Original Article

Access this article online
Quick Response Code:
Website:
www.jorthodsci.org
DOI:
10.4103/jos.jos_215_23

Morphology of maxillary and frontal sinuses in different skeletal vertical malocclusions

Hafiz Zuhair Ahmed, Irfan Qamruddin, Hina Siddiqui, Sooraj Lohana, Sohail Khan, Sunia Soomar, Hunny and Afreen Panjwani

Abstract

BACKGROUND: On every patient's lateral cephalogram, the frontal and maxillary sinuses are the most often seen paranasal sinuses. Impacted teeth alter the morphology of the frontal and maxillary sinuses. Consequently, it has an impact on the patient's look and occlusion.

OBJECTIVE: To determine the mean height, width, and index of maxillary and frontal sinuses and compare them among high, average, and low-angle patients underwent orthodontic treatment.

MATERIAL AND METHODS: A total of 192 cephalometric radiographs of patients who presented with malalignment of teeth having high, average, and low angles and underwent orthodontic treatment were selected. On radiograph, frontal sinus, maxillary sinus, and cephalometric landmarks were traced. Patients were divided into different classes of skeletal vertical malocclusion. The morphology of maxillary and frontal sinuses on lateral cephalogram was measured. Means ± SDs of the quantitative variable were calculated. ANOVA test was applied to compare maxillary and frontal sinus heights, widths, and indexes between high-angle, average-angle, and low-angle patients.

RESULTS: The mean ± SD of height, width, and index of frontal sinus was 30.41 ± 2.59, 10.81 ± 1.53, and 3.44 ± 0.68, respectively, while these findings for maxillary sinus were 40.09 ± 2.36, 36.33 ± 3.38, and 1.11 ± 0.07, respectively. The mean frontal sinus width was significantly different among profile angles ($P < 0.001$), while the mean maxillary sinus width, mean maxillary sinus width, and mean maxillary sinus index were significantly different among profile angles with $P < 0.001$.

CONCLUSION: In comparison to high- and low-angle profiles, the frontal sinus width was greater in the average angle profile. The average width, breadth, and index in the maxillary sinus varied statistically between different angle profiles. In comparison to high- and low-angle profiles, the height, width, and index of the maxillary sinus were all higher in the average angle profile.

Keywords:

Angle, average, frontal sinus, height, width, index, low, maxillary sinus

Department of Orthodontics, Sindh Institute of Oral Health Sciences, Jinnah Sindh Medical University, Karachi, Pakistan

Address for correspondence:
Dr. Hafiz Zuhair Ahmed, A-227, 14-B, Shadman Town # 1, North Karachi, Karachi, Pakistan.
E-mail: drzuhair 984ahmed@gmail.com

Submitted: 24-Dec-2023
Revised: 24-Aug-2024
Accepted: 06-Nov-2024
Published: 25-Mar-2025

Introduction

The third main issue with dental health is malocclusion, which can lower self-esteem owing to changes in appearance, speech, functionality, and psychological factors, lowering a person's quality of life.[1,2] Serious malocclusions that develop as a result of craniofacial defects may call for intensive orthodontic and occasionally surgical therapy (orthognathic surgery) to be fixed. Orthodontic abnormalities should be viewed as a health issue since they are linked to emotional discomfort, poor periodontal health, and reduced masticatory performance.[3]

Knowing the craniofacial region's potential for development is crucial for treatment planning in orthodontics. Planning orthodontic treatment and maintaining the outcomes of orthodontic treatment are both

How to cite this article: Ahmed HZ, Qamruddin I, Siddiqui H, Lohana S, Khan S, Soomar S, *et al*. Morphology of maxillary and frontal sinuses in different skeletal vertical malocclusions. J Orthodont Sci 2025;14:5.

significantly impacted by the stage of growth spurt in the teen or preadolescent years.[4]

Since Broadbent introduced radiography in 1931, lateral cephalograms have evolved into an essential tool for orthodontic evaluation and treatment planning.[5,6]

Different anatomical sites are utilized to analyze various malocclusions that can be exactly portrayed in a lateral cephalogram; however, at this time, various additional points are also derived and employed to establish a point of diagnosis in orthodontics.[7]

The bony chambers that surround the midface are known as paranasal sinuses.[5,6] OPG and PA Ceph can also show paranasal sinuses, but lateral Ceph is recommended above the other two since it does not produce the duplication effect.[8] The anatomical sinuses are classified into four sinuses in the human body, which are the maxillary sinus, ethmoidal sinus, frontal sinus, and sphenoidal sinus. In virtually all patients' lateral cephalograms, the maxillary and frontal sinuses may be seen.[6] The biggest paranasal sinus is the maxillary sinus. Each maxillary bone has a pair of these bony chambers.[9]

Maxillary sinus examination is essential while diagnosing orthodontic issues because it may influence the strategies of treatment. There should be precautions made to ensure that the selected course of therapy does not compromise the integrity of the maxillary sinus.[10,11]

The maxillary sinus's size and location have an impact on the orthodontic treatment strategy. Similar to the dental malocclusions, the maxillary sinus may be impacted by skeletal, anteroposterior, or vertical malocclusions that range in size and location.[12,13] There are many bone malocclusions that might impact the maxillary sinus.[11] In a study that examined the maxillary sinus's size and volume variations in relation to individuals with various breathing patterns, it was shown that mouth breathers had lower maxillary sinus volumes than normal breathers.[14]

When it comes to individuation, the frontal sinus has been discovered to be individual and has been compared to fingerprints; even monozygotic twins do not exhibit identical frontal sinus morphologies.[15] Since over a century ago, radiographic examination of the frontal sinuses has been used to confirm identity. It is frequently utilized when dental or other medical records are absent, if the jaw and maxilla cannot be retrieved, and in very difficult identifications.[16]

A disproportionately large frontal sinus can be detected with facial asymmetry and can lead to major cosmetic issues. The size of the frontal sinus is related to the development pattern. Men have a wider frontal sinus than women, which makes the former's forehead look less broad and the latter more inclined. In women, the upper jaw is more pronounced due to less forehead and nasal projection. Consequently, compared to male patients, more female individuals need therapy for prognathic maxilla.[17]

In orthodontics, there are three different categories for skeletal vertical malocclusions: high angle (hyperdivergent or increased vertical face growth pattern), low angle (hypodivergent or decreased vertical face growth pattern), and normal angle (normodivergent or in between high- and low-angle vertical face growth).[14] They are separated based on the ratio of SNMP, FHMP, MMA, and FHI (S-Go/N-Me) as well as the rise or reduction in angle.[6,18] The volume and size of the maxillary sinuses have an impact on the length of orthodontic therapy, especially in extraction instances where shifting teeth to the sinus region is crucial for bone resorption and apposition.[14] Because the pattern of increasing development in bones follows the same pattern in paranasal sinuses, the morphology of the maxillary and frontal sinus is changed by impacted teeth and other disorders. Prognathic individuals also tend to have spherical, enlarged frontal sinuses. Consequently, it has an impact on the patient's look and occlusion.[14,19]

Prior research has used CBCT and PA Ceph to examine the growth and development of the paranasal sinuses, their relationship to skeletal maturity, and their impact on various forms of malocclusion, but lateral Ceph has shown superior results. [14,20,21]

In the Pakistani population, Mahmood *et al*.[20] reported the average frontal and maxillary sinus height, breadth, and index as 27.806.89 mm, 10.931.27 mm, and 3.020.62 mm for the frontal sinus and 44.785.45, 46.264.47, and 0.960.10 for the maxillary sinus.[21]

Mahmood *et al*.[21]reported the mean comparison of maxillary and sphenoid sinus height, width, and index in males and females in the Pakistani population as 40.26 ± 8.52 (males) and 37.60 ± 6.42 (females), 45.42 ± 4.88 (males) and 42.99 ± 4.42 (females), and 0.87 ± 0.13 (males) and 0.87 ± 0.12 (males) for maxillary sinus and 16.40 ± 4.09 (males) and 15.35 ± 2.80 (females), 36.91 ± 6.68 (males) and 35.28 ± 6.87 (females), and 0.45 ± 0.12 (males) and 0.44 ± 0.09 (males).[21]

Dhiman *et al*.[6] reported the mean MSA (maxillary sinus area) and FSA (frontal sinus area) in skeletal class I malocclusion in males and females as 1363.6 ± 109.55 and 1311.42 ± 81.5 for MSA and 206.2 ± 16.81, 258.63 ± 12.17 for FSA.[6]

This study compared the height, breadth, and index of the maxillary and frontal sinuses in high-angle, average-angle, and low-angle instances in our community since morphological differences across racial groups can occur.

Material and Methods

This cross-sectional study was conducted after getting approval from Institutional Review Board of Jinnah Sindh Medical University. The study was carried out from January 2021 to August 2021 at Department of Orthodontics, Sindh Institute of Oral Health Sciences, Jinnah Sindh Medical University (JSMU), Karachi, Pakistan. Prior to enrolment of patients in the study, participants were briefed about the purpose and benefits of the study and a written consent was taken.

We consider reported findings of Mahmood *et al*.[20] for frontal sinus height, 28.80 ± 7.74 mm (males) and 26.30 ± 6.35 mm (females). Keeping this as reference, we used WHO software for sample size calculation and took the mean average frontal sinus height between males and females as 27.55 ± 7.04 mm and the margin of error as 1, with 95% confidence interval. The sample size calculated was 192. The non probability consecutive sampling was used for sample collection.

Patients of both the genders with age range from 13 to 30 years presented with malalignment of teeth and underwent orthodontic treatment having high angle, average angle, and low angle. The height, width, and index of maxillary and frontal sinuses were measured on lateral cephalogram and reported in terms of millimeters.

Assessment of maxillary sinus morphology on lateral cephalogram was done by using Endo *et al*. method.[21,25] The x-axis parallel to the Frankfort horizontal plane and the y-axis perpendicular to the Frankfort horizontal plane were made through the sella point [Annexure 1]. Assessment of the frontal sinus morphology on a lateral cephalogram was done by using the method of Ertuk [Annexure 2].[20]

Measurements to classify vertical skeletal malocclusion were made as Annexure 3.

High angle was considered if patients have SN-MP >37°, FH-MP >29°, MMA >29°, and FHI (S-Go/N-Me) <62%. Average angle was considered if patients have SN-MP 32 ± 4°, FH-MP 25 ± 2°, MMA 25+-2°, and 62% ≤ FHI (S-Go/N-Me) ≤ 68%. Low angle was considered if patient have SN-MP <28°, FH-MP <21°, MMA <21°, and FHI (S-Go/N-Me) >68%.

Patients were selected by the primary investigator or by the train representatives of the primary investigator. Patients were instructed to arrange themselves in the cephalostat with the sagittal plane of the head vertical, the Frankfort plane horizontal, the teeth in centric relation, and the head rest in natural head position in order to get a standard lateral cephalogram for each subject. Frontal sinus, maxillary sinus, and cephalometric landmarks were marked on the acquired radiograph using 0.5 mm lead pencils shown in Annexure# I and II. Patients were divided into different classes of skeletal vertical malocclusion described in Annexure 3. The morphology of maxillary and frontal sinuses on lateral cephalogram was measured by the methods described by Endo *et al*. and Ertuk.[20,21,25] To minimize the error bias in tracing methods, lateral cephalogram tracings were evaluated twice by the same examiner with an interval of 1-week difference. All the data were controlled anonymously and kept confidential as per the international ethical guideline. This study used SPSS 20.0 (SPSS, Inc.; Chicago, Illinois) for data compilation and its analysis. The mean ± SD of the quantitative variables such as FSH, FSW, MSH, MSW, and maxillary and frontal sinus indexes was calculated. ANOVA test was used to compare maxillary and frontal sinus heights, widths, and indexes between high-angle, average-angle, and low-angle patients. In our study, 5% significance level was set; while using the stratification technique, the confounding factors such as age group and sex were modified and controlled. Post stratification, ANOVA test was applied.

Results

It was observed that there were 49 (25.5%) male and 143 (74.5%) female patients. Cephalometric radiograph showed 64 (33.3%) high-angle profiles, 65 (33.9%) average-angle profiles, and 63 (32.8%) low-angle profiles. The overall mean age was 19.04 ± 2.89 years. The age was stratified in two groups, and it was found that 97 (50.5%) patients belonged to age 18 years or less and 95 (49.5%) patients belonged to age more than 18 years. The results are also presented in Table 1.

Descriptive statistics of height, width, and index of frontal and maxillary sinuses were evaluated. The results showed that the mean ± SD of height, width, and index of frontal sinus was 30.41 ± 2.59 mm, 10.81 ± 1.53 mm, and 3.44 ± 0.68 mm, respectively, while these findings for maxillary sinus were 40.09 ± 2.36 mm, 36.33 ± 3.38 mm, and 1.11 ± 0.07 mm, respectively. The detailed descriptive statistics are presented in Table 2.

The descriptive statistics of height, width, and index of frontal and maxillary sinuses were also evaluated according to gender and angles profiles. It was observed that among males, the mean ± SD of height, width, and index of frontal sinus was 29.79 ± 1.90 mm, 10.50 ± 1.47 mm, and 3.54 ± 0.73 mm, respectively, while these findings for females were 30.62 ± 2.76, 10.92 ± 1.54, and 3.40 ± 0.66, respectively. Among

Table 1: Frequency distribution of demographics and angle profile

(*n*=192)	Frequency (*n*)	Percentage (%)
Gender		
Male	49	(25.5)
Female	143	(74.5)
Age (mean±SD)	19.04±2.89	
≤18 years	97	(50.5)
>18 years	95	(49.5)
Angle Profile		
High-Angle Profile	64	(33.3)
Average-Angle Profile	65	(33.9)
Low-Angle Profile	63	(32.8)

Table 2: Descriptive statistics of height, width, and index of frontal and maxillary sinus

	Frontal sinus			Maxillary sinus		
	Height	Width	Index	Height	Width	Index
Mean	30.41	10.81	3.44	40.09	36.33	1.11
Standard Deviation	2.59	1.53	0.68	2.36	3.38	0.07
Median	30.21	11	3.37	40.01	36.66	1.09
Range	13	7	3.8	10	15	1.39
Minimum	25	8	0.96	36	29	0.95
Maximum	38	15	4.76	46	44	1.39

males, the mean ± SD of height, width, and index of maxillary sinus was 40.04 ± 2.60 mm, 35.97 ± 3.50 mm, and 1.12 ± 0.08 mm, respectively, while these findings for females were 40.11 ± 2.27 mm, 36.45 ± 3.35 mm, and 1.11 ± 0.07 mm, respectively. Among high-angle profiles, the mean ± SD height, width, and index of frontal sinus were 29.95 ± 4.11 mm, 10.72 ± 1.72 mm, and 3.37 ± 0.50 mm, respectively, while these findings for average angle profile were 30.90 ± 1.41 mm, 11.38 ± 1.33 mm, and 3.39 ± 0.58 mm, respectively, and among low-angle profiles, the mean ± SD of height, width, and index of frontal sinus was 30.37 ± 0.97 mm, 10.32 ± 1.32 mm, and 3.54 ± 0.89 mm respectively. Among high-angle profiles, the mean ± SD height, width, and index of maxillary sinus was 39.26 ± 2.13 mm, 36.83 ± 2.88 mm, and 1.07 ± 0.04 mm, respectively, while these findings for average angle profile were 42.08 ± 1.98 mm, 38.53 ± 3.34 mm, and 1.10 ± 0.08 mm, respectively, and among low-angle profiles, the mean ± SD of height, width, and index of maxillary sinus was 38.87 ± 1.45 mm, 33.55 ± 1.46 mm, and 1.16 ± 0.06 mm, respectively. The detailed descriptive statistics are presented in Table 3.

The mean differences of height, width, and index of frontal sinus and maxillary sinus were compared among profile angles using ANOVA. The results showed that the mean frontal sinus width was significantly different among profile angles ($P < 0.001$), while the mean maxillary sinus width, mean maxillary sinus width, and mean maxillary sinus index were significantly different among profile angles with $P < 0.001$. The detailed results are presented in Table 4.

The mean differences of height, width, and index of frontal sinus and maxillary sinus were compared among profile angles using ANOVA according to gender and age groups. The detailed results are presented in Table 5.

Discussion

For diagnosis and monitoring the effectiveness of therapy, lateral cephalograms have been most often employed, and they are frequently included in orthodontic records.[1] Dental and skeletal malocclusions may have an impact on the development of the maxillary sinuses, which are closely related to the maxilla anatomy and the upper posterior teeth.[22] Over the years, a number of indices have been created to assess malocclusions taking into account various aspects of their development, such as identification, classification, severity, need, applicability, priority of treatment, functional changes, psychosocial disorders, and evaluation of the effectiveness and solubility of orthodontic treatment.[23]

The majority of the indices were suitable for individual assessments, but their use in public health was challenging because of certain applicability requirements, such as the need for specialists, plaster models, additional tests like cephalometric radiographs, photographs, special equipment, and the requirement for long-term monitoring in addition to requiring only objective or subjective assessments. As a result, in the context of public health, the significance of determining the need and priority for the treatment of individuals is underlined, as well as the relevance of gathering information to properly allocate the required resources to satisfy the population's demand and prevent social disparities.[24]

Despite the fact that several research studies detailing the incidence and varieties of malocclusion have been published, the many methods and indices used to measure and record occlusal connections, the age variations across the research populations, examiner subjectivity, specialized aims, and different sample sizes make it challenging to compare these results.[25,26]

According to Endo *et al*.[25], there is no discernible difference in the maxillary sinus measurements across the various bone classes in either gender.[27] Males and females have significantly different volumes of the maxillary sinus, according to research by Emirzeoglu *et al*.[26] This is mostly because males have taller and broader maxillary sinuses than females.[28] Oktay discovered that sex was only a significant factor in

Table 3: Descriptive statistics of height, width, and index of frontal and maxillary sinus according to gender and angle profile

Gender/ profile	Descriptive values	Frontal sinus			Maxillary sinus		
		Height	Width	Index	Height	Width	Index
Male	Mean	29.79	10.50	3.54	40.04	35.97	1.12
	Standard Deviation	1.90	1.47	0.73	2.60	3.50	0.08
	Median	30.00	10.79	3.48	40.00	35.41	1.10
	Range	8	5	3.78	10	14	0.43
	Minimum	25	8	0.96	36	29	0.96
	Maximum	33	13	4.74	46	44	1.39
Female	Mean	30.62	10.92	3.40	40.11	36.45	1.11
	Standard Deviation	2.76	1.54	0.66	2.27	3.35	0.07
	Median	30.55	11.00	3.33	40.01	36.83	1.09
	Range	13	7	3.80	10	15	0.43
	Minimum	25	8	0.96	36	29	0.95
	Maximum	38	15	4.76	46	44	1.38
High Angle Profile	Mean	29.95	10.72	3.37	39.26	36.83	1.07
	Standard Deviation	4.11	1.72	0.50	2.13	2.88	0.04
	Median	29.19	11.00	3.33	40.00	37.61	1.07
	Range	13	7	2.01	6	11	0.19
	Minimum	25	8	2.54	36	32	0.95
	Maximum	38	15	4.55	42	43	1.14
Average Angle Profile	Mean	30.90	11.38	3.39	42.08	38.53	1.10
	Standard Deviation	1.41	1.33	0.58	1.98	3.34	0.08
	Median	31.06	11.21	3.33	41.58	39.00	1.08
	Range	5	5	2.10	7	15	0.34
	Minimum	28	9	2.46	39	29	1.05
	Maximum	33	14	4.56	46	44	1.39
Low Angle Profile	Mean	30.37	10.32	3.54	38.87	33.55	1.16
	Standard Deviation	0.97	1.32	0.89	1.45	1.46	0.06
	Median	30.23	10.18	3.51	38.88	33.44	1.18
	Range	4	5	3.80	5	5	0.22
	Minimum	28	8	0.96	36	31	1.05
	Maximum	32	13	4.76	41	36	1.27

Table 4: Comparison of frontal and maxillary sinus height, width, and index with angle profiles

Angle Profile	Frontal sinus			Maxillary sinus		
	Height	Width	Index	Height	Width	Index
High	29.95±4.11	10.72±1.72	3.37±0.50	39.26±2.13	36.83±2.88	1.07±0.04
Average	30.90±1.41	11.38±1.33	3.39±0.58	42.08±1.98	38.53±3.34	1.10±0.08
Low	30.37±0.97	10.32±1.32	3.54±0.89	38.87±1.45	33.55±1.46	1.16±0.06
P	0.113**	<0.001*	0.303**	<0.001*	<0.001*	<0.001*

ANOVA test was applied. *Significant at 0.01 levels **Not Significant at 0.05 levels

angle Class II malocclusion and that both malocclusion and sex factor had no influence on the size of the maxillary sinus.[29]

In order to ascertain the prevalence of the angle categorization of malocclusion in connection to various age groups and genders of patients seeking orthodontic treatment in dental colleges, research was carried out. The individuals were divided into three categories of malocclusion, and the results were then compared with those of previous research that had been done in a similar manner.[25] When the results of this study are compared to other findings from the literature, it is discovered that the conclusions on the various types of malocclusions are consistent with those of another study.[30-35]

Malocclusion is more common in females than in males, however this variation in prevalence between the sexes is not statistically significant.[25] This distinction emphasizes the distinction between orthodontic treatment desire and necessity. Girls often seek therapy in higher numbers than boys because women are more aware of esthetics than males are, according to research by Foster and Al-Zubair.[36,37]

According to research findings, malocclusion occurs more frequently in mixed dentition than in permanent teeth.

Table 5: Comparison of frontal and maxillary sinus height, width, and index with angle profiles

	Angle Profile	FRONTAL SINUS			MAXILLARY SINUS		
		Height	Width	Index	Height	Width	Index
Males	High	28.05±2.10	10.10±1.42	3.40±0.54	38.59±2.01	36.13±2.63	1.07±0.04
	Average	30.97±1.20	11.31±1.33	3.57±0.72	42.43±1.92	38.05±3.87	1.13±0.11
	Low	30.04±1.00	9.87±1.30	3.65±0.91	38.45±1.33	33.17±1.29	1.16±0.05
	P	<0.001*	0.006*	0.651**	<0.001*	<0.001*	0.006*
Females	High	30.53±4.41	10.91±1.78	3.36±0.50	39.47±2.14	37.04±2.94	1.07±0.04
	Average	30.87±1.50	11.41±1.34	3.32±0.50	41.93±2.01	38.73±3.13	1.09±0.07
	Low	30.48±0.95	10.46±1.32	3.51±0.89	39.01±1.47	33.66±1.50	1.16±0.06
	P	0.758**	0.011*	0.326**	<0.001*	<0.001*	<0.001*
Age ≤18 Years	High	31.33±4.61	10.82±2.12	3.64±0.48	38.49±2.15	35.66±2.17	1.08±0.02
	Average	31.00±1.64	11.69±1.38	3.32±0.61	41.55±2.21	37.76±4.41	1.12±0.11
	Low	30.51±0.74	10.40±1.18	3.70±0.69	38.99±1.42	33.65±1.49	1.16±0.05
	P	0.510**	0.004*	0.042*	<0.001*	<0.001*	0.001*
Age ≤18 Years	High	28.80±3.29	10.64±1.33	3.30±0.52	39.90±1.91	37.79±3.06	1.06±0.05
	Average	30.76±1.04	10.98±1.16	3.48±0.53	42.78±1.38	39.55±1.33	1.08±0.01
	Low	30.24±1.15	10.25±1.47	3.39±1.03	38.76±1.49	33.44±1.45	1.17±0.07
	P	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

ANOVA test was applied. *Significant at 0.01 levels **Not Significant at 0.05 levels

This finding is supported by several additional studies, including one by Thilanders and Brito.[25,38] This outcome is brought on by a few traits, such as an anterior open bite and greater over jet in the mixed dentition, which can self-correct by ceasing habitual mouth breathing and other environmental influences.[35,39] Or that might be because various oral behaviors, such as nail biting, non-nutritive sucking habits, and tongue thrusting, which are more noticeable in mixed dentition than in permanent teeth, have an effect on the dentition.[40]

For orthodontists, learning about the maxillary sinus is extremely valuable. The association between the maxillary sinus and various orthodontic applications has been the subject of several investigations. The volume of the maxillary sinus was discovered to be affected by several orthodontic treatment techniques, including fast maxillary expansion, orthognathic surgery, up righting upper molars, and traction of severely impacted canines.[10] Moving teeth through the sinus is another way that orthodontic therapy and the maxillary sinus are related. The danger of root resorption and unintended tilting increased as a result of shifting teeth via the maxillary sinus, and treatment duration increased.[12,41]

The maxillary sinus volumes of right and left sides did not significantly change in Okşayan *et al*.[13] study of participants with various vertical development patterns. Additionally, when the maxillary sinus's length was compared between the right and left sides, there was no statistically significant difference in expansion and its relationship to the back teeth was examined.[43] When Tikku *et al*.[42] compared the volume of the maxillary sinus in normal and mouth breathers, they discovered a substantial difference in the right and left sides of the sinus in the mouth breathers' group. They asserted that the difference was brought about by a long-term inflammatory response that thickened the sinus' bone walls.[44]

According to the findings of a study,[10] using both software programs on people with normal face patterns, hyperdivergent facial patterns, and hypodivergent facial patterns, there was no statistically significant change in the volume of the maxillary sinus. However, when the upper airway and maxillary sinus volume were compared in various dental and skeletal malocclusions, it was shown that individuals with low anterior facial height, or in other words, with hypodivergent faces, had reduced volume of the maxillary sinus. This can also be explained by the age difference in the sample of that study and the present study. In addition, Ryu *et al*.[43] discovered that people with skeletal open bites had a higher maxillary sinus cranio-caudal height and cross-sectional area than people with skeletal normal overbite, but there were no appreciable differences in their anteroposterior and mediolateral dimensions. Unlike our study, where measurements were taken from specific slices and the complete volume was not taken into account, their study did not assess the total volume. Additionally, Tikku *et al*.[42] and Agacayak *et al*.[44] discovered that nose breathers had larger sinuses than mouth breathers in adults and children, who mostly had hyperdivergent faces. The discrepancy between the findings of previous investigations and the current study, however, can be explained by the fact that, in contrast to the present study, the vertical growers in both trials were originally mouth breathers. The function of the nasal cavity is reduced as a result of the mouth breathing habit, which also slows the development of the maxillary sinus. Furthermore, pathological diseases that reduce the sinus volume are more likely to affect mouth breathers.

In the context of orthodontic treatment, the morphology of the maxillary sinus has significant implications for treatment planning, particularly in high-angle and low-angle malocclusions.[20] In high-angle cases, characterized by increased vertical growth, larger maxillary sinuses may permit more aggressive tooth movements, facilitating the correction of open bite tendencies. This anatomical understanding allows orthodontists to implement strategies such as high-pull headgear to control vertical growth effectively.[45] Conversely, in low-angle cases, where the vertical dimension is reduced, smaller maxillary sinuses may necessitate a more conservative approach, focusing on intrusion of posterior teeth to enhance vertical dimension.[44] Recognizing these differences informs orthodontic decision-making, ensuring that treatment plans are tailored to individual anatomical variations, thereby optimizing outcomes and minimizing complications such as sinusitis or relapse.[6]

Up to the age of 20, frontal sinuses continue to expand in size as they get bigger with age.[45,46] According to the phases of hand-wrist development at various age groups, the area, height, and breadth of frontal sinuses were measured in both sexes in research. Individuals older than 8 years old were also included in that study, just like in Mahmood *et al*.[20] At the conclusion of the investigation, they discovered that males had wider and taller frontal sinuses than females. Additionally, they discovered a statistically significant link between both genders' cervical vertebral growth stages and the width and height of frontal sinuses.[46,20]

Limitations of the study

The short sample size was the primary drawback of our study. The cephalometric radiography and the single-center experience and nonrandomized research design are further limitations of the current investigation. The digital cephalometry and cone beam computed tomography (C.B.C.T) can produce better results keeping the ethical consideration. The study was done in an urban setting. Therefore, its findings might not apply to bigger populations.

Conclusion

According to the study's findings, the average angle profile had a higher frontal sinus width than the high- and low-angle profiles. The average height, width, and index in the maxillary sinus varied statistically between different angle profiles. In comparison to high- and low-angle profiles, the average angle profile had a higher height, width, and index of the maxillary sinus.

Financial support and sponsorship

Nil.

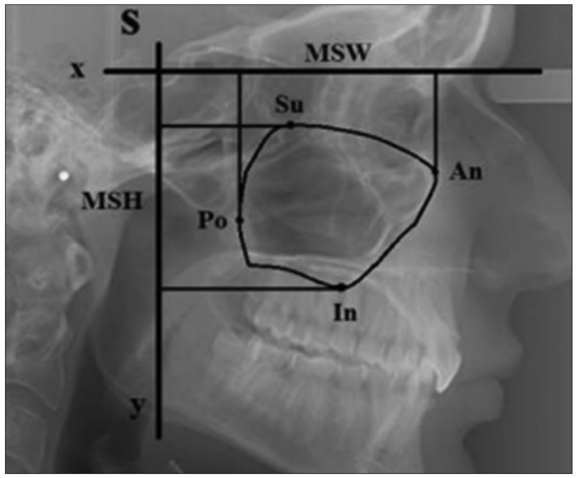
Conflicts of interest

There are no conflicts of interest.

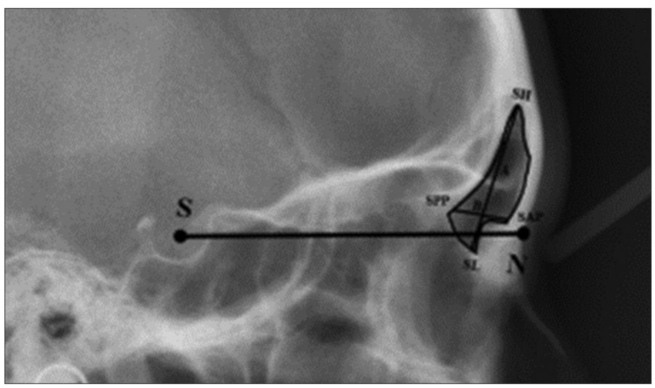
References

1. Moimaz SAS, Gonçalves CS, Chiba FY, Garbin AJI, Saliba TA. Malocclusion indices and their applications in public health: A review study. Arch Health Investig 2021; 10:1156–63.
2. Ghafari M, Bahadivand-Chegini S, Nadi T, Doosti-Irani A. The global prevalence of dental healthcare needs and unmet dental needs among adolescents: A systematic review and meta-analysis. Epidemiol Health 2019;41: e2019046.
3. Mohammad BH, Abdul-Jabbar MF, Mohammed MH. Prevalence of angle's classification of malocclusion among patients attending Orthodontic Department in College of Dentistry- retrospective cross-sectional study. EDJ 2022; 4:111-7.
4. Alijani S, Farhadian N, Alafchi B, Najafi M. Relationship of frontal sinus size and maturation of cervical vertebrae for assessment of skeletal maturity. Front Dent 2020; 17:1-6.
5. Salehi P, Heidari S, Khajeh F. Relationship between frontal sinus surface area and mandibular size on lateral cephalograms of adults. J Isfahan Dent Sch 2012; 8:244-50.
6. Dhiman I, Singla A, Mahajan V, Jaj HS, Seth V, Negi P. Reliability of frontal sinus with that of maxillary sinus in assessment of different types of skeletal malocclusions. Indian Orthod Soc 2015; 49:96-103.
7. Durão AR, Pittayapat P, Rockenbach MIB, Olszewski R, Ng S, Ferreira AP, *et al*. Validity of 2D lateral cephalometry in orthodontics: A systematic review. Prog Orthod 2013; 14:31.
8. Maspero C, Farronato M, Bellincioni F, Annibale A, Machetti J, Abate A, *et al*. Three-dimensional evaluation of maxillary sinus changes in growing subjects: A retrospective cross-sectional study. Materials (Basel) 2020; 13:1007.
9. Abdelhamid N, Nadim M, Elkadi A. Correlation between maxillary sinus volume and different facial patterns using cone beam computed tomography in adults. Dent Sci Updat 2022; 3:57-64.
10. Oishi S, Ishida Y, Matsumura T, Kita S, Kuma T, Imamura T, *et al*. A cone-beam computed tomographic assessment of the proximity of the maxillary canine and posterior teeth to the maxillary sinus floor: Lessons from 4778 roots. Am J Orthod Dentofac Orthop 2020; 157:792-802.
11. Cappellette M Jr, Alves F, Nagai LHY, Fujita R, Pignatari S. Impact of rapid maxillary expansion on nasomaxillary complex volume in mouth-breathers. Dental Press J Orthod 2017; 22:79-88.
12. Oz AZ, Oz AA, El H, Palomo J. Maxillary sinus volume in patients with impacted canines. Angle Orthod 2017; 87:25-32.
13. Okşayan R, Sökücü O, Yeşildal S. Evaluation of maxillary sinus volume and dimensions in different vertical face growth patterns: A study of cone-beam computed tomography. Acta Odontol Scand 2017; 75:345-9.
14. Shamlou AA, Tallman SD. Frontal sinus morphological and dimensional variation as seen on computed tomography scans. Biology 2022; 11:1145.
15. Christensen AM, Hatch GM. Advances in the use of frontal sinuses for human identification. In New Perspectives in Forensic Human Skeletal Identification. Cambridge, MA, USA: Academic Press; 2018.
16. Metin-Gürsoy G, Akay G, Tuncer BB. Frontal sinus: Is it a predictor for vertical malocclusions? Anat Sci Int 2021; 96:62-9.
17. Yili X, Yingyi H, Jiaqian F, Fan L, Lei Y. Correlation between the size of the maxillary sinus and vertical growth patterns: A 3-dimensional cone-beam computed tomographic study.
18. Wang XM, Ma LZ, Wang J, Xue H. The crown-root morphology of central incisors in different skeletal malocclusions assessed with cone-beam computed tomography. Prog Orthod 2019; 20:20.

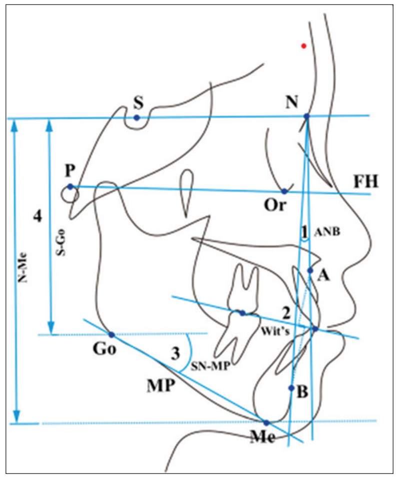
19. Mahmood HT, Shaikh A, Fida M. Association between frontal sinus morphology and cervical vertebral maturation for the assessment of skeletal maturity. Am J Orthod Dentofac Orthop 2016; 150:637–42.
20. Mahmood HT, Shaikh A, Fida M. Reliability and validity of maxillary and sphenoid Sinus morphological variations in the assessment of Skeletal maturity. J Ayub Med Coll Abbottabad 2018; 30:360–5.
21. BasdraEK, Stellzig A, Komposch G. The importance of the maxillary sinuses in facial development: A case report. Eur J Orthod 1998; 20:1-4.
22. Peres KG, Frazão P, Roncalli AG. Epidemiological pattern of very severe malocclusion in Brazilian adolescents. Rev Public Health 2013; 47:109-17.
23. Mohammad BH, Jabbar MFA, Mohammed MH. Prevalence of angle's classification of malocclusion among patients Attending Orthodontic Department in College of Dentistry. Retrospective cross-sectional study. Egypt Dent J 2021; 4:111-7.
24. Bilgic F, Gelgor IE, Celebi EE. Malocclusion prevalence and orthodontic treatment need in central Anatolian adolescents compared to European and other nations' adolescents. Dent Press J Orthod 2015; 20:75–81.
25. Endo T, Abe R, Kuroki H, Kojima K, Oka K, Shimooka S. Cephalometric evaluation of maxillary sinus sizes in different malocclusion classes. Odontology 2010; 98:65-72.
26. Emirzeoglu M, Sahin B, Bilgic S, Celebi M, Uzun A. Volumetric evaluation of the paranasal sinuses in normal subjects using computer tomography images: A stereological study. Auris Nasus Larynx 2007; 34:191-5.
27. Oktay H. The study of the maxillary sinus areas in different orthodontic malocclusions. Am J Orthod Dentofacial Orthop 1992; 102:143-5.
28. Aslam K, Nadim R, Saher R. Prevalence of angles malocclusion according to age groups and gender. Pak Oral Dent J 2014; 34:362–4.
29. Laganà G, Masucci C, Fabi F, Bollero P, Cozza P. Prevalence of malocclusions, oral habits and orthodontic treatment need in a 7- to 15-year-old school children population in Tirana. Prog Orthod 2013; 14:12.
30. Omutimba D, Ramadan A, Refaat E. Prevalence of different classes of malocclusion among dental students at Moiuniversity in kenya. Alex Dent J 2016; 41:1–3.
31. Tak M. Prevalence of malocclusion and orthodontic treatment needs among 12-15 years old school children of Udaipur, India. Eur J Dent 2013; 7:45–53.
32. Atashi MHA. Prevalence of malocclusion in 13–15-year-old adolescents in Tabriz. J Dent Res Dent Clin Dent Prospects 2007; 1:13–8.
33. Oshagh M, Ghaderi F, Pakshir HR, Baghmollai AM. Prevalence of malocclusions in school age children attending the orthodontics department of Shiraz University of Medical Sciences. East Mediterr Health J 2012; 16:1245–50.
34. Foster TD, Day AJ. A survey of malocclusion and the need for orthodontic treatment in a Shropshire school population. Br J Orthod 1974; 1:73–8.
35. Al-Zubair N. Perception of occlusion and reasons for not seeking orthodontic treatment among Yemeni children. J Orthod Res 2014; 2:68.
36. Thilander B, Pena L, Infante C, Parada SS, de Mayorga C. Prevalence of malocclusion and orthodontic treatment need in children and adolescents in Bogota, Colombia. An epidemiological study related to different stages of dental development. Eur J Orthod 2001; 23:153–67.
37. Tausche E, Luck O, Harzer W. Prevalence of malocclusions in the early mixed dentition and orthodontic treatment need. Eur J Orthod 2004; 26:237–44.
38. Omer M, Abuaffan A. Prevalence of oral habits and its effect in primary dentition among Sudanese preschool children in Khartoum City. Indian J Dent Educ 2015; 8:57–62.
39. Sun W, Xia K, Huang X, Cen X, Liu Q, Liu J. Knowledge of orthodontic tooth movement through the maxillary sinus: A systematic review. BMC Oral Health 2018; 81:91-106.
40. Cha S, Zhan C, Zhao Q. Treatment of Class II malocclusion with tooth movement through the maxillary sinus. Am J Orthod Dentofac Orthop 2020; 157:105-16.
41. Kosumarl W, Patanaporn V, Jotikasthira D, Janhom A. Distances from the root apices of posterior teeth to the maxillary sinus and mandibular canal in patients with skeletal open bite: A cone-beam computed tomography study. Imaging Sci Dent 2017; 47:157-64.
42. Tikku T, Khanna R, Sachan K, Srivastava K, Munjal N. Dimensional changes in maxillary sinus of mouth breathers. J Oral Biol Craniofac Res 2013; 3:9-14.
43. Ryu J, Choi S, Cha J, Lee K, Hwang C. Retrospective study of maxillary sinus dimensions and pneumatization in adult patients with an anterior open bite. Am J Orthod Dentofac Orthop 2016; 150:796-801.
44. Agacayak K, Gulsun B, Koparal M, Aksoy O, Adiguzel O. Alterations in maxillary sinus volume among oral and nasal breathers. Med Sci Monit 2015; 21:18-26.
45. Kjær I, Pallisgaard C, Brock-Jacobsen MT. Frontal sinus dimensions can differ significantly between individuals within a monozygotic twin pair, indicating environmental influence on sinus sizes. Acta Otolaryngol 2012;132:988–94.
46. Metin-Gürsoy G, Akay G, Baloş Tuncer B. Frontal sinus: Is it a predictor for vertical malocclusions?. Anat Sci Int 2021; 96:62-9.



ANNEXURE I: Endo *et al*. method for maxillary sinus assessment. An: anterior point on maxillary sinus. Po: posterior point on maxillary sinus. Su: superior point on maxillary sinus. In: inferior point on maxillary sinus. MSH: line projected on y-axis, joining points Su and In, denoting maximum maxillary sinus height. MSW: line projected on x-axis, joining points Po and An, denoting maximum maxillary sinus width. S: anatomical center of Sella turcica as shown in annexure #1



ANNEXURE II: Ertuk's method for frontal sinus assessment. SH: the highest point on the frontal sinus; SL: the lowest point on the frontal sinus; A: line joining SH and SL denoting maximum frontal sinus height; SPP: posterior point on the frontal sinus; SAP: anterior point on the frontal sinus; B: line joining SPP and SAP denoting the maximum frontal sinus width perpendicular to line A; S: anatomic center of Sella turcica; N: deepest point in the midline at the frontonasal suture. As shown in annexure # 2



ANNEXURE III: Cephalometric landmarks. ANS (Anterior nasal spine)—tip of the median sharp bony process of the palatine bone in the hard palate. PNS (Posterior nasal spine)—tip of the posterior spine of the palatine bone of the hard palate. A, A-point, deepest bony point on the contour of the premaxilla below ANS; B: B-point, deepest bony point on the contour of the mandible above pogonion's, sella, center of Sella turcica; N: nasion, the most anterior limit of the frontonasal suture on the frontal bone in the facial midline; SN: connection between S and N, stands for anterior cranium base plane; Go, gonion, the most posterior inferior point of mandible angle; Me, Menton, most inferior point of the bony chin; MP: connection between Me and Go, stands for mandibular plane; SNMP: angle between SN and MP; Orbitale (Or): lowest point on margin of orbit Porion (P), midpoint on upper edge of external auditory meatus. Frankfort horizontal plane, plane passing through porion and orbitale; FHMP: angle between FH and MP.MMA, angulation of the maxillary plane with the mandibular plane 3. S-Go, the distance between lines parallel to FH plane passing through S and Go, represents the posterior facial height; N-Me: the distance between lines parallel to FH plane passing through N and Me, represents for the anterior facial height; FHI (S-Go/N-Me), facial height index, the ratio of posterior and anterior height, stands for vertical growth pattern of individual shown in annexure-3