

Anthropometry of the Sphenoid sinus and its association with vertical skeletal facial growth patterns

SADJ APRIL 2026, Vol. 81 No.3 P139-P143

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ABSTRACT

Introduction

The prediction of craniofacial growth plays a vital role in the establishment of accurate diagnosis and proper treatment planning among orthodontic patients. It was hypothesized that the pneumatization of the sphenoid sinus could influence the vertical skeletal growth pattern of the craniofacial complex. However, the effect of sphenoid sinus on vertical skeletal growth is scarce in the literature.

Aims and Objectives: The study was conducted to determine the association between sphenoid sinus width and height and vertical skeletal facial types.

Materials and method: Sphenoid sinus width (SSW) and height (SSH) were measured on 209 lateral cephalographs (aged 7-55 years; mean of 19.35 ± 8.81 years) recruited for the study. Frankfort mandibular plane angle (FMA) was used to categorise participants into normo-, hypo- and hyper-divergent skeletal types. Unpaired t-test was used to compare the mean SSW and SSH according to gender and One-Way ANOVA used to determine if there were significant differences in the skeletal patterns. Significance for this study was set at < 0.05 .

Results.

The SSW was significantly different among the vertical skeletal types, $P=0.006$, unlike the SSH ($P=0.464$). The mean SSW was significantly higher in hypodivergent facial types compared to normodivergent ($P=0.024$) and hyperdivergent ($P=0.000$). In addition, only SSW showed statistical significant correlation ($r = -0.164$, $P=0.017$) with FMA.

Conclusion. Sphenoid sinus width could be an adjunctive predicting tool in determining the direction of vertical facial growth.

Key words

Sphenoid sinus, pneumatization, vertical skeletal facial growth.

INTRODUCTION

The sphenoid sinus is the most posterior of the para-nasal sinuses located in the midline of the calvarium within the body of the sphenoid bone.¹ The growth and development of the sphenoid sinus initially progresses in the anterior-posterior, transverse and inferior planes, and later superiorly at the age of seven years, reaching its full size after puberty. This process is closely associated with the development of the craniofacial complex.²

Sagittal, transverse and vertical growth patterns of the craniofacial complex play crucial role in the classification of occlusion, malocclusion and also on the effect of orthodontic treatment. Due to the interplay among craniofacial structures, growth in a particular region could affect the outcome of development in another location. Several studies have reported how the morphology and dimensions of the paranasal sinuses could be an etiological factor of malocclusion, affect the spatial orientation of the anterior cranial base and also be used for the determination of gender.³⁻⁶

Sphenoid sinus has been adjudged to be a reliable adjunctive tool in the prediction of mandibular growth.⁷ Its dimensions have been reported to be significantly associated with cervical vertebrae maturation stages in predicting skeletal maturity among Indian.⁸ Furthermore, studies have shown that sphenoid sinus could be a reliable tool for the gender determination.^{9,10}

The influence of the paranasal sinus on the vertical and sagittal growth pattern have been reported in the literature.¹¹⁻¹⁴ Nathini *et al*¹¹ observed that the dimension of the frontal sinus could possibly be used as a predictor of the vertical growth pattern of orthodontic patient. On the contrary, Göymen *et al*¹³ did not report any significant difference in frontal and maxillary sinuses width and height among hyperdivergent, hypodivergent and normodivergent vertical facial patterns. In another study, sphenoid sinus volume was observed to be significantly increased in individuals with skeletal class II pattern compared to Class I and Class III skeletal patterns.¹⁴

The numbers of study conducted to determine the association between the dimensions of the sphenoid sinus and vertical growth pattern is scarce in the literature. Hence, we could not identify studies specifically relating sphenoid sinus pneumatization and vertical skeletal jaw pattern.

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1. Osaronse A Aghimien was responsible for the conceptualization, design of the study, data acquisition, critical review of intellectual content and final approval for the article to be published (60% contribution).
2. Alice A Umweni was involved in the critical review of intellectual content, design of the study, data acquisition, final approval for the article to be published (40% contribution).

Conflict of interest:

The authors declare no conflict of interest.

Therefore, this study was conducted to determine if the sphenoid sinus dimension have any form of association with the vertical skeletal jaw growth pattern using lateral cephalographs. The null hypothesis in this study was that there is no statistically significant difference in the sphenoid width and height in the hyperdivergent, hypodivergent and normodivergent facial pattern. Also, this current study also assumes that the sphenoid sinus width and height do not have any significant correlation with the Frankfort mandibular plane angle.

MATERIAL AND METHODS

This research was a cross sectional descriptive study involving 209 pre-treatments lateral cephalographs of orthodontic patients. The lateral cephalographs were randomly selected from patients who had visited the City Specialist Hospital and from a private orthodontic clinic both within the city metropolis. The age range of the patients' lateral cephalographs was 7 – 55 years; comprising of 79 males and 130 females with a mean age of 19.35 ± 8.81 years. Ethical clearance (A732/8) was obtained prior to commencement of the study.

Selection criteria: clear and undistorted pre-treatments lateral cephalographs were recruited for the study. Individuals with documented history of congenital anomaly and cephalographs with signs of pathological findings that could affect craniofacial growth and development were excluded from the study.

Data collection

The lateral cephalographs of the study participants were taken using the Planmeca Proline XC cephalostat manufactured by Planmeca OY (Helsinki, Finland) 2006 model with a magnification factor of 1.08-1.13. All lateral cephalographs were manually traced on a 0.003inch matte acetate paper using a pointed 0.5mm thick HB pencil under a light box. Linear measurements were obtained using plastic meter rule while angular measurements were obtained using standard plastic protractor. In order to guide against exhaustion by the investigator, a maximum of seven lateral cephalographs were traced per day. All 209 lateral cephalographs were traced by the same investigator over a period of five weeks.

Cephalometric landmarks and sphenoid sinus parameters

The classification of the vertical facial skeletal pattern was done using the Frankfort mandibular plane angle (FMA). A line connecting the orbitale and the anatomic porion indicates the Frankfurt plane. This plane was used to correspond to the positioning of the cephalostat and the subsequent measurement of all cephalographs in this current study. On the other hand, the mandibular plane indicates a line connecting the gnathion to the gonion. The reference value for FMA utilised in this study was $20.8^\circ \pm 3.1^\circ$ for normal occlusion among Nigerians.¹⁵ Frankfort mandibular plane angle (FMA) between 17.7° - 23.9° was considered normodivergent while values less than 17.7° were considered hypodivergent and values greater than 23.9° were considered hyperdivergent.

The size of sphenoid sinus expressed in height and width (anterior-posteriorly dimension) were measured from maximum vertical and horizontal dimension of the sphenoid sinus⁸ (Figure 1).

SH: the highest point on sphenoid sinus, SL: the lowest point on sphenoid sinus, SP: posterior point on sphenoid sinus and SA: anterior point on sphenoid sinus in millimeters (mm).

SSH: line joining points SH and SL denoting maximum sphenoid sinus height (yellow line).

SSW: line joining points SP and SA denoting maximum sphenoid sinus width (red line), representing the anterior-posterior dimension.

Reliability test

Twenty (20) lateral cephalographs were traced twice at one-week interval to ascertain intra-rater reliability. Intra-class correlation coefficient (ICC) was used to determine the intra-rater reliability by the investigator. The ICC reliability were as follows: sphenoid sinus width i.e., anterior-posteriorly, (ICC 0.949, P value=0.000), sphenoid sinus height (ICC=0.871, P=0.003) and FMA (ICC=0.804, P=0.012). The findings shows that the intra-rater reliability was statistically significant with the anterior-posterior dimension of the sphenoid sinus showing the greatest value.

Normality distribution was determined using Shapiro-Wilk and were as follows SSW; 0.241, 0.071 and 0.531 for normodivergent, hypodivergent and hyperdivergent skeletal patterns respectively and SSH 0.322, 0.067 and 0.780 for normodivergent, hypodivergent and hyperdivergent skeletal patterns respectively. Parametric tools were thereafter used to analyse the data.



Figure 1. Landmark for measurement of the sphenoid sinus width i.e., anterior-posteriorly, (red) and height (yellow).

Statistical analysis

The data collected were entered and analysed using Statistical Package for the Social Sciences (SPSS) version 22. Descriptive statistics were used to describe data in terms of frequency and percentage, mean and standard deviation. Unpaired t-test was used to compare the mean sphenoid sinus width and sphenoid sinus height in relation to gender in the different vertical skeletal patterns. One-way analysis of variance (ANOVA) was applied to test if the sphenoid sinus width and height differ significantly in the different vertical skeletal facial patterns and Tukey post hoc test was used to determine where the significant difference may have occurred. In addition, Pearson's correlation coefficient was used to test the association between sphenoid sinus dimension and Frankfort mandibular plane angle. Significance for this study was determined when the confidence level (p value) was < 0.05 .

Results

Table 1. Mean age and the distribution of the study participants

	N(%)	Mean	SD	SEM
Male	79 (37.8)	17.04	8.26	0.93
Female	130 (62.2)	20.75	8.86	0.78
Total	209 (100)	19.35	8.81	0.61

SEM: Standard error of mean

A total of 209 pre-treatment lateral cephalographs were analysed in this study. The mean age of the study participants was 19.35 ± 8.81 years. Majority of the participants were females 130 (62.2%), while the male participants accounted for 37.8% of the pre-treatment lateral cephalographs.

Table 2 describes the mean FMA of the different vertical skeletal patterns according to gender, which were not statistically significant. The results showed that among participants with normodivergent skeletal patterns, females

Table 2. Mean Frankfort-Mandibular Plane Angle (FMA) according to gender

	Gender	N(%)	Mean (°)	SEM	P value
Normodivergent	Male	24	21.38 ± 2.10	0.43	0.218
	Female	47	22.00 ± 1.76	0.26	
	Total	71	21.79 ± 1.89	0.22	
Hypodivergent	Male	11	14.09 ± 3.21	0.97	0.102
	Female	9	11.89 ± 2.32	0.77	
	Total	20	13.10 ± 2.99	0.67	
Hyperdivergent	Male	44	31.32 ± 5.00	0.75	0.077
	Female	74	29.89 ± 3.65	0.42	
	Total	118	30.42 ± 4.24	0.39	

had slightly higher FMA than males although not statistically significant ($P=0.218$). However, male participants had higher FMA than females among those with hypodivergent and hyperdivergent skeletal patterns, $P=0.102$ and $P=0.077$ respectively.

Table 3 showed the comparison of the sphenoid sinus width and height in relation to genders in the different vertical facial types. Among the normodivergent participants, the mean SSW and SSH were not significantly different between genders, $P=0.782$ and $P=0.108$ respectively. Similar observations were seen among the hypodivergent participants, $P=0.307$ in the SSW and $P=0.554$ in SSH. However, female SSW ($26.28 \pm 6.07^\circ$) was statistical significantly greater than the mean SSW of males ($22.50 \pm 6.22^\circ$), $P=0.002$ among participants with hyperdivergent facial types.

Comparison of the sphenoid width (anterior-posterior dimension) and height among the three vertical skeletal patterns (normodivergent, hypodivergent and Hyperdivergent) was conducted using One-Way analysis of

Table 3. Comparison of mean sphenoid sinus width and height in the different vertical skeletal pattern according to gender.

	Gender	N(%)	Mean(mm)	SEM	Min	Max	P-Value
Normodivergent							
SSW	Male	24	25.86 ± 5.72	1.167	12	35	0.782
	Female	47	25.47 ± 6.02	0.878	12	38	
SSH	Male	24	13.38 ± 3.80	0.78	5	20	0.108
	Female	47	11.87 ± 3.34	0.49	5	21	
SSW	Total	71	25.61 ± 5.88	0.70	12	38	
SSH	Total	71	12.38 ± 3.55	0.42	5	21	
Hypodivergent							
SSW	Male	11	31.00 ± 7.07	2.13	20	44	0.307
	Female	9	28.22 ± 4.66	1.55	20	35	
SSH	Male	11	13.82 ± 2.09	0.63	11	17	0.554
	Female	9	13.00 ± 3.57	1.19	8	17	
SSW	Total	20	29.75 ± 6.12	1.37	20	44	
SSH	Total	20	13.45 ± 2.80	0.63	8	17	
Hyperdivergent							
SSW	Male	44	22.50 ± 6.22	0.94	8	38	0.002
	Female	74	26.28 ± 6.07	0.71	9	40	
SSH	Male	44	12.25 ± 4.22	0.64	4	21	0.794
	Female	74	12.45 ± 3.36	0.39	5	21	
SSW	Total	118	24.87 ± 6.37	0.59	8	40	
SSH	Total	118	12.37 ± 3.69	0.34	4	21	

Table 4. One-way ANOVA comparison

	Sum of squares	df	Mean square	F	Sig	Post hoc test		
						Normodivergent vs Hypodivergent	Normodivergent vs Hyperdivergent	Hyperdivergent vs Hypodivergent
Total								
SSW	406.811	2	203.406	5.318	0.006	0.024	0.710	0.004
SSH	20.877	2	10.439	0.820	0.442	0.464	1.000	0.426
Male								
SSW	682.679	2	341.339	8.910	0.000	0.066	0.087	0.000
SSH	32.641	2	16.320	1.087	0.343	0.947	0.490	0.457
Female								
SSW	61.733	2	30.866	0.865	0.424	-	-	-
SSH	14.513	2	7.256	0.640	0.529	-	-	-

variance. When genders were not considered, there was a statistically significant difference in the sphenoid sinus width among the vertical skeletal patterns., $P=0.006$. Tukey post hoc test showed that the differences were between the normodivergent and hypodivergent ($P=0.024$) and between hyperdivergent and hypodivergent ($P=0.004$) facial types. It was observed that the difference was only noted in male participants between hyperdivergent and hypodivergent ($P=0.000$) vertical skeletal patterns. Female participants did not show any significant difference in SSW nor in SSH among the different vertical skeletal patterns.

Table 5. Pearson correlation coefficient between sphenoid sinus dimensions and Frankfort mandibular plane angle

	R	SIG
SSW	-0.164	0.017
SSH	-0.041	0.556

Pearson correlation was conducted to determine the association with the sinus width and height and the Frankfort mandibular plane angle (FMA). It showed that SSW (anterior-posterior dimension) has a weak and negative statistically significant level of association with the FMA ($R=-0.164$, $P=0.017$).

DISCUSSION

An in-depth understanding of the potential influence of sphenoid growth and development on the skeletal pattern is necessary for improved diagnosis and prediction of craniofacial growth pattern. Vertical growth pattern could be a factor to consider between making the decision whether to extract or not in orthodontic treatment planning. While Tulley¹⁶ reported a reduction in vertical dimension after extraction of first premolars, on the contrary, Staggers¹⁷ reported an increase in vertical dimension among extracted and non-extracted patients. In another study, the author reported a statistically significant increase in the post-treatment vertical dimension among patient that had extraction¹⁸. It is therefore important to choose the proper treatment mechanics when managing patients that have hyperdivergent skeletal pattern to prevent further increase in the vertical dimension because conventional mechanics have not shown to decrease

vertical dimension among growing patients.¹⁹ Researches correlating the effect of vertical growth pattern with the dimension of the sphenoid sinus is not as visible in the literature compared to studies relating frontal and maxillary sinuses to vertical and sagittal skeletal jaw patterns.¹¹⁻¹⁴ This present study was conducted to evaluate sphenoidal sinus dimensional in terms of width (anterior-posterior dimension of the sphenoid sinus) and height in relation to normodivergent, hypodivergent and hyperdivergent vertical skeletal pattern.

Some authors have reported significant level of association between sphenoid sinus width and height and the cervical vertebrae maturation stages in evaluating skeletal maturity and for the prediction of mandibular growth.^{7,8} In a study conducted among a population in Indian, using cone beam computed tomography (CBCT), the sphenoid sinus volume was reported to be larger among Class II sagittal skeletal malocclusion compare to Class I and Class III sagittal skeletal malocclusion.¹⁴ Findings from this current study would be compared to observations made between the pneumatization of the other paranasal sinuses and the effect that had on the vertical facial skeletal patterns.

This current study has shown that the sphenoid sinus width was significantly different in the different vertical skeletal pattern. It further revealed that the SSW dimension was significantly higher among the hypodivergent skeletal pattern compared to normodivergent and hyperdivergent individuals. An increase in sphenoid sinus width has been positively correlated with an increase in condylar length.⁷ Increase in condylar length has been reported to be more associated with hypodivergent vertical pattern.²⁰ This could be due to the more anteriorly inclined condylar head in hypodivergent individuals.²¹ When genders were considered differently, male participants with hypodivergent patterns had significantly larger SSW compared to hyperdivergent patterns. Sphenoid sinus height did not show significantly different among the different vertical facial pattern irrespective of gender.

Oksayan *et al*¹² observed that maxillary sinus width was significantly lower among high-angle participants than low-angle participants. This finding is comparable to lower sphenoid sinus width among hyperdivergent participants

compared to hypodivergent participants. In the same vein, in 2016, Nathani et al¹¹ reported that significant difference in the frontal sinus dimensions also exist among the different vertical skeletal facial pattern and suggested that it could be used as a tool for growth pattern prediction. On the contrary, a study conducted among a Turkish population did not show significant differences in the frontal and maxillary sinus width and height among high-angle, low-angle and medium angle vertical skeletal types.¹³ This present study revealed a significant negative weak correlation between sphenoid sinus width and the Frankfort mandibular plane angle. That is, an increase in the sphenoid sinus width is associated with a decrease in the Frankfort mandibular plane angle, tending towards a hypodivergent vertical facial pattern. There is a dearth of information concerning the direct relationship between the sphenoid sinus and Frankfurt mandibular plane angle, however the growth of the sphenoid sinus does affect the shape of the sella turcica, with hypodivergent skeletal pattern having larger posterior clinoid distance but smaller posterior clinoid height when compared to normodivergent and hyperdivergent skeletal patterns.²² In this current, the sphenoid sinus height was not significantly different among the different vertical facial types.

Considering that the pneumatization of the sphenoid sinus continues till puberty,¹⁷ a good knowledge of its development could help to predict the vertical skeletal facial growth pattern. This could assist the orthodontist to make early and informed decisions whether to redirect the growth of the jaws or not since this current shows a negative correlation between the sphenoid sinus width (anterior-posterior dimension) and FMA. Also, the decision to embark on extraction or non-extraction orthodontic treatment protocol could be made if a patient's vertical skeletal jaw pattern is predictable, since other studies¹⁸ have shown that extraction could worsen a vertically growing skeletal pattern. In this current study the sphenoid sinus width could be a useful adjunctive tool in the prediction of the vertical skeletal facial type.

Limitation and recommendation

This study was conducted using lateral cephalometric radiograph which could only reveal the anterior-posterior view of a paired 3-dimensional sinus. The use of three-dimensional view with cone beam computed tomography could have given us more insight into the anterior-posterior, vertical and transverse dimensions of the sphenoid sinus.

Conclusion

On the average, this current study showed that there was statistically significant difference in the sphenoid sinus width among the normodivergent, hypodivergent and hyperdivergent vertical facial patterns, $P=0.006$. The sphenoid sinus width among hypodivergent was significantly higher than normodivergent ($P=0.024$) and hyperdivergent ($P=0.004$) participants. Sphenoid sinus height did not show statistically significant difference among the vertical skeletal patterns.

When gender was considered, only male participants showed statistically significant difference in the sphenoid sinus width i.e., anterior-posterior dimension ($P=0.000$), as the hypodivergent facial types were significantly higher than

the hyperdivergent facial type ($P=0.000$). Female participants did not show significant differences in sphenoid sinus width and height among the different vertical skeletal patterns.

Also, this current study shows that only sphenoid sinus width had statistical negative weak correlation with the Frankfort mandibular plane angle, FMA ($r = -0.164$, $P=0.017$). This shows that as the sphenoid sinus width increases there would be a decrease in the FMA, tending towards a hypodivergent skeletal patterns.

Conflict of interest

The authors declare no conflict of interest.

Funding

This research was self-sponsored.

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