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Correlating Hard Palate, Maxillary Sinus & Upper Airways for Age, Gender and Facial Type Determination: A CBCT Study

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Abstract

Aim & Objectives: To assess the dimensions of hard palate, volumes of maxillary sinus and upper airways in three different age groups and to gender.

Materials And Method: 60 CBCT volumes acquired from the dental archives were used. Using Planmeca Romexis software, posterior width of the Hard palate is measured by drawing a line connecting the palatal cortical bone at the roots of the first molars of the right & left sides and of the first premolars. A perpendicular line drawn from the highest point of hard palate to the center of the horizontal lines determine the height of the hard palate. Using ITK SNAP software, the volumes of Maxillary sinus and upper airways is measured. Estimation of the upper airway space will limit to the level of C3.

Results: Intergroup comparison performed using "One way ANOVA test" revealed a statistically difference between age groups for width of hard palate at molar (p=0.033) and premolar level (p=0.024) as well as volume of maxillary sinus on the right (p=0.023) and left side (p=0.005). Intergroup comparison performed using "One way ANOVA test" revealed a statistically difference between facial types for volume of maxillary sinus on the right and left side (p <0.0001). Dendrogram generated using Hierarchical Ward's linkage method showed that volume of maxillary sinus could cluster all the three facial types with considerable degree of precision.

Discussion: An inverse relationship was observed between width of hard palate and volume of maxillary sinus in the current study. The decrease in width of the hard palate resulted in an increase in volume of maxillary sinus due to the fact that floor of the hard palate forms the lower boundary of the maxillary sinus.

Conclusion: The variation in dimensions of hard palate has an influence in volume of maxillary sinus which was observed with respect to age, would aid in determining the facial type of an individual and forensics.

Keywords: CBCT; Upper Airways; Forensics; Hard Palate; Maxillary sinus.

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INTRODUCTION

Numerous methods for age, gender and facial type determination have been proposed in forensics. These methods can be categorized as clinical, histological, biochemical and radiographic analysis. In living subjects, any or all of the above forensic methods could be used to determine age/gender, in cases where the chronological age could not be elucidated.[2] However, in case of a person who has deceased, post mortem changes such as mutilation, decomposition or skeletonization may make it difficult to identify. Forensic odontology techniques are considered to be a reliable tool

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when other identification methods fail to furnish the necessary details.[3] William and Rogers, as well as Krogman and Iscan, demonstrated that the skull and mandibular bones could be used to determine sex with 90% accuracy. [4]

The relationship between craniofacial morphology and respiratory function has been the focus of investigation since the late 19th century.[5] The hard palate is the bony part of the palate comprising the anterior part of the palate.[1] It is an important part of the human skull that contributes to the separation of the oral and nasal cavities. The morphometric features of the palate are also of great importance in clinical dental sciences.[6] Therefore it could be inferred that morphometric measurements of the maxillary sinus and upper airway is well correlated with measurements involving the hard palate.

Existing literature shows that maxillary alveolar bone and palatal slopes undergoes resorption occlusoapically with increasing age. Any change in dimensions of the hard palate would therefore obviously affect the sinus volume.

3D cone beam computed tomography (CBCT) is becoming a routine diagnostic imaging modality in maxillofacial applications due to its wide array of diagnostic capabilities and minimizing radiation dose to the patient.[7] Previous literature shows the developed accuracy and reliability of cone beam computed tomography (CBCT) over conventional imaging modalities.[8]

Hence the current retrospective aims to evaluate the utility of the dimensions of hard palate (width and length), volume of maxillary sinus (right and left), volume of upper airway in age, gender and facial type determination.

MATERIALS AND METHOD

Study Design

A Retrospective study.

Study Population

60 CBCT volumes acquired from the dental archives that were generated using Planmeca Promax 3D MID Proface CBCT machine and assessed with Romexis software. CBCT full skull images of the individuals between 2018 and 2021 from the dental archives of department of oral medicine and radiology will be collected for the study purpose.

Sample size Determination

Sample size calculation was done using Stata 17.1/SE software.

Samples were divided into 3 age groups and each group comprised of 20 samples with 10 males and 10 females in each group.

Group I – Age 20 - 35 years.

Group II – Age 36 – 50 years.

Group III – Age above 50 years.

Inclusion Criteria

- Images with good contrast and undistorted images.
- Presence of all upper erupted molars in both maxilla sides; male/female aged 20 years or older, and absence of any pathological conditions or deformities in the jaws.

Exclusion Criteria

- Images with artefacts.
- History of trauma or orthognathic surgery, presence of pathologic bone disease in maxilla.

METHOD

Morphometric assessment of hard palate was measured using PlanmecaRomexis software and the volumetric assessment of maxillary sinus and upper airways was performed using ITK SNAP software. Using Planmeca Romexis software, in Coronal section, a horizontal line connecting the palatal cortical bone at the roots of the first molar (Fig. 1) was drawn with the measuring tool determining the posterior width of the hard palate and the same drawn with the measuring tool at the roots of the first premolars (Fig. 2). In Axial section, the centre and the highest point of the hard palate was focussed and in coronal section, a vertical line perpendicular to the horizontal line, both at the roots of first molar and first premolars, was drawn determining the length of the hard palate.

Using ITK SNAP software, volumes of right and left maxillary sinus and volume of upper airways was measured. For the volume of maxillary sinus,

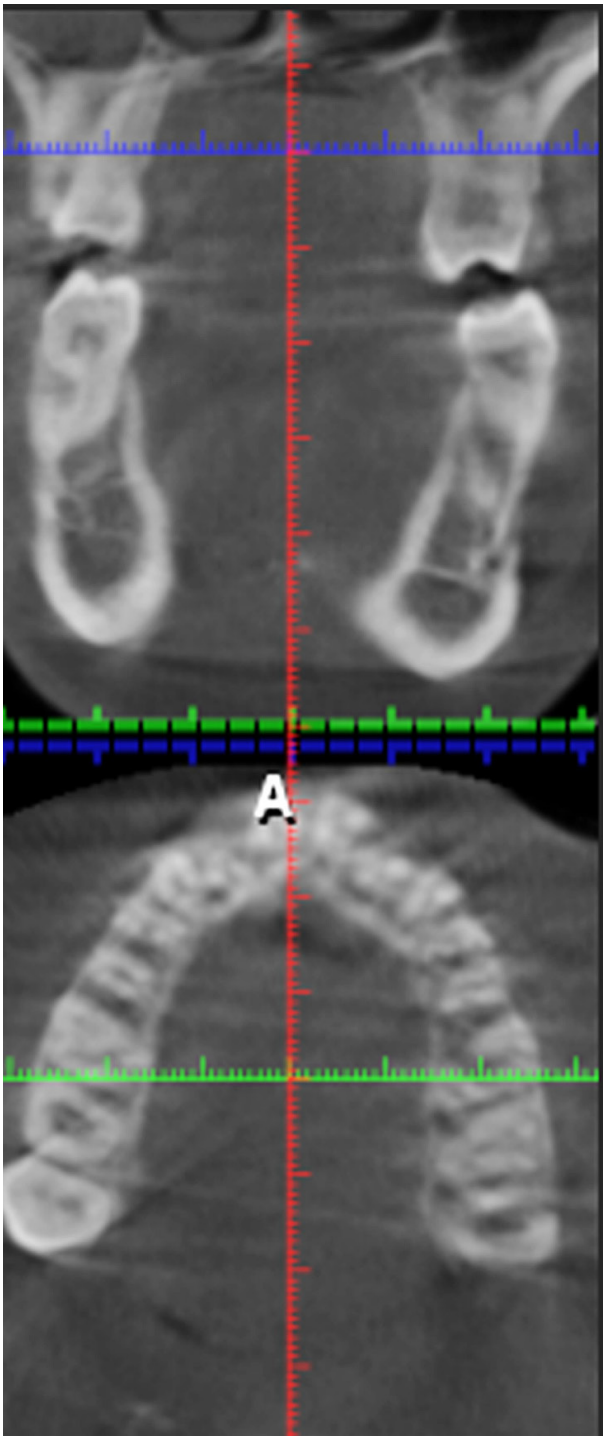

Fig. 1: The measuring tool determining the posterior width of the hard palate

in sagittal section, vertical toggle was placed at the centre of the first molar for standardization and the horizontal toggle at the centre of the maxillary sinus (Fig. 3). Then segmentation was done in sagittal, coronal and axial section, followed by adding a bubble cursor in the sagittal section, and finally colour labelling was done. This labelled segment

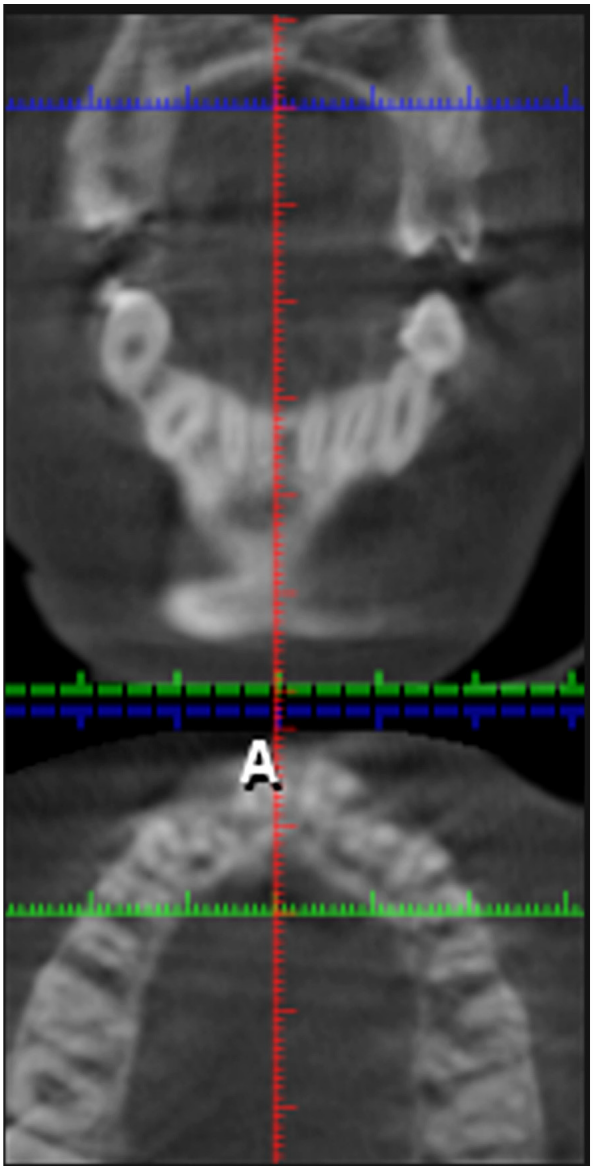

Fig. 2: The measuring tool at the roots of the first premolars

determines the volume of the maxillary sinus and this was done for the both sides of maxillary sinus. For the volume of upper airways, in sagittal section, with the superior limit of anterior glenoid process and the inferior limit of third cervical vertebra was marked (Fig. 4) and segmented in sagittal, coronal and axial sections, followed by adding a bubble cursor in the sagittal section and finally colour labelling was done. This labelled segment determines the volume of the upper airways.

Using the volume of right maxillary sinus, as default, the measurements were divided in three categories for determining the facial type of the samples:

Fig. 3: The horizontal toggle at the centre of the maxillary sinus

Group A: More than 20 = Dolichocephalic

Group B: 10 – 20 = Mesocephalic

Group C: less than 10 = Brachycephalic

The images and the measurements were saved as JPEG.

Statistical Analysis

The statistical analysis was performed using Stata/SE version 17.1 (Statacorp., College station, Texas). The normality of the data distribution was tested using Shapiro Wilk test. The equality of variances between the compared groups was performed using Bartlett test of sphericity. As the data was found to be normally distributed, the test of significance between the groups was performed using parametric tests. Intergroup comparison with respect to age group and facial type was performed using one way ANOVA followed by post hoc Tukey HSD test. Intergroup comparison with respect to gender was performed using unpaired t test. Multivariate regression analysis was performed to determine the relationship between volume of sinus with hard palate measurements as well as volume of airway with hard palate measurements as well as with volume of sinus. Cluster analysis was performed using Hierarchical Ward's linkage method to determine the accuracy of clustering using morphometric measurements of hard palate and sinus volume (whichever was significant). For all comparisons, $p<0.05$ is statistically significant.

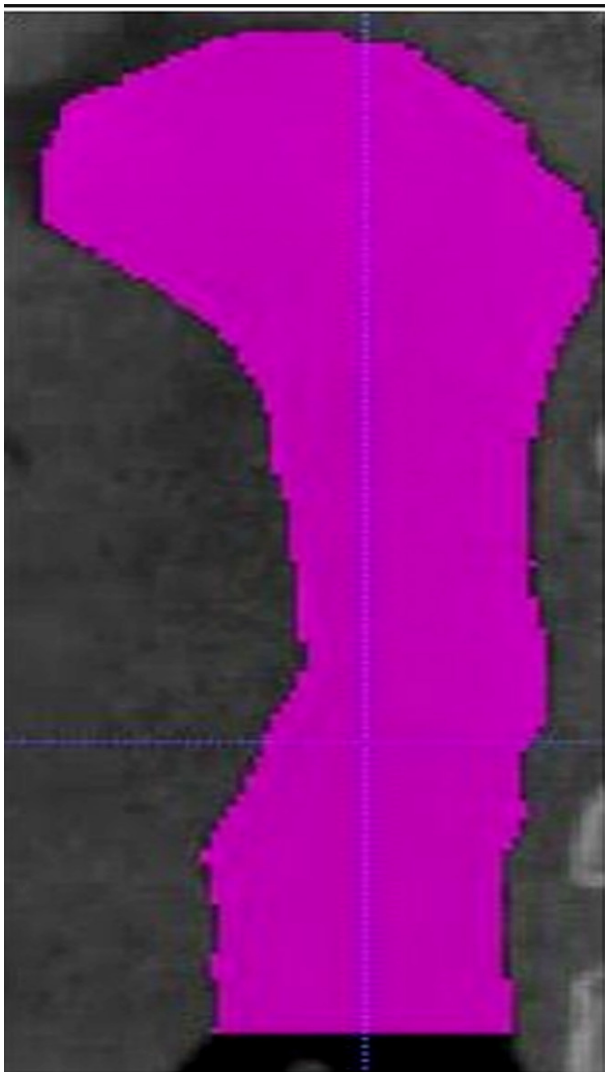

Fig. 4: The superior limit of anterior glenoid process and the inferior limit of third cervical vertebra was marked

RESULTS

Descriptive statistics such as mean, standard deviation and 95% confidence interval values for the morphometric variables of hard palate (length and width), sinus volume and airway volume with respect to the categorical variables (age group, gender and facial types) are represented in tables 1, 3 and 4). Median, IQR, minimum and maximum values for the morphometric variables with respect to the categorical variables (age group, gender and facial types) are represented using box and whisker plots (Figs. 5-10). The median (p50) is represented using the thick line in the vertical box, the first quartile (p25) and third quartile (p75) are represented by the upper and lower limit of the box. Maximum and minimum values are presented using upper and lower limit of

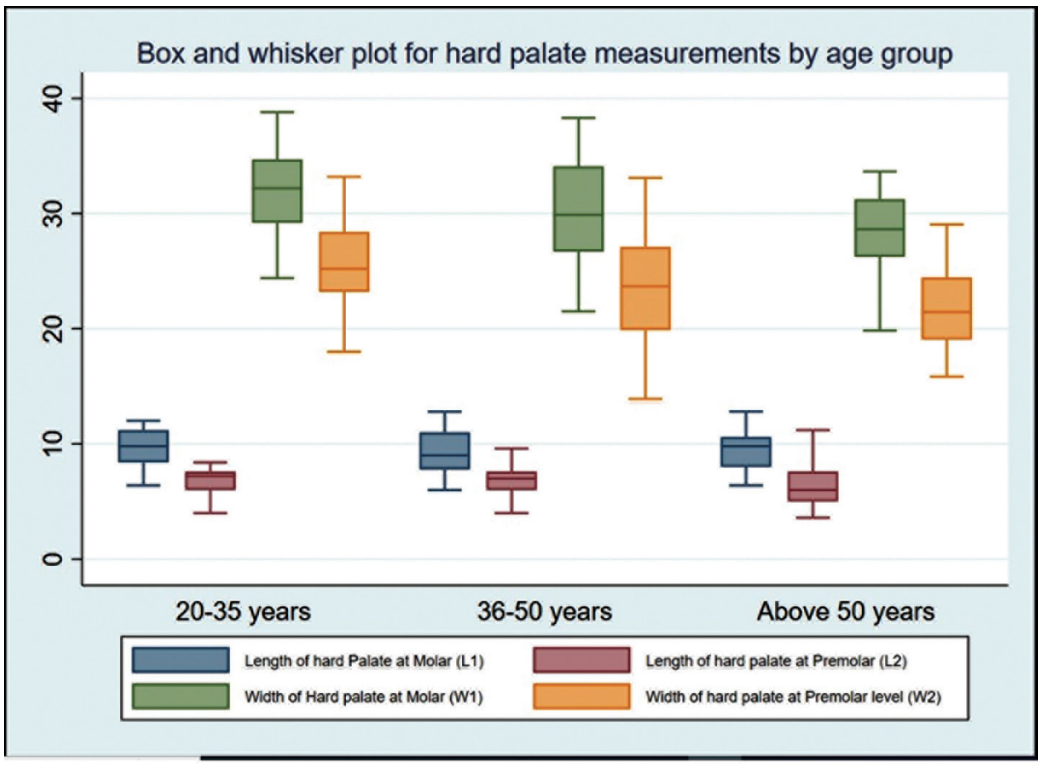

Fig. 5: Box and whisker plot for hard palate measurements by age group

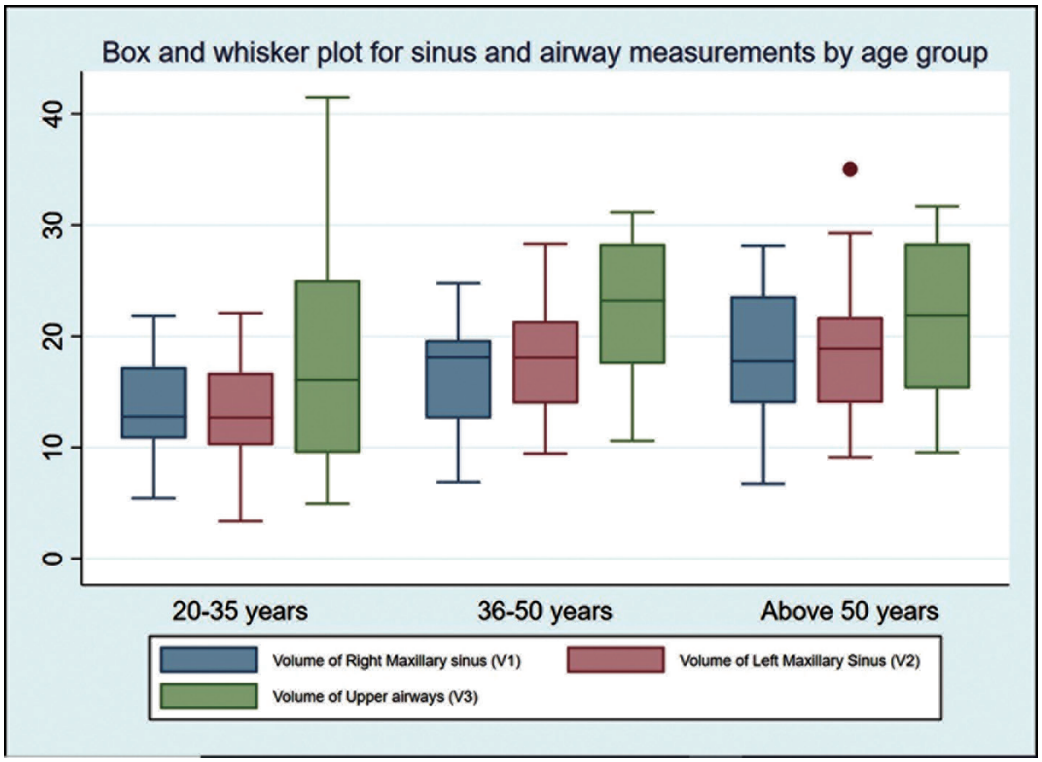

Fig. 6: Box and whisker plot for sinus and airways measurements by age group

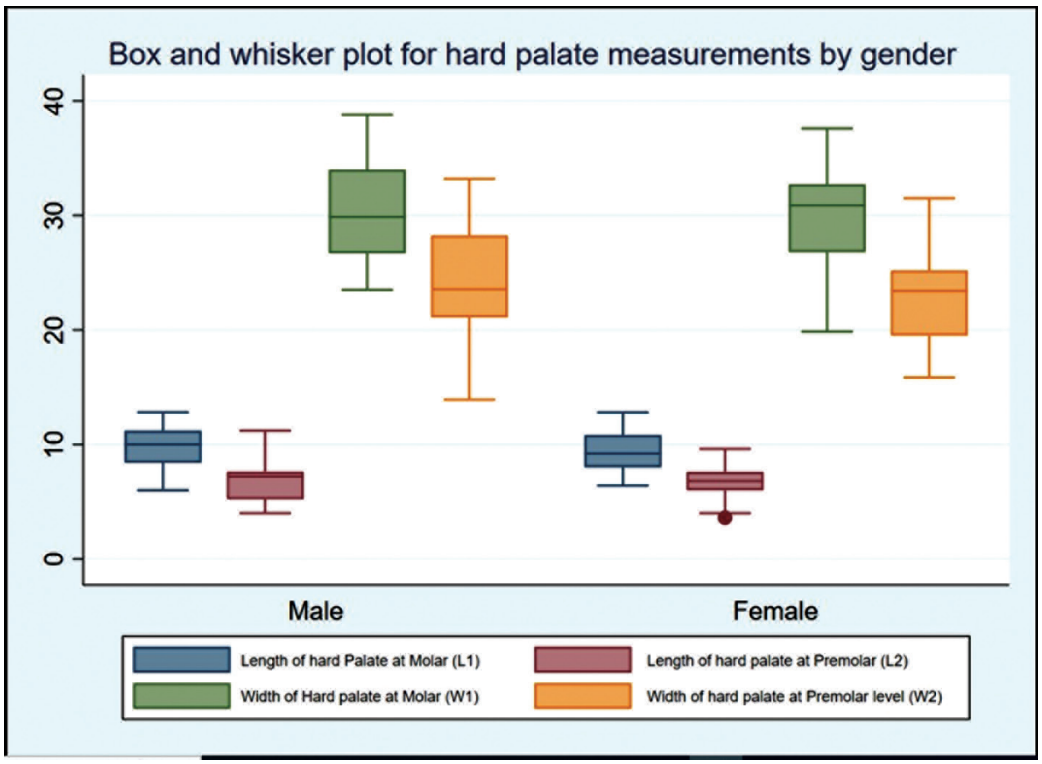

Fig. 7: Box and whisker plot for hard palate measurements by gender

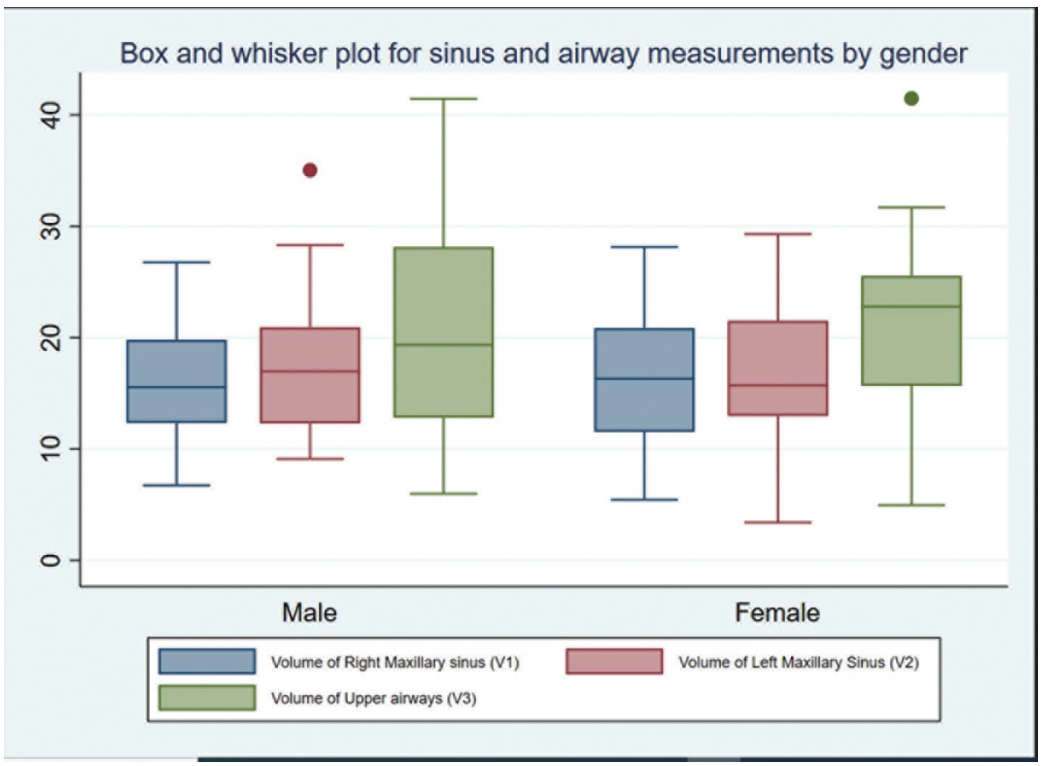

Fig. 8: Box and whisker plot for sinus and airways measurements by gender

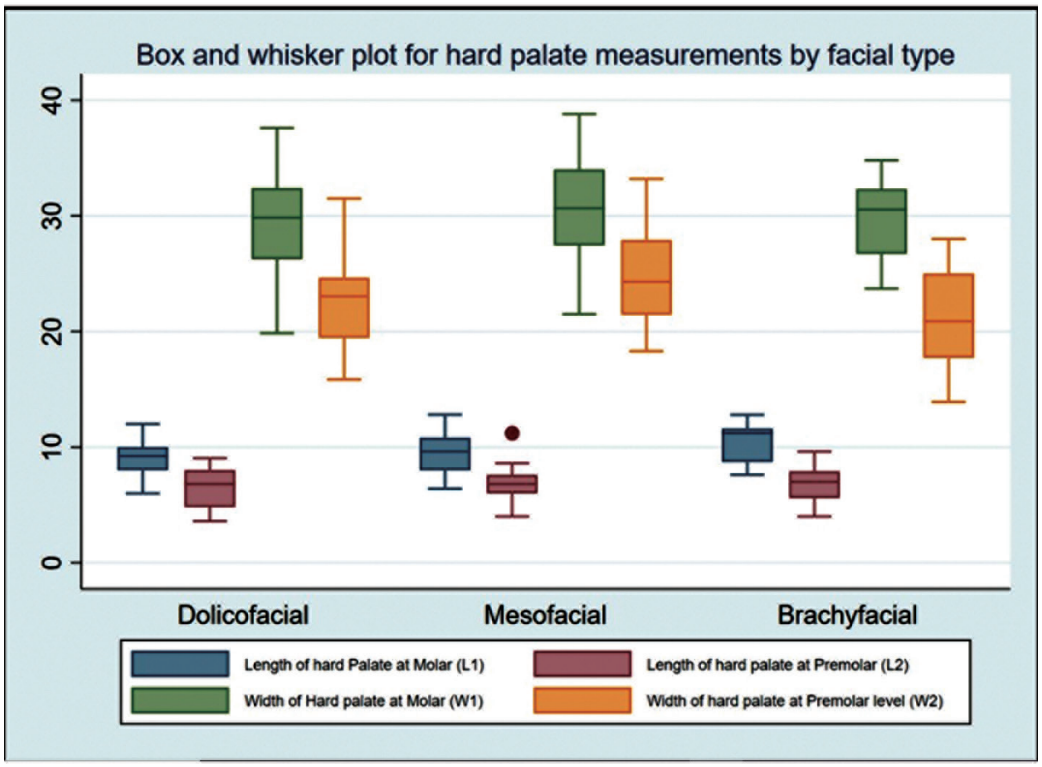

Fig. 9: Box and whisker plot for hard palate measurements by facial type

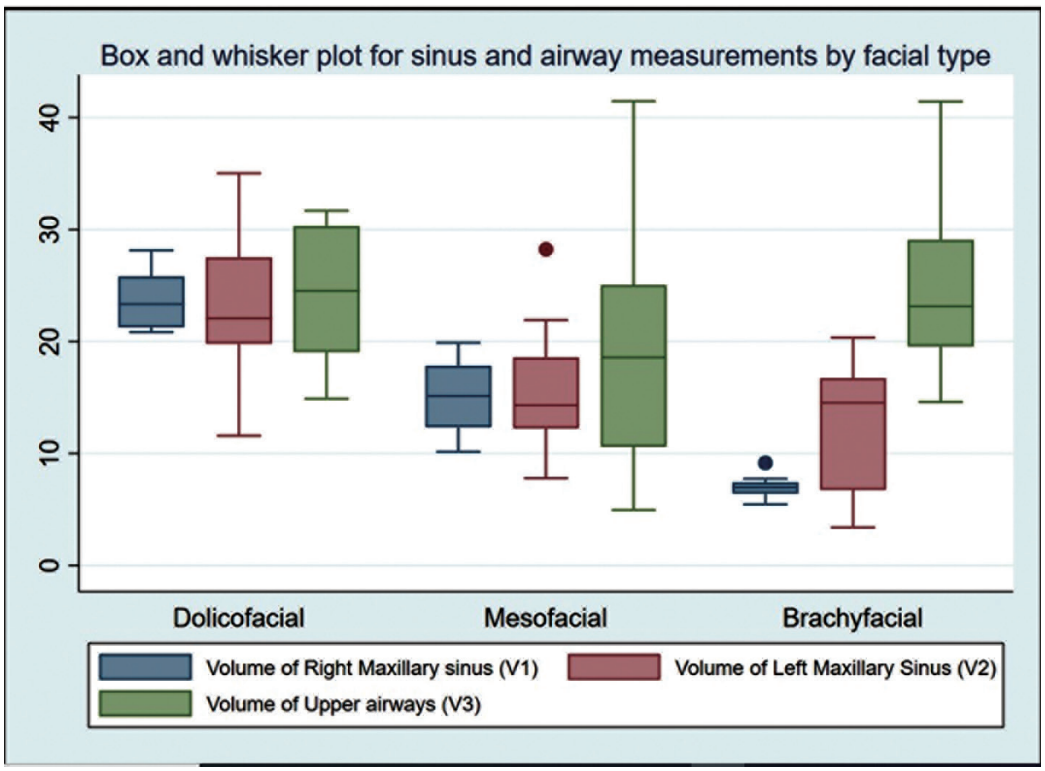

Fig. 10: Box and whisker plot for sinus and airways measurements by facial type

Tabic 1: Intcrgroup comparison by age group performed using one way ANOVA

		N	Mean	Std. Division	95% Confidence Interval for Mean		P value
					Lower Bound	Upper Bound	
Length of hard Palate at Molar (LI)	20-35 years	20	9.7850	1.57850	9.0462	10.5238	0.615
	36-50 years	20	9.2625	1.91761	8.3650	10.1600	
	Above 50 years	20	9.6445	1.66894	8.8634	10.4256	
Length of hard palate at Prcmolar (L2)	20-35 years	20	6.7720	1.21778	6.2021	7.3419	0.597
	36-50 years	20	6.9010	1.40608	6.2429	7.5591	
	Above 50 years	20	6.4245	1.88208	5.5437	7.3053	
Width of Hard palate at Molar (Wl)	20-35 years	20	31.9305	3.95551	30.0793	33.7817	0.033*
	36-50 years	20	29.9315	4.57455	27.7905	32.0725	
	Above 50 years	20	28.5415	3.36447	26.9669	30.1161	
	36-50 years	20	22.37400	6.032335	19.55078	25.19722	
	Above 50 years	20	21.60635	7.556012	18.07003	25.14267	

*p<0.05 is statistically significant **p<O.OOI is statistically highly significant

Table 2: Intergroup comparison by age group performed using post hoc Tukey test (after one way ANOVA)

Multiple Comparisons							
Tukey USD							
Dependent Variable	**(I)Age**	**(J) Age**	**Mean Difference (l-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
Length of hard Palate at Molar (LI)	20-35 years	36-50 years	.52250	.54633	.607	–.7922	1.8372
		Above 50 years	.14050	.54633	.964	–1.1742	1.4552
	36-50 years	Above 50 years	-.38200	.54633	.765	*1.6967	.9327
	20-35 years	36-50 years	-.12900	.48312	.961	–1.2916	1.0336
length of hard palate at Premolar (L2)		Above 50 years	.34750	.48312	.753	–.8151	1.5101
	36-50 years	Above 50 years	.47650	.48312	.588	–.6861	1.6391
Width of Hard palate at Molar (Wl)	20-35 years	36-50 years	1.99900	1.26349	.262	–1.0415	5.0395
		Above 50 years	3.38900	1.26349	.025*	.3485	6.4295

	36-50 years	Above 50 years	1.39000	1.26349	.518	–1.6505	4.4305
Width of hard palate at Premolar level (W2)	20-35 years	36-50 years	1.57000	1.31484	.462	–1.5940	4.7340
		Above 50 years	3.69050	1.31484	.018*	.5265	6.8545
	36-50 years	Above 50 years	2.12050	1.31484	.249	–1.0435	5.2845
Volume of Right Maxillary sinus (VI)	20-35 years	36-50 years	3.190950	1.728274	.164	7.34990	.96800
		Above 50 years	4.809250	1.728274	.020*	8.96820	-.65030
	36-50 years	Above 50 years	1.618300	1.728274	.620	5.77725	2.54065
Volume of Ieft Maxillary Sinus (V2)	20-35 years	36-50 years	4.847000	1.817845	.027*	9.22149	–.47251
		Above 50 years	5.822850	1.817845	.006*	10.19734	1.44836
	36-50 years	Above 50 years	.975850	1.817845	.854	5.35034	3.39864
Volume of Upper airways (V3)	20-35 years	36-50 years	3.061150	2.756911	.512	9.69543	3.57313
		Above 50 years	2.293500	2.756911	.685	8.92778	4.34078
	36-50 years	Above 50 years	.767650	2.756911	.958	5.86663	7.40193

*p<0.05 is statistically significant **p<0.001 is statistically highly significant

whiskers and the outliers as dots above and below the whiskers.

Intergroup comparison performed using "One way ANOVA test" revealed a statistically difference between age groups for width of hard palate at molar (p=0.033) and premolar level (p=0.024) as well as volume of maxillary sinus on the right (p=0.023) and left side (p=0.005) (Table 1). Lower values were observed for individuals aged above 50 years (Table 2).

Table 3: Intergroup comparison by gender performed using unpaired i test

	Gender	N	Mean	Std. Deviation	P value
l.cngth of hard Palate at Molar (LI)	Male	30	9.6710	1.73335	0.632
	Female	30	9.4570	1.71442	
l.cngth of hard palate at Prcmolar <L2)	Male	30	6.7837	1.68844	0.670
	Female	30	6.6147	1.34382	
Width of Hard palate at Molar (Wl)	Male	30	30.2913	4.19810	0.774
	Female	30	29.9777	4.20783	
Width of hard palate at Prcmolar level (W2)	Male	30	24.2847	4.76202	0.372
	Female	30	23.2703	3.93726	
Volume of Right Maxillary sinus (VI)	Male	30	16.17440	5.543685	0.952
	Female	30	16.08317	6.019271	

Volume of Left Maxillary Sinus (V2)	Male	30	17.53250	6.165781	0.470
	Female	30	16.36133	6.295987	
Volume of Upper airways (V3)	Male	30	20.81120	9.405346	0.900
	Female	30	21.38427	8.016159	

*p<0.05 is statistically significant **p<O.OOI is statistically highly significant

Table 4: Intergroup comparison by facial type performed using one way ANOVA

		N	Mean	Std. Deviation	95% Confidence Interval for Mean		P value
					Lower Bound	Upper Bound	
l.cngth of hard Palate at Molar (L1)	Dolicofacial	15	9.3240	1.59916	8.4384	10.2096	0.298
	Mesofacial	37	9.4735	1.71925	8.9003	10.0467	
	Brachyfacial	8	10.4325	1.83775	8.8961	11.968 9	
Length of hard palate at Prcmolar (L2)	Dolicofacial	15	6.6173	1.76500	5.6399	7.5948	0.953
	Mesofacial	37	6.7049	1.39859	6.2386	7.1712	
	Brachyfacial	8	6.8263	1.74071	5.3710	8.2815	
Width of Hard palate at Molar (Wl)	Dolicofacial	15	29.3307	4.62080	26.7718	31.8896	0.612
	Mesofacial	37	30.5516	4.08792	29.1886	31.9146	
	Brachyfacial	8	29.7125	3.92726	26.4292	32.9958	
Width of hard palate at Prcmolar level (W2)	Dolicofacial	15	22.7167	4.15923	20.4134	25.0200	.053
	Mesofacial	37	24.7781	4.09835	23.4116	26.1446	
	Brachyfacial	8	21.1387	4.87162	17.0660	25.2115	
Volume of Right Maxillary sinus (VI)	Dolicofacial	15	23.43133	2.422330	22.08989	24.77278	<0.0001*
	Mesofacial	37	15.13678	3.126956	14.09420	16.17936	
	Brachyfacial	8	7.02450	1.102596	6.10271	7.94629	
Volume of Left Maxillary Sinus (V2)	Dolicofacial	15	23.04760	5.817248	19.82612	26.26908	<0.0001*
	Mesofacial	37	15.44300	4.495615	13.94409	16.94191	
	Brachyfacial	8	12.46375	6.193450	7.28590	17.64160	
Volume of Upper air ways (V3)	Dolicofacial	15	23.83267	5.877931	20.57758	27.08776	0.083
	Mesofacial	37	19.15659	9.273067	16.06480	22.24839	

Brachyfacial	8	24.94750	8.317566	17.99384	31.90116

*p<0.05 is statistically significant **p<0.00l is statistically highly significant

'Iablc 5: Intcrgrotip comparison by facial type performed using post hoc Tukey test (after one way ANOVA)

Multiple Comparisons

Tukey USD

Dependent Variable	(1) Facial types	(J) Facial types	Mean Difference (I-J)	Std.Error	Sig.	95% Confidence Interval	
						lower Bound	Upper Bound
length of hard Palate at Molar (L1)	Dolicofacial	Mesofacial	–.14951	.52213	.956	–1.4060	1.1070
		Brachyfacial	1.10850	.74679	.306	–2.9056	.6886
	Mesofacial	Brachyfacial	–.95899	.66510	.327	–2.5595	.6415
Length of hard palate at Premolar (L2)	Dolicofacial	Mesofacial	–.08753	.47149	.981	–1.2221	1.0471
		Brachyfacial	–.20892	.67436	.949	–1.8317	1.4139
	Mesofacial	Brachyfacial	–.12139	.60059	.978	–1.5667	1.3239
Width of Hard palate at Molar (Wl)	Dolicofacial	Mesofacial	1.22095	1.28752	.612	–4.3193	1.8774
		Brachyfacial	–.38183	1.84150	.977	–4.8132	4.0496
	Mesofacial	Brachyfacial	.83912	1.64005	.866	–3.1075	4.7858
Width of hard palate at Premolar level(W2)	Dolicofacial	Mesofacial	2.06144	1.29039	.255	–5.1667	1.0438
		Brachyfacial	1.57792	1.84561	.671	–2.8634	6.0192
	Mesofacial	Brachifacial	3.63936	1.64371	.077	–.3161	7.5948
	Dolicofacial	Mesofacial	8.294550	.853008	.000**	6.24186	10.34724
Volume of Right Maxillary sinus (VI)		Brachyfacial	16.406833	1.220032	.000**	13.47093	19.34274
	Mesofacial	Brachyfacial	8.112284	1.086571	.000 **	5.49754	10.72703
Volume of I-cft Maxillary Sinus (V2)	Oolicofacial	Mesofacial	7.604600	1.554373	.000**	3.86413	11.34507
		Brachyfacial	10.583850	2.223174	.000 **	5.23396	15.93374
	Mesofacial	Brachyfacial	2.979250	1.979979	.296	1.78541	7.74391
Volume of Upper airways <V3)	Dolicofacial	Mesofacial	4.676072	2.584482	.176	1.54327	10.89542
		Brachyfacial	1.114833	3.696508	.951	10.01018	7.78051
	Mesofacial	Brachyfacial	5.790905	3.292144	.193	13.71318	2.13137

*p<0.05 is statistically significant **p<0.001 is statistically highly significant

There was no statistically significant difference between male and female for any of the morphometric variable (Table 3).

Intergroup comparison performed using "One way ANOVA test" revealed a statistically difference between facial types for volume of maxillary sinus on the right and left side ($p < 0.0001$) (Table 4). Higher values were observed for dolichofacial individuals and Lower values were observed for brachyfacial individuals (Table 5).

Multivariate regression revealed there was no relationship between volume of sinus with hard palate measurements as well as volume of airway with hard palate measurements as well as with volume of sinus.

Cluster analysis revealed width of hard palate as well as volume of maxillary sinus could accurately cluster patients above 50 years whereas it failed categorize patients aged 20-35 years as well as who are aged 36-50 years.

Dendrogram generated using Hierarchical Ward's linkage method showed that volume of maxillary sinus could cluster all the three facial types (Dolichofacial, mesofacial and brachyfacial) with considerable degree of precision.

DISCUSSION

Age, gender and facial type determination are paramount in forensic science in identification of deceased individuals. Skeletal structures are more resistant to external environmental stimuli and are more reliable in the field of Forensic medicine. Forensic odontologists can define their role of forensic medical specialists by providing more precise valuable dental records.

In the current study, there was significant reduction in width of hard palate with increasing age. The results of the current study are in agreement with the study done by Ayman et al. in 2018 which showed that dimensions of hard palate show significant reduction in adult age group and also has male-female predilection.

This might be attributed to the fact that resorption of the alveolar ridge increases with increasing age. The maxillary alveolar ridge usually resorbs at the expense of the crest. Usually, the crest of the ridge moves in superior and palatal direction (upwards and backwards). ***Alonso*** in 2015[11] found that dental status has a significant influence on buccal bone plate dimensions and not on palatal bone plate dimensions. Therefore, the width of the hard palate decreases as age increases.

An inverse relationship was observed between width of hard palate and volume of maxillary sinus in the current study. The decrease in width of the hard palate resulted in an increase in volume of maxillary sinus due to the fact that floor of the hard palate forms the lower boundary of the maxillary sinus. Hence volume of maxillary sinus showed an increasing trend in individuals aged above 50 years in the current study.

The study done by ***Waluyo et al. in 2020***[4], showed that there was a statistically significant difference between Indonesian male and female with respect to height, length and width of maxillary sinus. Whereas in the current study no significant difference was observed between males and females for either of the morphometric parameters.

In the current study no relationship was observed between volume of upper airway and facial growth pattern. This is in contrary to the study conducted by ***Fernandes et al.***[9] in 2017 which concluded that upper airway aids in facial growth pattern determination. The study done by ***Yueu Nejaim et al***[10] in 2017 also concluded that a correlation exists between pharyngeal space with mandible and hyoid bone. Hence it could be considered a parameter of significance in determining facial type and gender.

In the current study a significant difference in volume of maxillary sinus was observed with respect to facial type with higher values shown by dolichofacial type. This could be attributed to the downward and forward growth of maxilla in dolichocephalic individuals which causes the bounded volume of maxillary sinus to increase.

Strength of the study

- The utility of morphometric variables of hard palate (width) and sinus volume in forensic odontology has been established in the present study using robust statistical techniques. The accuracy of these morphometric variables in clustering/ classifying different age groups and facial types was determined and established using cluster analysis.

Limitations of the present study

- It's a preliminary study and it has to be

studied with larger samples for better reliability and to be used as routine tool in the forensic science.

Future scope

Future studies are required to determine any underlying relationship between these radiographic morphometric variables and other facial anthropometric measurements. Artificial intelligence frameworks using convoluted neural networks could be developed utilising the morphometric cut-off values determined from the current study for age, gender and facial type determination. These AI frameworks could serve as a remarkable supplementary tool in forensics.

CONCLUSION

Hence from light of the results of the current study it can be concluded that Width of hard palate and volume of maxillary sinus decreases with increasing age and hence could serve as a reliable adjunct in age determination in forensics. An inverse relationship exists between Width of hard palate and volume of maxillary sinus. Volume of maxillary sinus varies with facial type with higher values observed for dolichofacial individuals and lower values for brachyfacial type. Hence sinus volume could help in determining growth trend and pattern (Viz.) horizontal/vertical/ average (orthognathic) grower. It could help the clinician to predict and forecast developing skeletal malocclusion in the vertical dimension.

Hence, it can be concluded that the morphometric variables such as width of hard palate and volume of maxillary sinus could serve as reliable tool in age and facial type determination in Forensics.

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