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Is the Morphometry of Paranasal Sinuses Valid for Age and Gender Determination in a Sample of Egyptian Children Population?

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Abstract

Background: Morphometric studies on different skeletal bones using computed tomography images have been recorded. Despite these morphometric studies on age estimation from maxillary and frontal sinuses have been conducted in the world, there are no studies in Egypt for age and gender estimation from these parameters in children yet. Also, the characteristics of the Egyptian population in age estimation and gender determination by imaging using computed tomography may be different from other races. **Aim of the Work:** to assess the validity of frontal and maxillary sinuses for age and gender determination in a sample of Egyptian children. **Methods:** This descriptive study was conducted on 180 CT films belong to Egyptian children aged from 1m-18 yrs archived in Radiology department- Ain Shams University Hospitals. The studied CT films were equally classified regarding the gender and each group was equally sub-divided regarding the age into 3 subgroups i.e. 1m-6 yrs, >6-11 yrs, >11-18 yrs. **Results:** All the studied parameters (depth, width and height) of both maxillary and frontal sinuses showed validity for age determination in Egyptian children except frontal depth on both sides. Right frontal width had the highest accuracy for age estimation among all the studied parameters in all the studied age groups (92.85%) followed by left maxillary height (91.65%). On the other hand, only left frontal depth and right frontal width could be used for gender determination with accuracy of 64.05% and 64% respectively. **Conclusion:** Maxillary and frontal sinus measurements including depth, width, and height can be used in age determination in Egyptian children except frontal sinus depth on both sides. Right frontal width had the highest accuracy for age estimation among all the studied parameters in all the studied age groups. Left frontal depth and right frontal width are recommended in gender discrimination in children in the forensic medicine.

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Key words Medicolegal, Importance, Determination

Introduction

Morphometric studies on paranasal sinuses have been the target of many morphometric investigations all over the world for determination of age and gender (Mishra et al., 2020). The paranasal sinuses (maxillary, frontal, ethmoid, and sphenoid sinuses) are complex anatomical structures. The development and growth of these have been investigated utilizing several different methods ranging from cadaveric analysis to modern cross-sectional imaging with 3D modeling (Lee et al., 2022).

There are several studies in the literatures that used radiographic images to verify whether the frontal, maxillary, and sphenoid sinuses provide support for recognition in estimating sexual dimorphism, age, and ancestry. As for the ethmoid sinus, no data was found relating it to these variables (Barros et al., 2022).

Among these paranasal sinuses, frontal and maxillary sinuses were particularly selected because of their uniqueness justified by large inter-individual variation in the size, shape, symmetry, outer edges and number of septa. Therefore, their analysis meets the requirements of exclusivity, permanence and immutability providing technical and scientific information used in forensic identification (Xavier et al., 2015).

Recent studies on maxillary sinuses were recorded in assessment for age and gender (Najem et al., 2021). Also, estimation of age and gender from frontal sinuses has been studied by Issrani et al. (2022).

Despite these morphometric studies for age and gender estimation using maxillary and frontal sinuses parameters have been conducted on adults all over the world including Egypt, no studies using the previous morphometrics were carried out on Egyptian children population yet. Hence, as far as we know, this study is one of the pioneer studies performed on them.

Aim of the Work

This study aimed to assess the validity of frontal and maxillary sinuses for age and gender determination in a sample of Egyptian children population.

Patients and Methods

Type of Study: Descriptive (archive) study using computed tomography (CT) imaging records

Study Setting: The study was conducted in the archive of Radiology Department, Ain Shams University Hospitals (ASUH).

Study population: Egyptian children

Selection criteria for the study sample:

Inclusion criteria

- CT imaging records of Egyptian children (1m-18yrs).
- Availability of case records (Date of birth, date of imaging)
- CT scans with adequate quality without any distortions.

Exclusion criteria

- Frontal and maxillary sinuses inflammation, fractures, tumors, malformation or deformities recognized in CT scan.

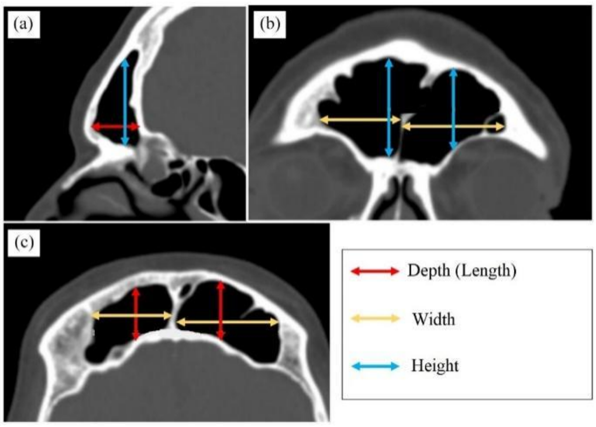
Sample Size:

CT films (brain and paranasal sinuses) of 180 children of age group from 1m-18 years. They were divided into 90 males and 90 females. Each gender was sub-divided into 3 equal age groups i.e. 0 - 6 years, >6 - 11 years and >11 – 18 years.

Study Tools:

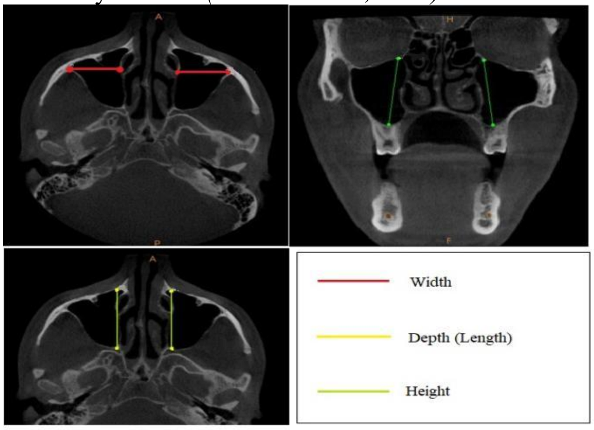
- Age of the selected CT films was confirmed by birth certificate or ID card which was already documented in medical records.
- Dimensions of scanned frontal and maxillary sinuses (right and left) were measured in millimeter (mm).
- The following sinuses parameters were measured:

Frontal sinuses: *(Wickramasinghe et al., 2022)*



- The height: the maximum distance from the frontal sinus ostium to the maximum superior height.
- The width: the maximum distance along the axial cuts at the level of the orbital roof i.e., the maximum distance between the medial and lateral lines of the sinus.
- The depth: the maximum distance from the anterior to the posterior sinus borders.

Maxillary sinuses: *(Shahnaz et al., 2016)*



- The height: the longest distance between the lowest points of the floor of the sinus to the highest point of the roof of the sinus in the coronal view.
- The width: the greatest distance horizontally from the medial surface to the most lateral point of maxillary sinus in the axial view.
- The depth: the longest distance from the most anterior point of the medial wall to the posterior point of maxillary sinus in the sagittal view.

Statistical analysis

The obtained data was revised, coded and organized for statistical analysis using IBM SPSS software package version 25.0**.** Data was presented and suitable analysis was done according to the type of data obtained for each parameter.

Ethical consideration:

This study was conducted after getting approval of head of Radiology department and the Ethical Committee of Faculty of Medicine, Ain Shams University, code number (FWA000017585).

Results

With respect to age differences in frontal sinus morphometry, table (1) and figures (1, 2) demonstrated statistically significant differences between the age groups regarding the width and height with $p \leq 0.05$. However, the depth of frontal sinus on both sides did not show any significance.

Table (2) and figures (3, 4) demonstrated that all the examined parameters (height, width, and depth) of the right and left maxillary sinuses varied significantly among the age groups under investigation with $p \leq 0.05$.

On the other hand, gender differences regarding the morphometry of frontal sinuses, table (3) and figure (5) showed that there was no significant difference between male and female children in all frontal sinus studied parameters except for left frontal depth and right frontal width. However, table (4) and figure (6) demonstrated that all the maxillary sinus studied parameters—depth, width, and height—did not significantly differ between male and female children.

According to table (5) and figure (7), 71.1% of the cases analyzed might have been accurately categorized as female children and 33.3% as male children based on the proper right frontal depth. According to right frontal width, 36.7% of the analyzed cases might have been accurately categorized as male children and 72.2% of the studied cases as female children. According to right frontal height, 71.1% of the cases under study could be appropriately categorized as children of the female gender and 28.9% as children of the male gender.

Using left frontal depth, it was possible to accurately classify 34.4% of the analyzed cases as male children and 74.4% of the studied cases as female children. According to left frontal width, 68.9% of the cases under study could be appropriately categorized as children of the female gender and 25.6% as children of the male gender. Based on left frontal height, it was possible to correctly classify 72.2% of the analyzed cases as female children and 26.7% of the studied cases as male children.

Based on the maxillary parameters, table (6) and figure (8) demonstrated that using right depth 63.3% of the cases could be accurately categorized as female children and 38.9% as male children. According to right width, 56.7% of the cases investigated could be accurately categorized as male children and 43.3% of the cases analyzed could be correctly classified as female children. According to right height, 40% of the cases could have been appropriately categorized as male children and 50% of the cases might have been correctly classified as female children.

While for left maxillary parameters, left depth revealed that 38.9% of the cases could be accurately categorized as male children and 58.9% of the cases could be correctly classified as females. Based on the left width, it was possible to correctly classify 42.2% and 55.6% of the examined cases as male and female children, respectively. On the basis of left height, 56.7% of the cases under study could be appropriately identified as child females and 50% as child males.

Table (7) and figures (9, 10) show that there was significant correlation between all the studied parameters of both maxillary and frontal sinuses (right and left) with age.

Table (8) showed that both right frontal width and height were statistically significant parameters for age determination, the following equation to estimate the age from right frontal sinus was predicted:

Age = 6.539+ (0.148 x Rt frontal width) + (0.203 x Rt frontal height). *(6.539= constant Beta coefficient, 0.148= Beta coefficient of right frontal width, 0.203= Beta coefficient of right frontal height)*

Table (9) showed that left frontal width and height were statistically significant parameters for age determination, the following equation to estimate age from left frontal sinus was predicted:

Age = 6.933 + (0.162x Lt Frontal width) + (0.155 x Lt Frontal height). *(6.933= constant Beta coefficient, 0.162= Beta coefficient of left frontal width, 0.155= Beta coefficient of left frontal height)*

Table (10) showed that right maxillary depth, width and height were statistically significant parameters for age determination, the following equation to estimate age from right maxillary sinus was predicted:

Age = -5.596 + (0.162 x Rt max. depth) + (0.138x Rt max. width) + (0.302 x Rt max. height). *(-5.596= constant Beta coefficient, 0.162= Beta coefficient of right maxillary depth, 0.138= Beta coefficient of right maxillary width, 0.302= Beta coefficient of right maxillary height)*

Table (11) showed that left maxillary depth, width and height were statistically significant parameters for age determination, the following equation to estimate age from left maxillary sinus was predicted:

Age = -5.674 + (0.161 x Lt. max. depth) + (0.146 x Lt max. width) + (0.281 x Lt max. height). *(-5.674= constant Beta coefficient, 0.161= Beta coefficient of left maxillary depth, 0.146= Beta coefficient of left maxillary width, 0.281= Beta coefficient of left maxillary height)*

Regarding receiver operating characteristic (ROC) analysis in differentiation between age groups 1m-6 yrs and >6-11 yrs using frontal sinus measurements, figure (11) revealed that right frontal depth and width along with left frontal height and width gave the highest sensitivity (100%). Right frontal height gave the highest specificity (68.3%) followed by right frontal depth (66%). Right frontal height had the highest accuracy (86%) followed by right frontal width (81.15%).

Regarding ROC analysis in differentiation between age groups > 6-11yrs and >11-18 yrs using frontal sinus measurements, figure (12) revealed that right frontal depth gave the highest sensitivity (96.2%) followed by left frontal depth (90.4%). Left frontal width gave the highest specificity (64.8%) followed by left frontal height (58.2%). Left frontal width had the highest accuracy (67%) followed by right frontal width (63.75%).

Regarding ROC analysis in differentiation between age groups > 1m-6 yrs and >11-18 yrs using frontal sinus measurements, figure (13) revealed that all frontal sinus measurements gave the highest sensitivity (100%) except left frontal depth. Right frontal width gave the highest specificity (85.7%) followed by left frontal width (74.1%). Right frontal width had the highest accuracy (92.85%) followed by left frontal width (87.05%).

Regarding receiver operating characteristic (ROC) analysis in differentiation between age groups 1m-6 yrs and > 6-11 yrs using maxillary sinus measurements, figure (14) revealed that right maxillary depth gave the highest sensitivity (88.3%) followed by right maxillary width (86.7%). Left maxillary depth gave the highest specificity (98.3%) followed by left maxillary width (96.7%). Right maxillary height had the highest accuracy (84.2%) followed by left maxillary height (83.35%).

Regarding ROC analysis in differentiation between age groups > 6-11yrs and >11-18 yrs using maxillary sinus measurements, figure (15) revealed that left maxillary depth gave the highest sensitivity (70%) followed by left maxillary height (68.3%). Right maxillary width gave the highest specificity (90%) followed by right maxillary height (85%). Left maxillary height had the highest accuracy (66.65%) followed by right maxillary height (65.15%).

Regarding ROC analysis in differentiation between age groups > 1m-6 yrs and >11-18 yrs using maxillary sinus measurements, figure (16) revealed that left maxillary depth gave the highest sensitivity (98.3%) followed by right maxillary height (91.7%). Left maxillary height gave the highest specificity (95%)

followed by right maxillary width and height as well as left maxillary width (93.3%). Left maxillary height had the highest accuracy (91.65%) followed by right maxillary height (91.5%).

Regarding ROC analysis in gender prediction using frontal sinus measurements, figure (17) revealed that right frontal depth gave the highest sensitivity (74.1%) followed by left frontal depth and height (71.4%). Left frontal width gave the highest specificity (94.4%) followed by right frontal height (81.8%). Left frontal depth gave the highest accuracy (64.05%) followed by right frontal width (64%).

Regarding ROC analysis in gender prediction using maxillary sinus measurements, figure (18) revealed that left maxillary depth gives the highest sensitivity (96.7%) followed by right maxillary depth (87.8%). Right maxillary width gives the highest specificity (84.4%) followed by left maxillary height (70%). Left maxillary depth gave the highest accuracy (57.2%) followed by right maxillary width (57.12%).

Table (1): Age differences regarding the morphometry of the frontal sinuses in all studied CT films.

		(N= 180)								Test value	P-value
		N	Mean	SD	Median	IQR		Min.	Max.		
Right frontal sinus											
Depth (mm)	**1m-6y**	60	8.98	±1.99	9.24	6.88	10.83	6.88	10.83	2.057	0.133
	>6y - 11y	60	11.89	±2.97	12.04	9.66	14.09	5.27	20.78		
	>11y - 18y	60	12.88	±4.55	13.04	9.87	15.98	3.98	26.88		
Width (mm)	**1m-6y**	60	9.16	±2.28	7.99	7.70	11.79	7.70	11.79	15.31	**<0.001 (sig.)**
	>6y - 11y	60	14.76	±5.00	14.20	10.58	18.72	5.07	24.27		
	>11y - 18y	60	18.56	±6.01	18.33	13.81	23.05	7.46	31.37		
Height (mm)	**1m-6y**	60	6.45	±0.56	6.30	5.99	7.07	5.99	7.07	6.844	**0.002 (sig.)**
	>6y - 11y	60	12.27	±3.93	12.50	9.52	14.84	4.69	19.87		
	>11y - 18y	60	14.94	±5.94	14.09	10.85	17.82	3.60	29.04		
Left frontal sinus											
Depth (mm)	**1m-6y**	60	12.11	±2.59	11.72	10.40	13.82	9.39	15.61	0.899	0.410
	>6y - 11y	60	12.16	±3.60	12.55	9.09	14.91	3.90	19.65		
	>11y - 18y	60	13.18	±4.42	13.73	9.85	16.59	3.66	25.99		
Width (mm)	**1m-6y**	60	10.97	±3.83	12.63	8.81	13.13	5.26	13.36	13.62	**0.001 (sig.)**
	>6y - 11y	60	14.36	±5.23	13.26	10.87	18.24	5.20	26.36		
	>11y - 18y	60	18.36	±6.35	17.78	13.29	22.82	5.88	30.64		
Height (mm)	**1m-6y**	60	8.89	±2.82	8.82	6.70	11.09	5.70	12.23	12.02	**0.002 (sig.)**
	>6y - 11y	60	11.88	±4.77	10.82	8.93	13.83	4.20	28.65		
	>11y - 18y	60	15.08	±6.32	14.61	10.10	18.63	2.80	29.94		

p≤0.05 is significant, p≤0.01 is highly significant, p> 0.05 is not significant, One-Way ANOVA test, Kruskal Wallis test

Table (2): Age differences regarding the morphometry of the maxillary sinuses in all studied CT films.

		(N= 180)								Test value	P-value
		N	Mean	SD	Median	IQR		Min.	Max.		
Right maxillary sinus											
Depth (mm)	**1m-6y**	60	20.25	±7.55	21.51	14.37	27.06	4.40	34.44	77.302	**<0.001 (sig.)**
	>6y - 11y	60	29.86	±4.38	29.26	26.64	33.82	20.92	39.06		
	>11y - 18y	60	31.66	±3.36	31.56	29.04	34.47	25.10	39.81		
Width (mm)	**1m-6y**	60	14.996	±5.626	15.730	11.09	18.32	4.880	29.000	71.55	**<0.001 (sig.)**
	>6y - 11y	60	23.568	±4.807	23.780	20.35	26.43	13.640	35.560		
	>11y - 18y	60	24.815	±4.138	24.420	22.14	27.97	11.550	33.200		
Height (mm)	**1m-6y**	60	16.70	±5.80	18.00	14.04	21.10	3.80	24.65	99.98	**<0.001 (sig.)**
	>6y - 11y	60	26.04	±4.04	26.05	23.28	29.09	17.89	35.77		
	>11y - 18y	60	28.76	±4.70	28.50	25.36	31.56	16.06	41.73		
Left maxillary sinus											
Depth (mm)	**1m-6y**	60	20.63	±7.22	21.91	15.37	26.07	5.69	32.33	83.69	**<0.001 (sig.)**
	>6y - 11y	60	30.16	±4.05	30.70	27.50	32.66	15.17	37.29		
	>11y - 18y	60	31.98	±3.46	32.68	29.36	34.35	23.80	37.28		
Width (mm)	**1m-6y**	60	15.37	±5.50	16.00	10.90	19.55	3.52	27.21	86.45	**<0.001 (sig.)**
	>6y - 11y	60	24.39	±4.70	24.43	21.06	27.79	13.31	34.01		
	>11y - 18y	60	25.79	±3.78	25.69	23.39	28.11	14.49	34.68		
Height (mm)	**1m-6y**	60	17.39	±6.00	18.67	14.44	21.38	3.77	27.82	101.36	**<0.001 (sig.)**
	>6y - 11y	60	27.05	±4.61	26.84	23.23	29.85	19.46	38.88		
	>11y - 18y	60	30.37	±4.85	29.85	27.11	33.66	21.47	44.15		

p≤0.05 is significant, p≤0.01 is highly significant, p> 0.05 is not significant, One-Way ANOVA test, Kruskal Wallis test

Table (3): Gender differences regarding the morphometry of the frontal sinuses in all age groups.

		(N= 180)								Test value	P-value
		N	Mean	SD	Median	IQR		Min.	Max.		
Right frontal sinus											
Depth (mm)	♂ **child**	90	12.91	±4.16	12.56	9.97	15.02	3.98	26.88	1.612	0.110
	♀ **child**	90	11.74	±3.54	11.87	8.60	14.11	5.27	22.26		
Width (mm)	♂ **child**	90	17.49	±5.23	18.02	14.05	21.54	7.70	29.31	1.947	**0.049 (sig.)**
	♀ **child**	90	15.57	±6.38	13.51	11.13	19.66	5.07	31.37		
Height (mm)	♂ **child**	90	13.65	±4.78	13.21	10.64	16.38	3.60	26.17	0.393	0.695
	♀ **child**	90	13.26	±5.76	13.07	9.07	15.98	4.26	29.04		
Left frontal sinus											
Depth (mm)	♂ **child**	90	13.48	±4.20	14.18	9.85	16.21	3.66	25.99	2.156	**0.033 (sig.)**
	♀ **child**	90	11.87	±3.65	12.29	9.28	14.75	4.37	19.64		
Width (mm)	♂ **child**	90	16.41	±6.03	15.06	12.05	21.78	5.26	30.64	0.296	0.767
	♀ **child**	90	15.99	±6.30	15.36	11.66	20.84	5.20	30.35		
Height (mm)	♂ **child**	90	13.55	±6.13	12.15	9.02	16.23	2.80	29.94	0.080	0.937
	♀ **child**	90	13.17	±5.50	12.55	9.71	15.29	4.20	29.65		

p≤0.05 is significant, p≤0.01 is highly significant, p> 0.05 is not significant, T: Student T Test, ZMWU: Mann–Whitney U test

Table (4): Gender differences regarding the morphometry of the maxillary sinuses in all age groups.

		(N= 180)								Test value	P-value
		N	Mean	SD	Median	IQR		Min.	Max.		
Right maxillary sinus											
Depth (mm)	♂ **child**	90	26.83	7.95	28.77	21.88	32.27	6.97	38.55	0.784	0.434
	♀ **child**	90	27.69	6.71	28.88	25.25	31.62	4.40	39.81		
Width (mm)	♂ **child**	90	21.141	6.656	22.065	16.41	25.38	5.084	33.200	0.029	0.977
	♀ **child**	90	21.112	6.472	21.840	16.55	25.64	4.880	35.560		
Height (mm)	♂ **child**	90	23.73	6.93	24.86	20.92	27.68	3.80	41.73	0.185	0.853
	♀ **child**	90	23.93	7.33	23.94	19.81	29.00	4.71	40.48		
Left maxillary sinus											
Depth (mm)	♂ **child**	90	27.37	7.55	29.30	23.91	32.65	6.11	37.29	0.406	0.685
	♀ **child**	90	27.81	6.81	29.02	25.11	32.94	5.69	37.23		
Width (mm)	♂ **child**	90	21.81	6.62	23.11	17.59	26.87	3.52	33.59	0.082	0.935
	♀ **child**	90	21.89	6.59	22.66	18.21	26.19	5.05	34.68		
Height (mm)	♂ **child**	90	24.46	7.33	25.13	21.30	29.14	3.77	44.15	0.837	0.404
	♀ **child**	90	25.41	7.78	26.27	21.06	30.23	5.23	39.88		

p≤0.05 is significant, p≤0.01 is highly significant, p> 0.05 is not significant, T: Student T Test, ZMWU: Mann–Whitney U test

Table (5): Discriminant analysis using right / left frontal sinus measurements to distinguish between males and females children.

		Real	Predicted		Total	Wilks lambda
			♂ child	♀ child		
Right frontal sinus	**Depth**	♂ **child**	30 (33.3%)	60 (66.7%)	90 (100%)	0.977
		♀ **child**	26 (28.9%)	64 (71.1%)	90 (100%)	
	Width	♂ **child**	33 (36.7%)	57 (63.3%)	90 (100%)	0.973
		♀ **child**	25 (27.8%)	65 (72.2%)	90 (100%)	
	Height	♂ **child**	26 (28.9%)	64 (71.1%)	90 (100%)	0.999
		♀ **child**	26 (28.9%)	64 (71.1%)	90 (100%)	
Left frontal sinus	**Depth**	♂ **child**	31 (34.4%)	59 (65.6%)	90 (100%)	0.959
		♀ **child**	23 (25.6%)	67 (74.4%)	90 (100%)	
	Width	♂ **child**	23 (25.6%)	67 (74.4%)	90 (100%)	0.999
		♀ **child**	28 (31.1%)	62 (68.9%)	90 (100%)	
	Height	♂ **child**	24 (26.7%)	66 (73.3%)	90 (100%)	0.999
		♀ **child**	25 (27.8%)	65 (72.2%)	90 (100%)	

Table (6): Discrimination function analysis using right / left maxillary sinus parameters to distinguish between male and female children.

		Real	Predicted		Total	Wilks lambda
			♂ child	♀ child		
Right maxillary sinus	Depth	♂ child	35 (38.9%)	55 (61.1%)	90 (100%)	0.997
		♀ child	33 (36.7%)	57 (63.3%)	90 (100%)	
	Width	♂ child	51 (56.7%)	39 (43.3%)	90 (100%)	1.00
		♀ child	51 (56.7%)	39 (43.3%)	90 (100%)	
	Height	♂ child	36 (40.0%)	54 (60.0%)	90 (100%)	1.00
		♀ child	45 (50.0%)	45 (50.0%)	90 (100%)	
Left maxillary sinus	Depth	♂ child	35 (38.9%)	55 (61.1%)	90 (100%)	0.999
		♀ child	37 (41.1%)	53 (58.9%)	90 (100%)	
	Width	♂ child	38 (42.2%)	52 (57.8%)	90 (100%)	1.00
		♀ child	40 (44.4%)	50 (55.6%)	90 (100%)	
	Height	♂ child	45 (50.0%)	45 (50.0%)	90 (100%)	0.996
		♀ child	39 (43.3%)	51 (56.7%)	90 (100%)	

Table (7): Spearman Correlation between the estimated age with different maxillary and frontal sinuses studied parameters.

	Age	
	R	p-value
Right Maxillary Depth	0.696	**<0.001**
Right Maxillary Width	0.657	**<0.001**
Right Maxillary Height	0.774	**<0.001**
Left Maxillary Depth	0.704	**<0.001**
Left Maxillary Width	0.693	**<0.001**
Left Maxillary Height	0.768	**<0.001**
Right Frontal Depth	0.274	**0.003**
Right Frontal Width	0.459	**<0.001**
Right Frontal Height	0.446	**<0.001**
Left Frontal Depth	0.237	**0.012**
Left Frontal Width	0.455	**<0.001**
Left Frontal Height	0.459	**<0.001**

p≤0.05 is considered statistically significant, p≤0.01 is considered high statistically, r: correlation coefficient

Table (8): Multiple linear regression analysis. Regression coefficient for right frontal sinus parameters for age determination of all studied CT films.

	Unstandardized Coefficients		Standardized Coefficients Beta	t	P
	B	S.E			
(Constant)	6.539	.800		8.174	**<0.001**
Right frontal Depth	-0.035	0.079	-0.042	-0.438	0.662
Right frontal Width	0.148	0.055	0.273	2.667	**0.009**
Right frontal Height	0.203	0.062	0.336	3.282	**0.001**

B: Beta coefficient for each independent variable, S.E: Standard error, <0.001: highly significant

Table (9): Multiple linear regression analysis. Regression coefficient for left frontal sinus parameters for age determination of all studied CT films.

	Unstandardized Coefficients		Standardized Coefficients Beta	t	P
	B	S.E			
(Constant)	6.933	0.756		9.172	**<0.001**
Left frontal Depth	-0.143	0.085	-0.176	-1.680	0.096
Left frontal Width	0.162	0.064	0.307	2.550	**0.012**
Left frontal Height	0.155	0.067	0.277	2.300	**0.023**

B: Beta coefficient for each independent variable, S.E: Standard error, <0.001: highly significant

Table (10): Multiple linear regression analysis. Regression coefficient for right maxillary sinus parameters for age determination of all studied CT films.

	Unstandardized Coefficients		Standardized Coefficients Beta	t	P
	B	S.E			
(Constant)	-5.596	0.826	-	-6.776	<0.001
Right Maxillary Depth	0.162	0.052	0.247	3.112	0.002
Right Maxillary Width	0.138	0.050	0.188	2.766	0.006
Right Maxillary Height	0.302	0.056	0.446	5.414	<0.001

B: Beta coefficient for each independent variable, S.E: Standard error, <0.001:highly significant

Table (11): Multiple linear regression analysis. Regression coefficient for left maxillary sinus parameters for age determination of all studied CT films.

	Unstandardized Coefficients		Standardized Coefficients Beta	t	P
	B	S.E			
(Constant)	-5.674	0.834		-6.799	<0.001
Left Maxillary Depth	0.161	0.055	0.239	2.927	0.004
Left Maxillary Width	0.146	0.057	0.199	2.579	0.011
Left Maxillary Height	0.281	0.050	0.440	5.599	<0.001

B: Beta coefficient for each independent variable, S.E: Standard error, <0.001: highly significant

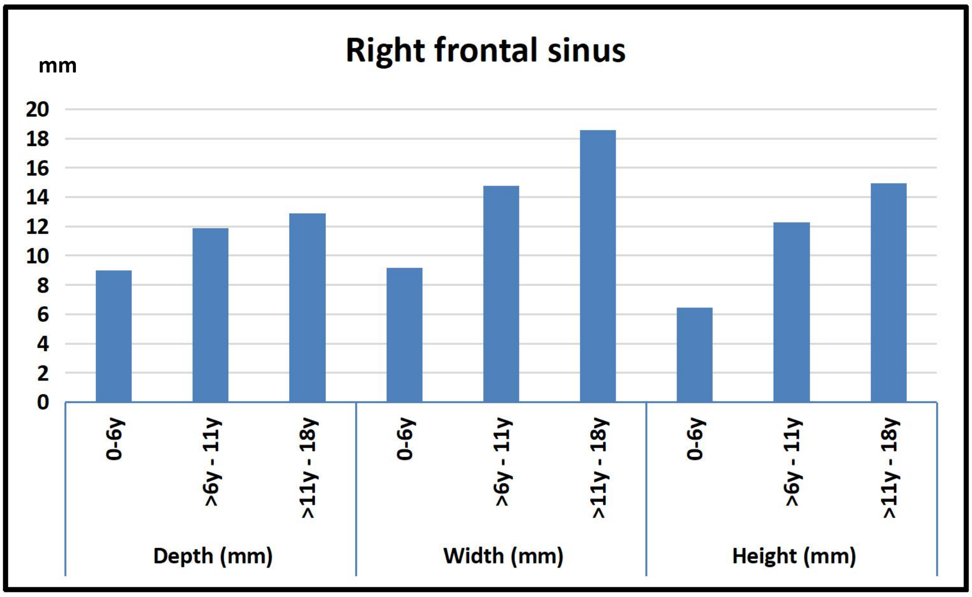


Figure (1): Age differences regarding the morphometry of right frontal sinus

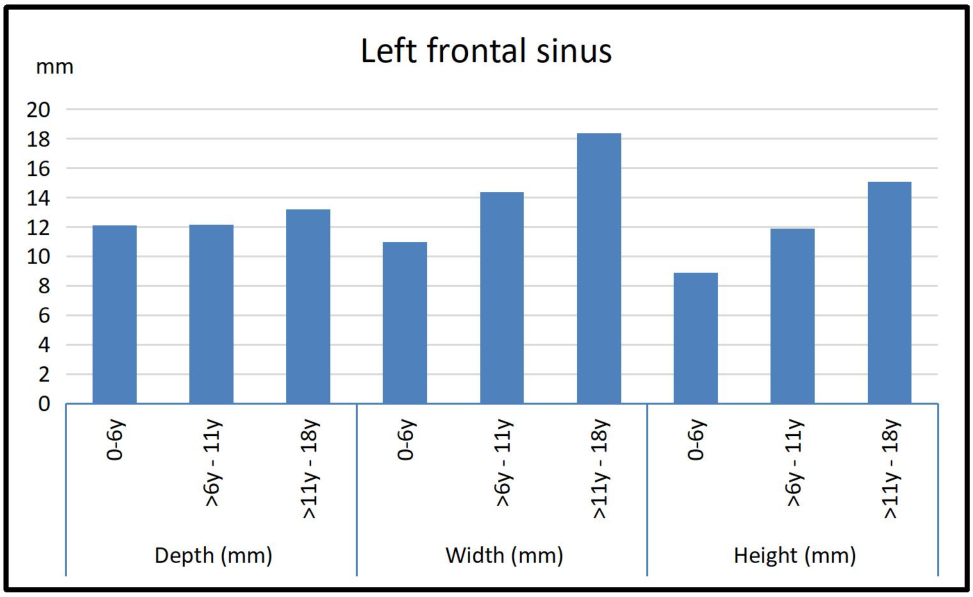


Figure (2): Age differences regarding the morphometry of left frontal sinus

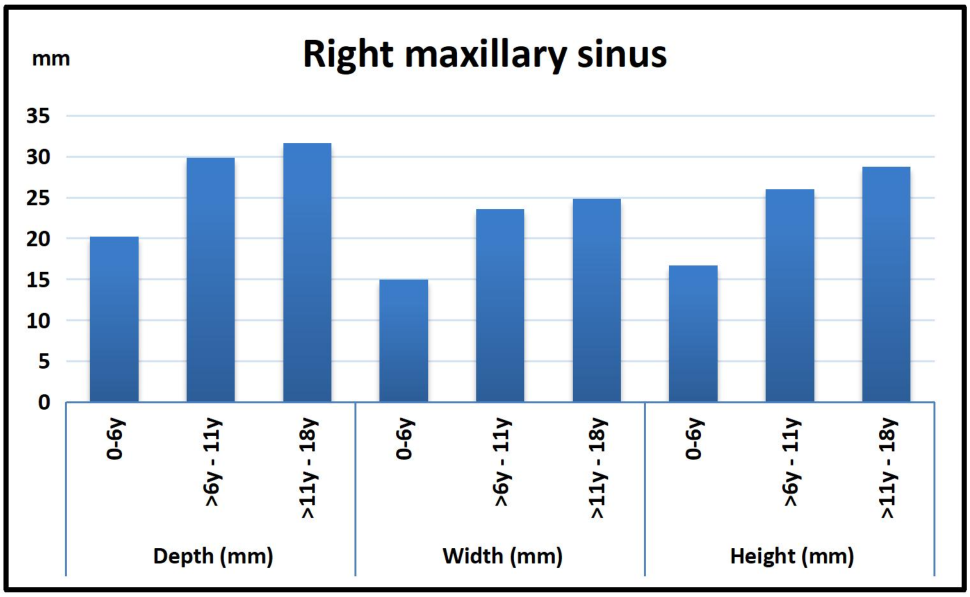


Figure (3): Age differences regarding the morphometry of right maxillary sinus.

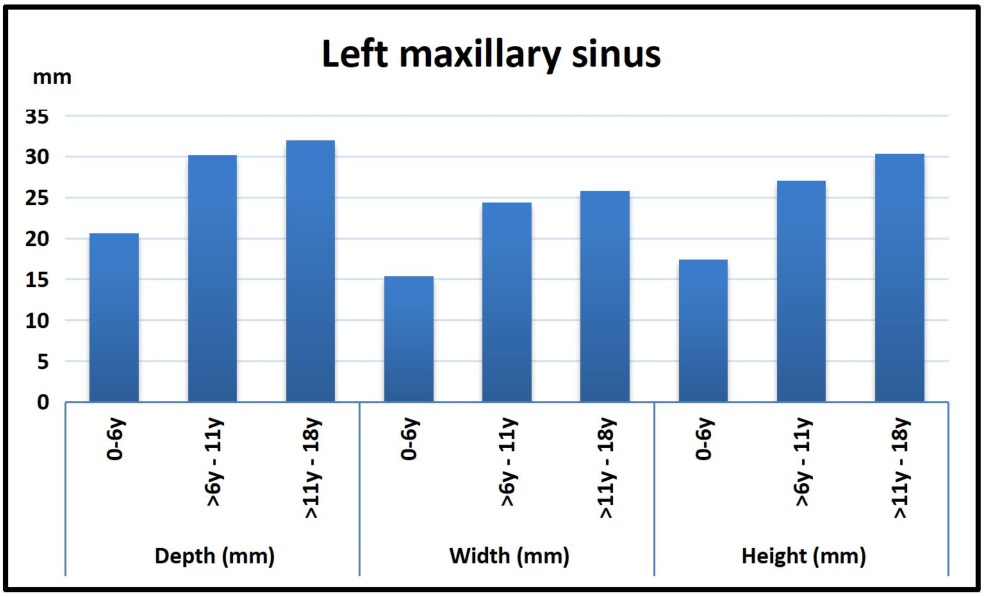


Figure (4): Age differences regarding the morphometry of left maxillary sinus

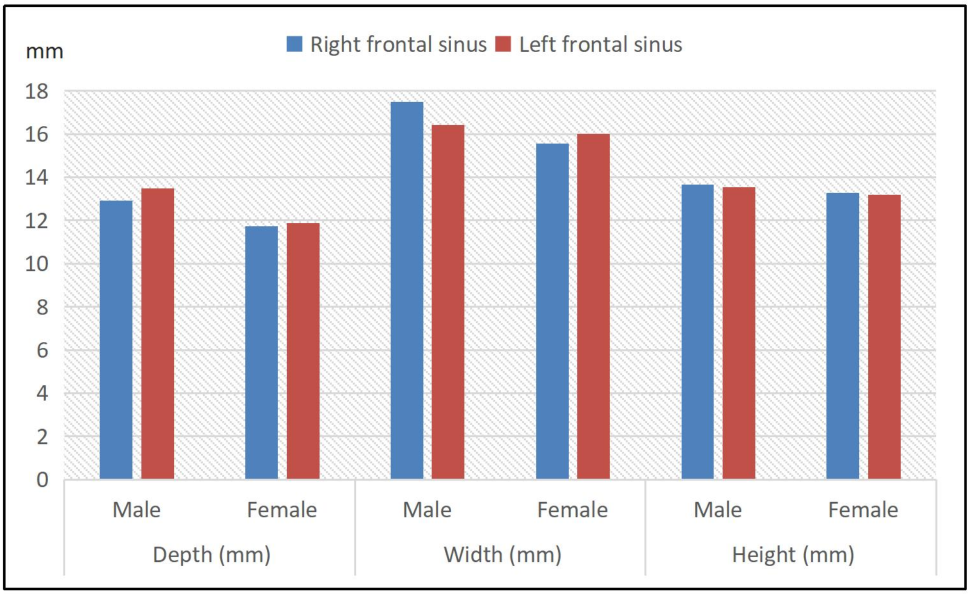


Figure (5): Gender differences regarding the morphometry of the frontal sinus in all age groups

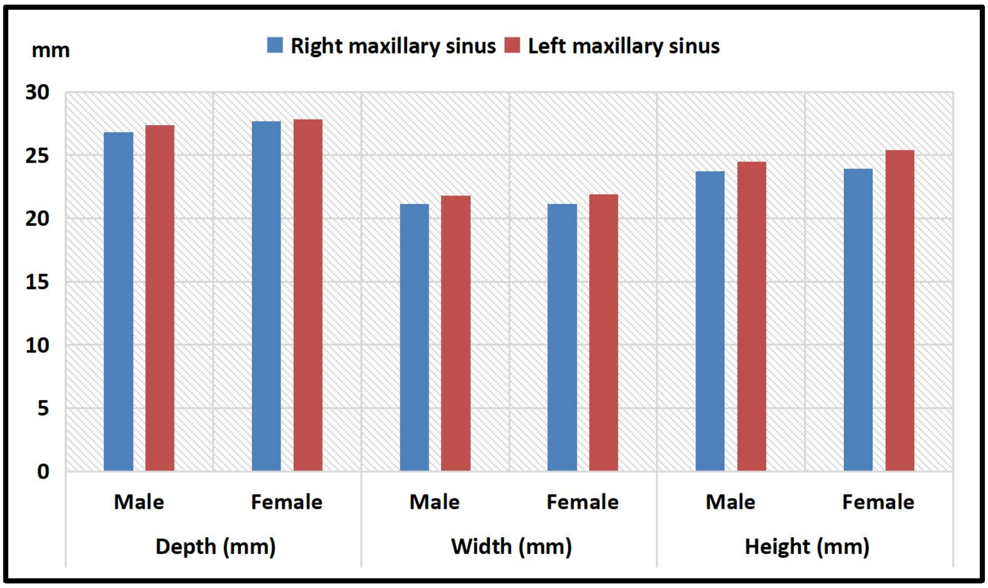


Figure (6): Gender differences regarding the morphometry of the maxillary sinus in all age groups

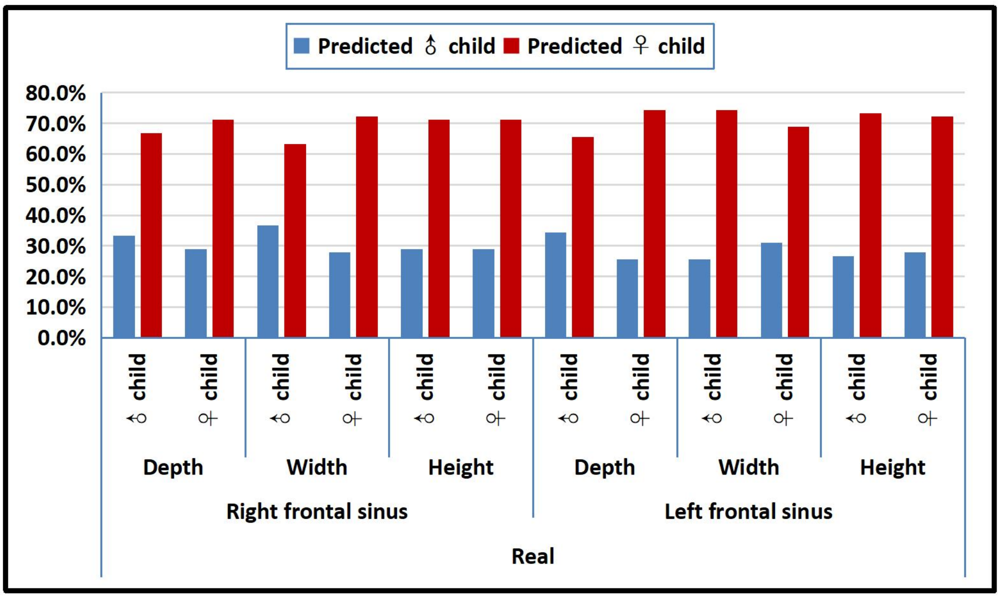


Figure (7): Discriminant analysis using right or left frontal sinus measurements to distinguish between males and females children

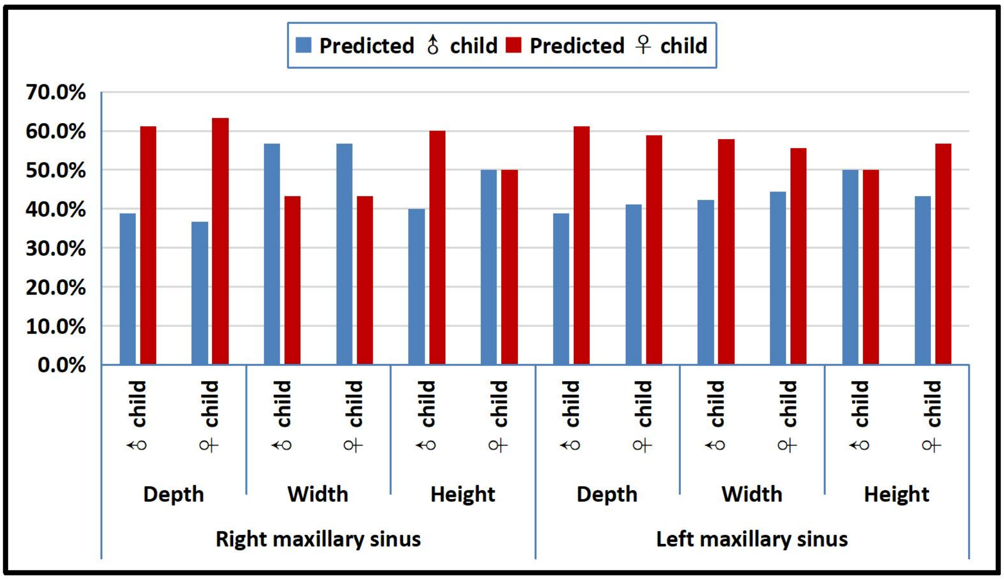


Figure (8): Discriminant analysis using right or left maxillary sinus measurements to distinguish between males and females children

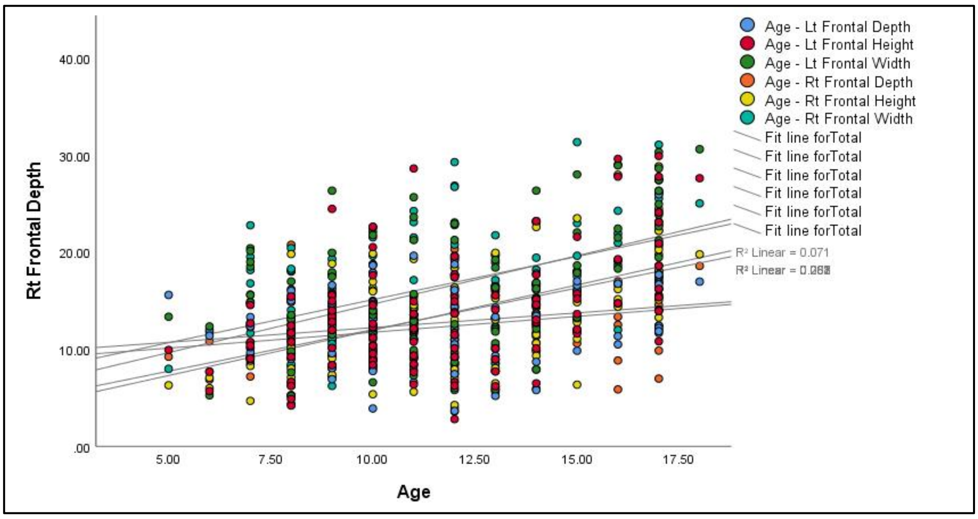


Figure (9): Correlation between age with different frontal sinus parameters.

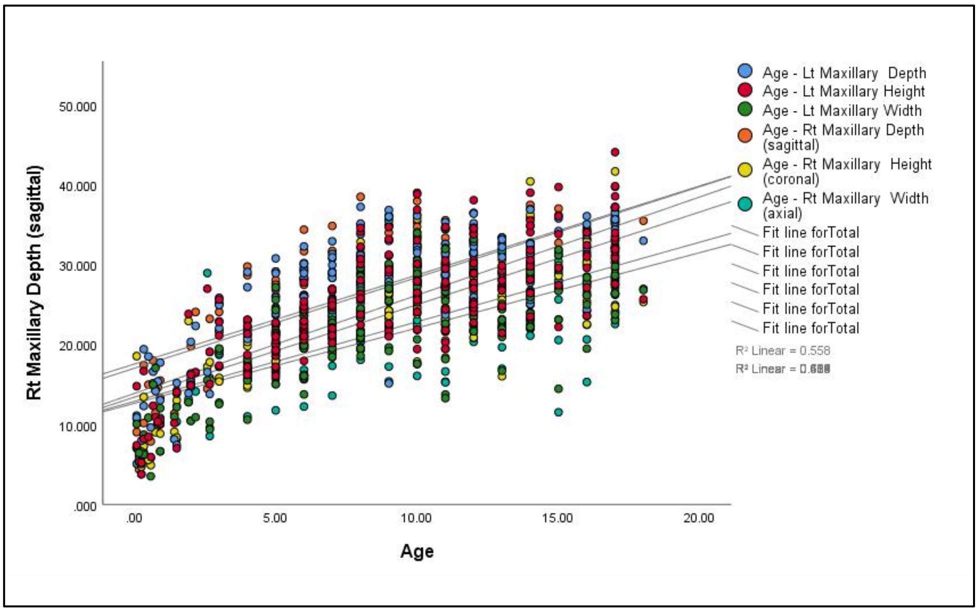


Figure (10): Correlation between age with different maxillary sinus parameters.

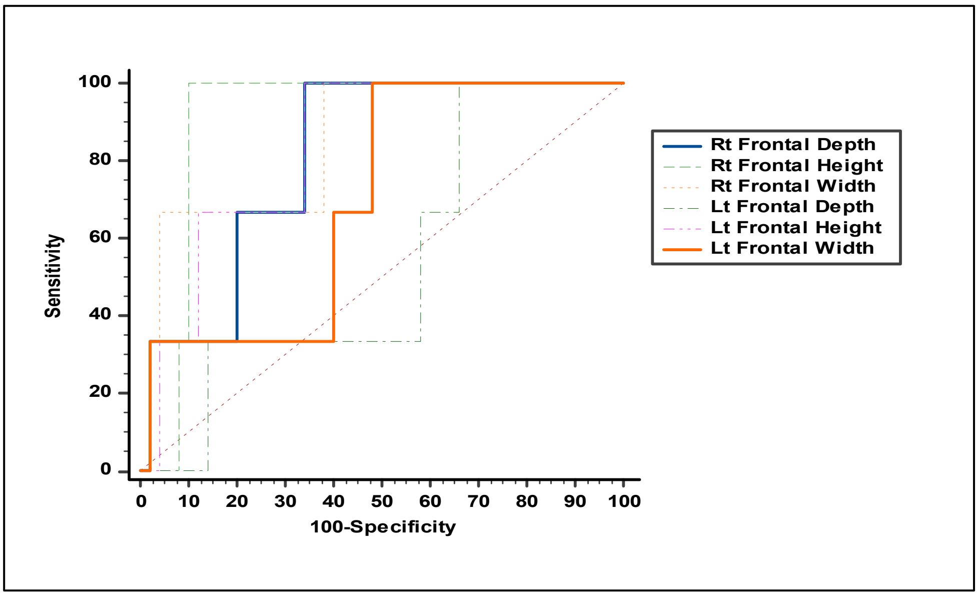


Figure (11): ROC curve of frontal sinus measurements in differentiation between of age groups 1m-6 yrs years & >6-11y.

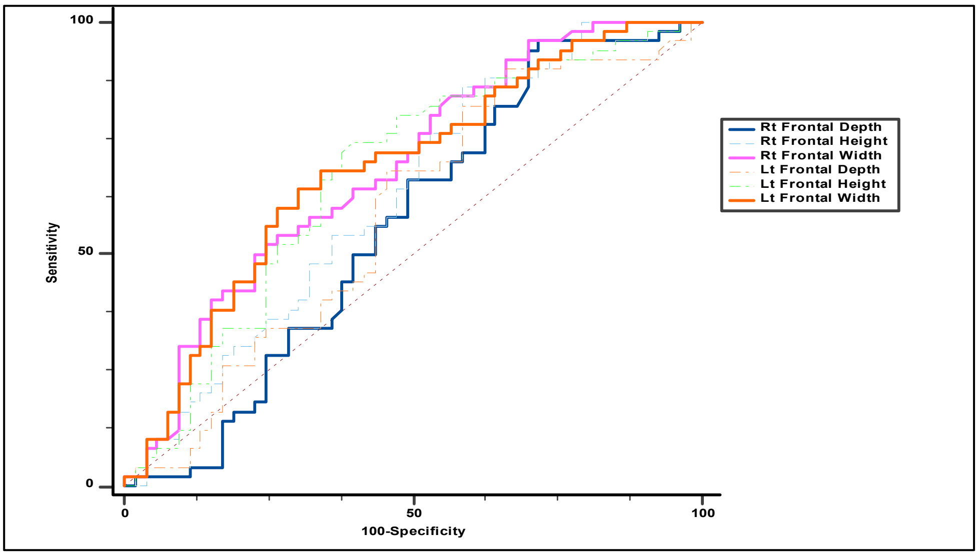


Figure (12): ROC curve of frontal sinus measurements in differentiation between age groups of >6-11 years and >11- 18 years.

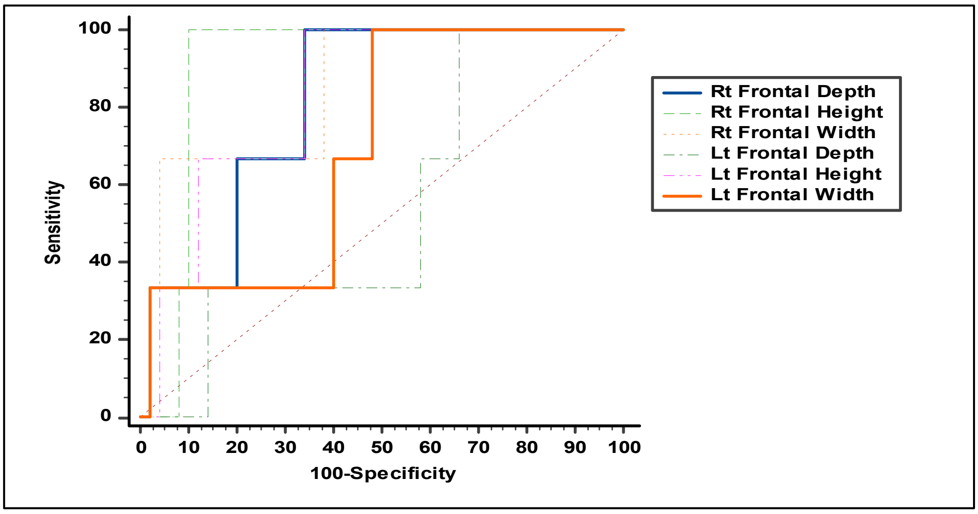


Figure (13): ROC curve of frontal sinus measurements in differentiation between age groups of 1m-6 yrs years and >11-18 years.

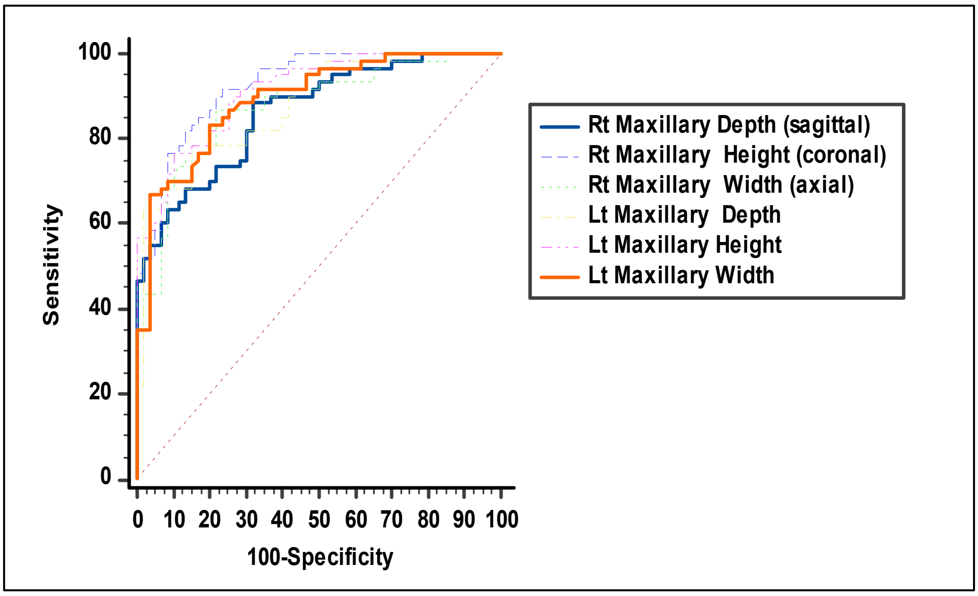


Figure (14): ROC curve of maxillary sinus measurements in differentiation between age groups 1m-6 yrs years and >6-11 years

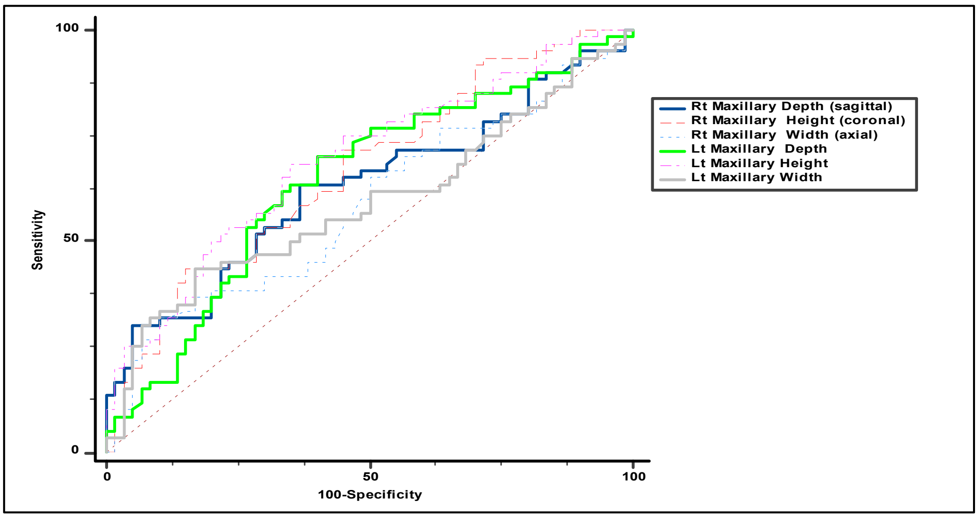


Figure (15): ROC curve of maxillary sinus measurements in differentiation between age groups of >6-11 years and >11-18 years.

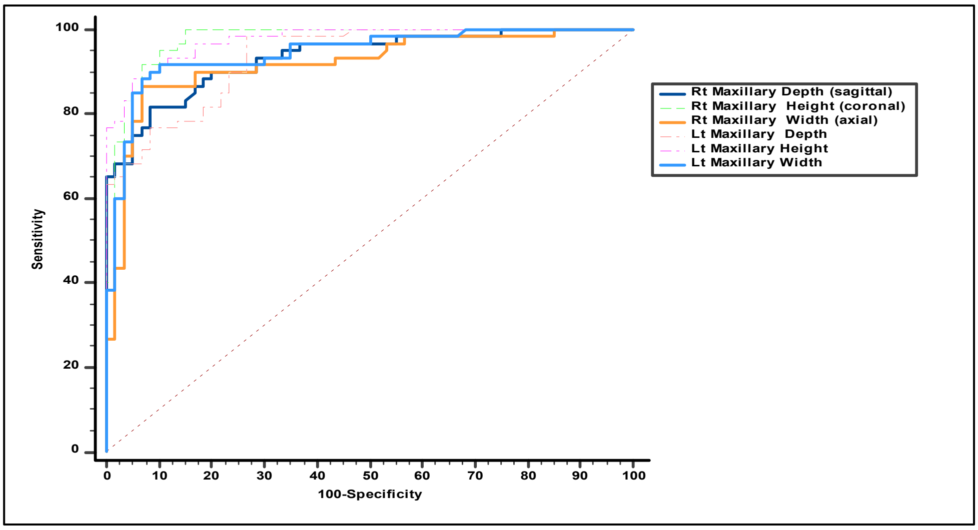


Figure (16): ROC curve of maxillary sinus measurements in differentiation between age groups of 1m-6 yrs y and >11-18 years.

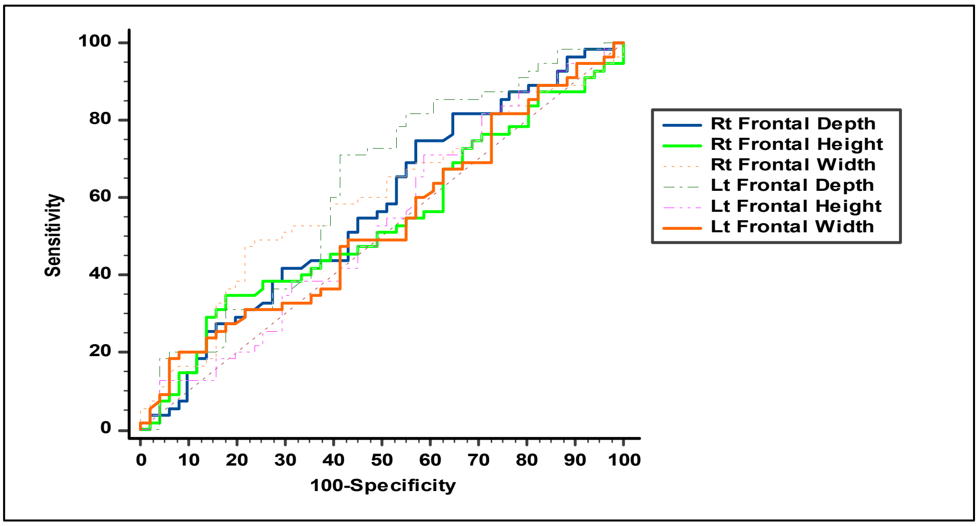


Figure (17): ROC curve of frontal sinus measurements in prediction of gender.

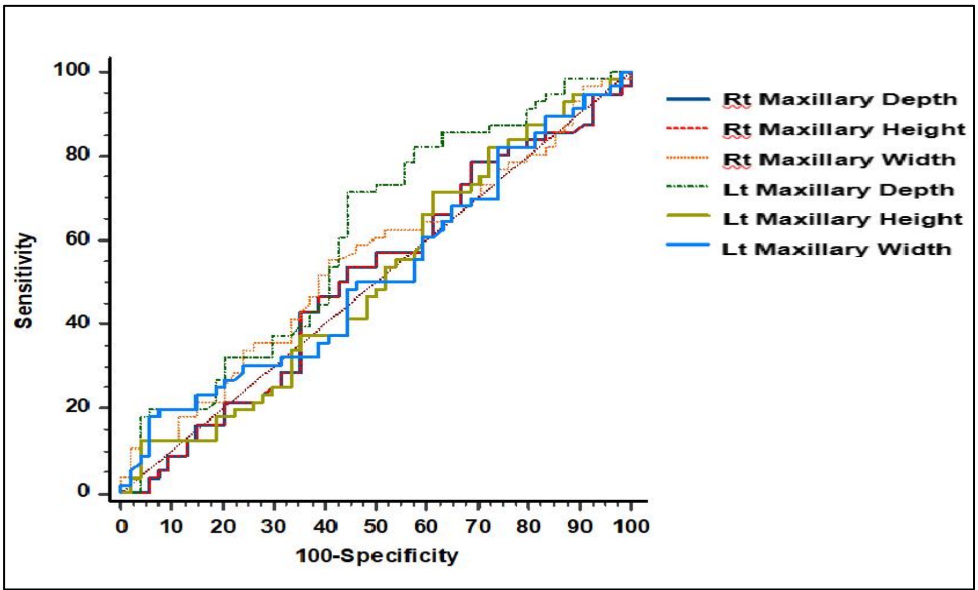


Figure (18): ROC curve of maxillary sinus measurements in prediction of gender.

Discussion

The face bones include hollow chambers called paranasal sinuses. The age and gender of the person varies based on size of the sinuses (Cohen et al., 2018).

In general, every sinus is asymmetrical with respect to its contralateral counterpart. Understanding the differences of paranasal sinus development is important from a clinical standpoint. Sinus anatomy and variations can be affected by infections, environmental factors, and genetic illnesses. Radiographs and CT assessment for identification in forensic medicine can benefit from understanding age-related variations in their dimensions and volume (Sahlstrand-Johnson et al., 2011).

It is mandatory to use the still intact bones which resist crushing and disfigurement. Among them are the maxillary and frontal sinuses which persist intact in most critical damaging conditions even with skull disfigurement (Sheikh et al., 2018).

The paranasal sinuses are hollow cavities lodged inside the facial bones. At birth, they are non-aerated and contains red marrow. With age progression, marrow transition phase from red to yellow takes place then pneumatization completes during childhood (Cohen et al., 2018; Yazici, 2019).

Thus, the goal of the current study was to determine the validity of the frontal and maxillary sinuses for determining age and gender in a sample of children from Egypt using CT imaging.

When examining age differences using the morphometry of the frontal sinuses, the width and height of the frontal sinus on both sides varied significantly among the age groups under study. On the other hand, the difference in frontal sinus depth between the right and left sides was statistically not significant.

According to Saldanha et al., (2013), the frontal sinus does not begin to develop until after the age of three. It reaches its maximum development between the ages of four and eight, and it continues to expand until the age of sixteen.

The frontal sinuses do not show any symptoms at birth, and they begin to expand normally around two years after birth. Usually by the time a child is 7 years old, an X-ray can identify the frontal sinus. The paranasal sinuses' additional growth fluctuates with time, and they might reach their maximum form and size near the end of adolescence, giving the face its most ultimate appearance (Azgın et al., 2020).

Regarding age differences using the morphometry of maxillary sinuses: all the studied parameters on both sides were of significance among the studied age groups.

The current study showed that both right and left maxillary sinuses depth were significantly higher in age group (11-18 yrs) followed by age groups (6-11 yrs) and (1m-6 yrs). Also, maxillary sinus width was significantly higher on both sides in age group (11-18 yrs) followed by age groups (6-11 yrs) and (1m-6 yrs) in both sides. Additionally, the heights of both sides were significantly higher in age group (11-18 yrs) followed by age groups (6-11 yrs) and (1m-6 yrs).

The study by Fathy et al., (2022) revealed statistically significant differences in maxillary sinus parameters between the age groups in females only.

The study by Sarilita et al. (2021) was against the existing findings, as no variations in the age estimation using parameters of right and left maxillary sinuses.

According to Tsyhykalo et al., (2023), a pouch in the lateral wall of the ethmoid's infundibulum marks the beginning of the maxillary sinus' growth around the tenth week. The maxillary sinus measures around 8 mm in depth, 4 mm in width, and 3 mm in height at birth. After birth, growth continues, and it is only finished at the start of adolescence.

The maxillary sinus develops in a transverse pattern up to the age of two. From then, it expands vertically between the ages of two and ten, reaching the level of the zygomatic recess and the nasolacrimal duct by the age of twelve (Pichierri et al., 2010).

Additionally, the current study found no statistically significant differences in the depth, width, and height of the maxillary sinus on either side between male and female children in any age group.

The volume and dimensions of the maxillary sinuses were significantly larger in males than in females, with the exception of children up to the age of six, according to a study by Masri et al., (2013) for sex determination, which contradicts the current findings.

With respect to gender differences as determined by frontal sinus morphometry, male and female children did not differ significantly in any of the studied parameters of frontal sinus across all age groups, with the exception of left frontal depth and right frontal width, which were significantly higher in male children.

The use of frontal sinus for gender determination is limited by the fact that frontal sinuses are unique to each individual, even in monozygotic twins (Belaldavar et al., 2014).

In a pilot investigation, Garhia et al., (2019) looked into the frontal sinus variability as a forensic identification tool using software analysis and radiography pictures. The breadth and height of the frontal sinus exhibited a significant difference with bigger values in males as opposed to females, which supported the current findings.

Verma et al., (2014) found different results in their South Indian sample of 50 males and 50 females, indicating that males typically had larger frontal sinus heights and widths than females.

Zulkiflee et al., (2022) study reported that frontal sinus had a strong evidence of sexual variation and was potential to be used in biological profiling among Columbian, Saudi, New Mexican and Iraq population.

Additionally, the present study revealed that there were significant differences between male and female children in the right frontal sinus depth in age groups (1m-6 yrs) and (11-18 yrs). Also, in frontal sinus width in age groups (1m-6 yrs) and (6-11 yrs) and in frontal sinus height in age group (1m-6 yrs).

However, there was a significant difference between male and female children in the left frontal sinus depth in age group (11-18 yrs) with non-significant differences regarding width, height and depth in age groups (1m-6 yrs) and (6-11 yrs).

The current results were corroborated by a study by Jasso-Ramírez et al., (2022) that examined the dimensions of the frontal, sphenoid, and maxillary sinuses in patients aged 1 to 20. The measurements showed that males had marginally higher dimensions of the frontal and maxillary sinuses than females. With the exception of the age groups above 16 yrs and those between the ages of 11 and 15 yrs, all groups showed statistically significant differences in the volume and depth of the paranasal sinuses. Within the same study, patients over 16 years of age had both sides' maxillary and frontal sinus volumes considerably higher than those of patients in age groups 11–15 years, 6–10 years, and under 5 years.

A study conducted by Shamlou and Tallman (2022), which shared some similarities with the current results, found that the greatest variations in population assignment were found in the frontal sinus's depth, followed by height. However, there were no statistically significant changes in the width.

Similarly, Hamed et al., (2014) discovered that females presented with smaller measurements than males, and that the right frontal depth was the best way to test for sexual dimorphism. This measurement estimated assigned sex with 67% accuracy.

Regarding the gender differences in the maxillary sinus morphometry, all age groups showed statistically non-significant differences in all examined parameters (depth, width, and height) between male and female children in both the right and left maxillary sinuses.

Najem et al., (2021) found statistically non-significant variations in maxillary sinus measures between the sexes for the studied age groups, which is consistent with our findings.

Unlike the current findings, Lorkiewicz-Muszyńska et al., (2015) found that Polish children between the ages of 8 and 17 had a statistically significant sexual dimorphism of maxillary sinus height, width, and volume, with the most notable variations between the ages of 14 and 17.

Also, Samhitha et al., (2019) reported that maxillary sinus on both sides in Indians males have higher values in height, depth and volume than females except right side width that was lesser in value than Indian females. All the parameters were more on left sinus in males except right maxillary height. In comparison to females, all the maxillary sinus parameters were more on right side. The difference between these results and the results of the current study may be due to the age diversity as they included cases aged 1-90 yrs.

Furthermore, Przystanska et al., (2020) found that all examined parameters of the maxillary sinuses were larger in males of the age group (2–3 years), with the exception of the depth, which was larger in females by the end of three years, at the age group of (6–9 years), and after the age of fifteen. The study used CT images of 170 cases, aged 0–18 years. They also reported that the maxillary sinus is the source of sexual dimorphism, which is least noticeable in the first year of life and most noticeable between the ages of 15 and 16 in the study.

A study by Deshmukh and Deversh, (2006) tested maxillary sinus measurements for gender assessment and found that the average accuracy reached 80%–87%.

Bangi et al., (2017) found in another study that maxillary sinus measurements may be used to determine gender with an overall accuracy of 88%.

These outcomes also lined up with those of Ekizoglu et al., (2014), who found that gender could be determined with an overall accuracy of 77.15% by the use of morphometric analysis of maxillary sinuses.

This inconsistency to the current results could be attributed to various factors such as the population ethnicity and racial factors in which the maxillary sinus was studied and the adopted radiographic techniques. Hence, parameters of maxillary sinuses could serve an auxiliary method for sex determination but should be applied with caution as recorded by Nunes Rocha et al., (2021).

Regarding discriminant analysis, there was a significant positive correlation between all the studied parameters of both maxillary and frontal sinuses (right and left) with age and gender.

According to the current study, 71.1% of the examined cases might have been classified as female children and 33.3% as male children if the right frontal depth had been used correctly. According to right frontal width, 36.7% of the analyzed cases might have been accurately categorized as male children and 72.2% of the studied cases as female children. According to right frontal height, 71.1% of the cases under study could be appropriately categorized as children of the female gender and 28.9% as children of the male gender.

According to left frontal depth, 34.4% of the examined cases could be accurately categorized as male children and 74.4% of the analyzed cases as female children. Based on left frontal width analysis, it was possible to accurately classify 68.9% of the researched cases as female children and 25.6% of the studied cases as male children. According to left frontal height, 26.7% of the analyzed cases might have been accurately categorized as male children and 72.2% of the studied cases as female children.

In a study on Persian by Mitra et al. (2016), left frontal height showed the best results for sex determination with accuracy of 61.3% among all the studied age groups.

Right and left widths were shown to be the most reliable characteristics for determining sex in a simple logistic regression study of gender by various parameters. The accuracy rate in classifying males and females ranged from 67.70% to 95.90% (Shireen et al., 2019).

Among the examined cases, 38.9% and 63.3% respectively, could be appropriately identified as male and female children using the appropriate right maxillary depth. On the other hand, based on right maxillary width, it was possible to classify 56.7% of the cases as male children and 43.3% of the cases as female children. Furthermore, based on right maxillary height, it was possible to correctly classify 50% of the cases under study as female children and 40% of the cases as male children.

Also, 58.9% of the examined cases could be accurately categorized as female children and 38.9% of the researched cases as male children using left maxillary depth. Furthermore, based on left maxillary height, it was possible to correctly classify 50% and 56.7% of the examined cases as male and female children, respectively. Furthermore, the analysis of left maxillary width revealed that 42.2% and 55.6% of the patients under investigation could be appropriately identified as male and female children, respectively.

A study conducted by Ahmed et al., (2015) revealed that, with an overall accuracy of 61.3%, the left maxillary sinus width was the best discriminating characteristic.

In the multivariate analysis of a study by Uthman et al., (2011), maxillary sinus parameters correctly identified 74.4% of the studied cases as males and 73.3% as females

According to Amin and Hassan (2012), the maxillary sinus height had the highest accuracy in predicting gender, accounting for 70.8% of male predictions and 62.5% of female predictions.

The accuracy of maxillary sinus measurements was found to be 69.4% in females and 69.2% in males, according to Teke et al., (2007). The study also found that even with a relatively low accuracy rate of less than 70%, CT measurements of the maxillary sinuses might be helpful in forensic medicine to support gender determination.

In contrast to the present results, Przystanska et al., (2020) stated that the maxillary sinus depth is developmentally the most stable parameter because throughout the investigated ontogenesis, the sexual differences were very similar. The most evident sexual dimorphism was observed in the volume of the maxillary sinus.

Receiver ROC analysis was performed to determine the validity of frontal and maxillary sinus measurements in determination of age and gender.

According to the current study, all frontal sinus parameters—aside from frontal sinus depth on both sides—could be used to determine age. Right frontal width had the highest accuracy for age determination. While the sensitivity of frontal sinus parameters for age determination was ranging from 69.2% to 100%.

Only left frontal depth and right frontal width could be used for gender determination with accuracy of 64.05% and 64% successively.

A study conducted by Shamlou and Tallman (2022), found that the most significant variations in identifying a particular group were found in the frontal sinus depth, followed by height. However, neither ascribed sex differences nor population affinity showed statistically significant differences over the width.

Similarly, Hamed et al., (2014) discovered that the right frontal depth was the most accurate way to qualify sexual dimorphism, accurately estimating assigned sex with 67% of the samples; females showed smaller measures than males.

Suman et al., (2016) found that a frontal sinus dimensions were particularly useful when no other means of identification were available and the configuration of frontal sinus was an excellent individualizing feature.

The frontal sinus forms around the fourth or fifth fetal month and is actively developing at two or three years of age, which could account for the current results. The frontal sinus is visible on radiographs by the time a child is four or five years old. During adolescence, it continues to develop and change anatomically, with the left and right cavities developing separately (Shamlou and Tallman, 2022).

Also, the current study showed that all maxillary sinus parameters could be used for age determination. Left maxillary height had the highest accuracy for age determination. While the sensitivity of maxillary sinus parameters for age determination was ranging from 31.7% to 98.3%

Sidhu et al., (2014), highlighted maxillary sinus measurements as one of the most reliable methods of human identification due to its high specificity.

Ahmed et al., (2015) illustrated that the left maxillary sinus width was the best discrimination parameter that could be used to study sex dimorphism with accuracy of 61.3%.

This conclusion also agrees with that of Ekizoglu et al., (2014), who found that morphometric examination of maxillary sinuses would be useful with an overall accuracy of 77.15% for human identification.

In contrast to the present study, Sharma et al. (2014) reported that maxillary sinus depth was the best discriminant parameter with an overall accuracy of 69.81%.

Furthermore, a study by Elamin et al., (2021) revealed a negative association between age and the height, width, and depth of the maxillary sinus. Both males and females appeared to have smaller maxillary sinuses as they aged. In contrast, there were no notable differences in the maxillary sinus parameters based on gender.

Furthermore, maxillary sinus measurements could not be utilized to determine age or gender, according to Najem et al., (2021), who demonstrated statistically non-significant variations in maxillary sinus measures for gender discrimination. The discrepancy between the current study's findings may be due to the use of distinct age groups and populations in the research.

Conclusion

Maxillary and frontal sinuses' measurements can be used in age determination in children.

In forensic medicine, left frontal depth and right frontal width can be utilized as supplementary instruments to determine a child's gender.

- Age prediction from right frontal sinus:

$$\text{Age} = 6.539 + (0.148 \times \text{Rt frontal width}) + (0.203 \times \text{Rt frontal height})$$

- Age prediction from left frontal sinus:

$$\text{Age} = 6.933 + (0.162 \times \text{Lt. Frontal width}) + (0.155 \times \text{Lt Frontal height})$$

- Age prediction from right maxillary sinus:

$$\text{Age} = -5.596 + (0.162 \times \text{Rt max. depth}) + (0.138 \times \text{Rt max. width}) + (0.302 \times \text{Rt max. height})$$

- Age prediction from left maxillary sinus:

$$\text{Age} = -5.674 + (0.161 \times \text{Lt. max. depth}) + (0.146\ \text{Lt max. width}) + (0.281 \times \text{Lt max. height})$$

Recommendations

The current study recommended the following:

- Conduct similar study on larger sample size of Egyptian children with narrower age subgroups.
- Compare the current findings using CT with findings by other imaging techniques e.g. X-ray and MRI.
- For gender determination, further studies on other non-studied parameters that might enrich the current findings.
- Create database for Egyptian children for anthropometric data.

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هل قياس أشكال الجيوب الأنفية صالح لتحديد العمر و الجنس في عينة من الأطفال المصريين؟

رضوى رجب محمد [1] وأماني السيد عبد الرحمن[1] و أحمد محمد ابو الهدى[2] و ولاء طلعت توفيق [1]

الخلفية العلمية: تم تسجيل دراسات مورفومترية على عظام هيكلية مختلفة باستخدام صور التصوير المقطعي .على الرغم من إجراء هذه الدراسات المورفومترية حول تقدير العمر من الجيوب الفكية والجيوب الأمامية في العالم، إلا أنه لا توجد دراسات في مصر لتقدير العمر والجنس من هذه المعايير لدى الأطفال حتى الآن .كما أن خصائص السكان المصريين في تقدير العمر وتحديد الجنس عن طريق التصوير باستخدام التصوير المقطعي قد تختلف عن الأجناس الأخرى.**الهدف من العمل: كان الهدف من هذا العمل هو تقييم مدى صلاحية الجيوب الأمامية والفكية لتحديد العمر والجنس في عينة من الأطفال المصريين**. **طريقة البحث:** أجريت هذه الدراسة الوصفية على 180 فيلم مقطعي لأطفال مصريين تتراوح أعمارهم بين 1 شهر إلى 18 سنة محفوظة في قسم الأشعة بمستشفيات جامعة عين شمس بالقاهرة. تم تصنيف أفلام الأشعة المقطعية المدروسة بالتساوي فيما يتعلق بالجنس وتم تقسيم كل مجموعة بالتساوي فيما يتعلق بالعمر إلى 3 مجموعات فرعية، أي 1 شهر-6 سنوات و>6-11 سنة و>11-18 سنة. **النتائج:** أظهرت جميع العوامل المدروسة (العمق، العرض، الارتفاع) للجيوب الفكية و الأمامية صلاحية لتحديد العمر لدى الأطفال المصريين باستثناء العمق الأمامي في كلا الجانبين .كان عرض الجيب الأمامي الأيمن هو الأعلى دقة لتقدير العمر بين جميع العوامل المدروسة في جميع الفئات العمرية المدروسة (92.85%) يليه ارتفاع الجيب الفكي الأيسر 91.65% .من ناحية أخرى، يمكن استخدام العمق الأمامي الأيسر والعرض الأمامي الأيمن فقط لتحديد الجنس بدقة 64.05% و64%على التوالي.
الخلاصة :يمكن استخدام قياسات الجيب الفكي العلوي و الأمامي بما في ذلك العمق والعرض والارتفاع في تحديد العمر لدى الأطفال المصريين باستثناء عمق الجيب الأمامي على كلا الجانبين .كان العرض الأمامي الأيمن هو الأعلى دقة في تقدير العمر بين جميع العوامل المدروسة في جميع الفئات العمرية المدروسة.و يوصى باستخدام العمق الأمامي الأيسر والعرض الأمامي الأيمن في التمييز بين الجنسين عند الأطفال في الطب الشرعي.

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