
Left Maxillary Sinus Volume	Female	84	14.13	4.73	
	Male	66	17.14	5.4	0.000*
Total Maxillary Sinus Volume	Female	84	27.99	9.19	
	Male	66	34.04	9.82	0.000*
Palatal Vault Angle	Female	84	37.72	5.09	
	Male	66	39.23	5.15	0.074

* The 95% confidence intervals were calculated and a $p<0.05$ was considered statistically significant.

Table 3. The relationship between gender and palatal arch shape (X^2: The Chi-square value, df: the degree of freedom, p: the significance value, n: the number of patient, %: frequency)

Types of palatal arch	GENDER				Total	X^2	df	p
	Female		Male					
	n	%	n	%				
Oval-shaped	27	32.14	18	27.27	45	**8.384**	**2**	**0.015**
U-shaped	50	59.52	31	46.97	81			
V-shaped	7	8.33	17	25.76	24			
Total	84	100	66	100	150			

Table 4. The comparison of right and left maxillary sinus volumes in female, male and all patients (, df: the degree of freedom, p: the significance value)

Gender		Paired Samples Test								
			Paired Differences							
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	p-value
						Lower	Upper			
Female	Pair 1	The volume of right maxillary sinus-the volume of left maxillary sinus	-0.26	2.32	0.25	-0.77	0.24	-1.03	83	0.304
Male	Pair 1	The volume of right maxillary sinus-the volume of left maxillary sinus	-0.24	3.53	0.43	-1.10	0.63	-0.54	65	0.589
Total patients	Pair 1	The volume of right maxillary sinus-the volume of left maxillary sinus	-0.25	2.90	0.24	-0.72	0.22	-1.06	149	0.292

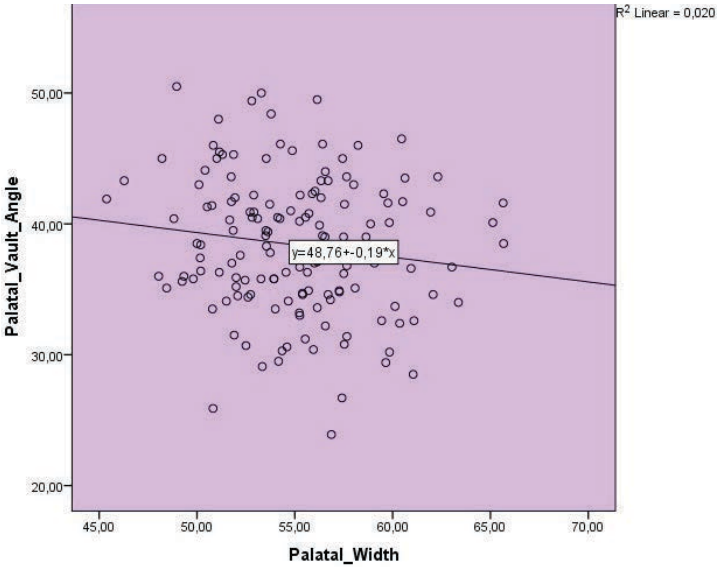

Figure 4. The correlation analysis graph of palatal width and palatal arch

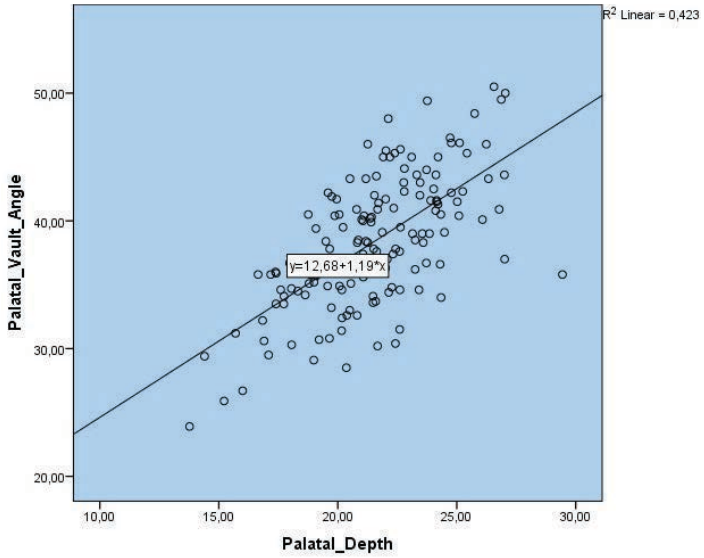

Figure 5. The correlation analysis graph of palatal length and palatal arch

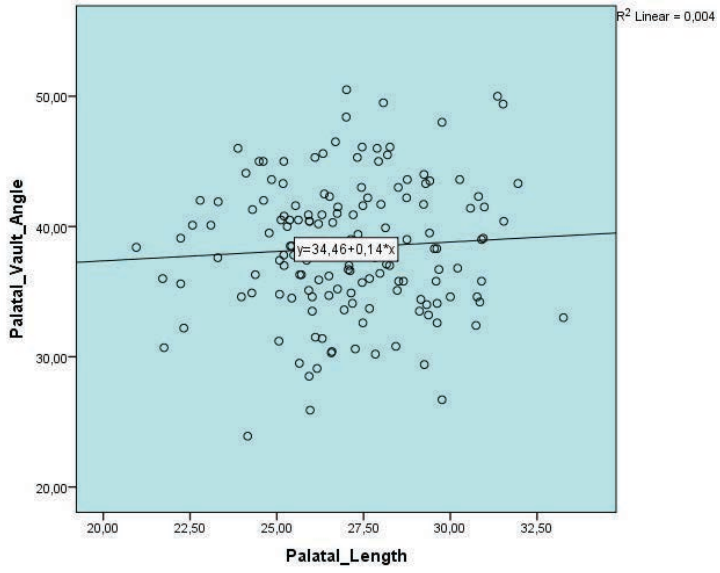

Figure 6. The correlation analysis graph of palatal depth and palatal arch

Table 5. The peearson correlation analysis of between parameters (r=correlation coefficient, p: the significance value)

Parameters		Gender	Palatal arch shape	Total Maxillary Sinus Volume	Left Maxillary Sinus Volume	Right Maxillary Sinus Volume	Palatal Depth	Palatal Length	Palatal Vaut Angle	Palatal Width
Palatal Width	r	.405**	-.077	.270**	.273**	.245**	.162*	.190*	-.141	1
	p	.000	.349	.001	.001	.003	.048	.020	.086	
Palatal Vault Angle	r	.146	.120	.258**	.243**	.252**	.651**	.066	1	
	p	.074	.143	.001	.003	.002	.000	.420		
Palatal Length	r	.164*	.027	.011	.009	.013	.145	1		
	p	.045	.742	.894	.917	.878	.077			
Palatal Depth	r	.444**	.161*	.382**	.330**	.405**	1			
	p	.000	.049	.000	.000	.000				
Right Maxillary Sinus Volume	r	.298**	.130	.959**	.842**	1				
	p	.000	.112	.000	.000					
Left Maxillary Sinus Volume	r	.287**	.047	.961**	1					
	p	.000	.565	.000						
Total Maxillary Sinus Volume	r	.304**	.092	1						
	p	.000	.263							
Palatal arch shape	r	.167*	1							
	p	.041								
Gender	r	1								
	p									

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

As a result of the correlation analysis between the parameters, a high level of correlation was detected between the right ($_1$) and left ($_2$) sinus maxillaris volumes and total sinus maxillaris volumes (r_1=0.959, r_2=0.961). A high correlation was also observed between right and left sinus maxillaris volumes (r=0.842). A moderate correlation was also observed between palatal vault angle and palatal depth (r=0.651) (Table 5).

Discussion

The hard palate, located in the center of the cranium and consisting of maxilla and palatine bone, is one of the important structures of the stomatognathic system and plays a role in many orofacial functions[1,21]. Its placement allows it to be in close contact with the nasal cavity, oral cavity and maxillary sinuses. Palatal morphology varies depending on the individual[2-4]. Face type, growth pattern and gender have an impact on hard palate dimensions, while hard palate measurements are related to upper airways and maxillary sinus volumes. Palatal width and height were found to be higher in men in previous studies[22,23]. In our study, all parameters measured except the palatal vault angle were found to be statistically significant between genders and the values were higher in male individuals.

There are differences in maxillary arch shape and size depending on the population in which the study is performed. Although in previous studies the dominant form in the Korean and Saudi populations was found to be oval[24], in our study it was determined that the most common palatal arch shape in both men and women was U-shaped. The least common palatal arch shape in both genders was V-shaped, and it was determined that gender caused a significant difference in the shape of the palatal arch.

In our study, CBCT, which provides three-dimensional imaging with high specificity and sensitivity and low radiation load, enabled reliable diagnosis in the formation of maxillofacial complex bone structures. Although different population studies continue to exist in the literature, the small number of studies conducted on the Turkish population increases the value of our results. Our study provides important data, considering that the linear dimensions of the hard palate are related to the volumes of the maxillary sinuses, that this relationship shows the clinical and anatomical importance of the hard palate, and that procedures involving the airways and/or maxillary sinuses can provide clinical information. Although our study contributes to the literature and contains informative information for other studies, there is a need for studies with larger sample groups and more data.

Conclusions

There is a relationship between the morphology of the hard palate and maxillary sinus volumes in close proximity to the maxillofacial region. This relationship should be taken into consideration in dental practice, and clinicians should take these relationships into account during the procedures they perform in the maxillary region.

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Correspondence

Melek Tassoker
Department of Dentomaxillofacial Radiology
Faculty of Dentistry, Necmettin Erbakan University, Turkey
e-mail: dishekmelek@gmail.com