Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(6), 2113-2128 | ISSN:2251-6727

Evaluating the Reliability of Frontal Sinus with that of Maxillary Sinus in Assessing Different Types of Skeletal Malocclusion.

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(Received: 16 September 2024 Revised: 11 October 2024 Accepted: 11 December 2024)

KEYWORDS

Frontal sinus, maxillary sinus, skeletal malocclusion, gender determination.

ABSTRACT:

Introduction:

The frontal sinus and maxillary sinus are commonly used anatomical structures for assessing skeletal malocclusion due to their proximity to the craniofacial region and they can be easily seen and assessed on lateral cephalogram. The aim of this study was to evaluate the reliability of frontal sinus and maxillary sinus in assessing different skeletal malocclusion and evaluate for gender discrimination.

Materials and Methods:

180 subjects, 90 males and 90 females (18 – 25 years) were divided into three groups based on ANB angle, Wits appraisal, Beta Angle, W angle and Yen angle into skeletal Class I, Class II, and Class III. The height, width, area, and perimeter of frontal and maxillary sinus were measured using AutoCAD, frontal sinus index was calculated as ratio of frontal sinus width to height and maxillary sinus index was calculated as ratio of maxillary sinus width to height.

Results:

The frontal sinus height, width, area, and frontal sinus index were statistically significantly greater in skeletal Class III followed by Class II and Class I malocclusion. The maxillary sinus height, width, area, and maxillary index were greater in skeletal Class II followed by Class I and Class III malocclusion, however, the difference between skeletal malocclusions was statistically insignificant.

Conclusion:

The frontal sinus dimensions are reliable in assessing skeletal malocclusions. The maxillary sinus dimensions are not predictable in assessing skeletal malocclusions. Frontal sinus area exhibits gender dimorphism suggesting frontal sinus area can be used to for gender determination.

Introduction

The paranasal sinuses are pair of four air-filled bony cavities that surrounds and opens into the nasal cavity.[1] The paranasal sinuses includes frontal sinus, maxillary sinus, ethmoidal sinus, and sphenoidal sinus. The function of paranasal sinus is to reduce the weight of the skull, add resonance to voice, humidify air and regulate intra-nasal pressure.[2] Among the paranasal sinuses, frontal sinus and maxillary sinus occupy significant amount of space within the craniofacial bones. The growth of paranasal sinus very closely follows a growth

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trend similar to other craniofacial bones.[3] It is assumed that development and growth of frontal and maxillary sinus may be affected by different skeletal malocclusion. [4,5]

The frontal sinus is located within frontal bone behind the superciliary arch, and opens through the frontonasal duct into the anterior part of the hiatus semilunaris. It is rudimentary or absent at birth and it is the last paranasal sinus to develop. The frontal sinus bud is present at birth within the ethmoidal region, and becomes radiographically visible at the age of 5 years.[3] According to Tanner, the frontal sinus enlargement ceases at 16 years in boys and 14 years in girls.[6] **Rossouw et al** observed enlarged frontal sinus in patients having mandibular prognathism.[7] The variation in pneumatisation of frontal sinus results in individualized morphology, including differences in size, shape, and symmetry. Its irregular contours and distinctive features makes the frontal sinus anatomically unique for each individual. This characteristic feature of frontal sinus makes it widely used in forensic science.[3]

The maxillary sinus is a part of nasomaxillary complex, largest of paranasal sinuses and is the first paranasal sinus to develop. [8] The maxillary sinus opens into middle meatus of nose in posterior part of hiatus semilunaris.[9] The development of the maxillary sinus begins at the ethmoidal infundibulum in the third month of fetal life. Radiographically, the maxillary sinus becomes distinguishable in anteroposterior view by around 5 months after birth. After birth, the maxillary sinus continues to expand both laterally and inferiorly during rapid growth phases, occurring from birth to 3 years of age and from 7 to 12 years of age. It is pyramidal in shape and plays an important role in facial contour formation. The floor of the maxillary sinus is formed by the alveolar process of the maxilla and have a close anatomical and functional relationship with the posterior maxillary teeth.[10] **Dibbets[11] and Hopkins et al[12]** concluded that cranial base tends to be larger in skeletal Class II malocclusion as compared to skeletal Class I and Class III malocclusion and individuals with larger cranial base tend to have larger maxillary sinus.

The frontal sinus and maxillary sinus are commonly used anatomical structures for assessing skeletal malocclusion due to their proximity to the craniofacial region and they can be easily seen and assessed on lateral cephalogram of all patients. [13] Both, frontal sinus and maxillary sinus have been investigated for their potential in assessing skeletal malocclusion, their reliability may vary depending on anatomical factors, imaging techniques, and landmark identification.

Therefore, the objective of the study was to evaluate the reliability of frontal sinus and maxillary sinus in assessing different skeletal malocclusion and to find whether frontal sinus and maxillary sinus can be used for gender determination.

Aim and Objectives

The aim of the study was to evaluate the reliability of frontal sinus with that of maxillary sinus in assessing different types of skeletal malocclusions.

The objectives of the study were as following:

1. To evaluate the dimensions and area of frontal sinus in various skeletal malocclusions using AutoCAD software.
2. To evaluate the dimensions and area of maxillary sinus in various skeletal malocclusions using AutoCAD software.
3. To evaluate the reliability of frontal sinus and maxillary sinus in assessing different types of skeletal malocclusions.
4. To find whether frontal sinus or maxillary sinus exhibits gender dimorphism.

Material and Methods

The present study **'Evaluating the reliability of frontal sinus with that of maxillary sinus in assessing different types of skeletal malocclusion'** was carried out at the Department of Orthodontics and Dentofacial Orthopaedics, Government Dental College & Hospital, Ahmedabad. It was approved by the Institutional Ethical Committee (IEC). For this study cephalogram of 180 subjects with age ranging from 18-25 years visiting the Department of Orthodontics for orthodontic treatment were selected as samples.

Inclusion criteria:

- Age group of the subjects in the range of 18-25 years.
- Presence of all the permanent teeth upto second molars.
- No history of previous orthodontic treatment.

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- No gross facial asymmetry.

Exclusion criteria:

- Paranasal sinus pathology.
- Apparent facial disharmony.
- Cleft lip and palate.

Selection Criteria:

Lateral cephalogram for each subject was taken by positioning individual in cephalostat with the Frankfort horizontal plane parallel to floor in centric occlusion with lips relaxed using *Vatech PHT 30 LFO smart machine (Korea*

), a film to focus distance of 150 cm and a film to median plane distance of 15 cm at a voltage of 85kVP, current of 10mA and a scan time of 16.9 seconds.

A total of 180 subjects including 90 males and 90 females were divided into three groups based on the sagittal discrepancy indicators including ANB angle, Wits appraisal, Beta Angle, W angle and Yen angle into skeletal Class I, Class II, and Class III malocclusion groups.

	Group	Sagittal Discrepancy Indicators		Total	Subgroup
1	Class I	ANB	0° to 4°	60	A1= 30 Males
		Beta angle	27° to 35°		
		W angle	51° to 55°		A2= 30 Females
		Yen angle	117° to 123°		
2	Class II	ANB	>4°	60	B1= 30 Males
		Beta angle	<27°		
		W angle	<51°		B2= 30 Females
		Yen angle	<117°		
3	Class III	ANB	<0°	60	C1= 30 Males
		Beta angle	>35°		
		W angle	>55°		C2= 30 Females
		Yen angle	>123°		

Cephalogram thus obtained were traced with AutoCAD 2024 software after identifying various points and planes on cephalogram and various linear and angular parameters were measured.

Reference Points: (Figure 1)

- ***N- Nasion***. The most anterior point on the fronto-nasal suture in the midsagittal plane.
- ***S- Sella turcica***. The geometric centre of pituitary fossa.
- ***Point A.*** The most posterior midline point in the concavity between the ANS and the prosthion.
- ***Point B.*** The most posterior midline point in concavity of the mandible between infradentale and pogonion.
- ***C-Point.*** The centre of the condyle found by tracing the head of the condyle and approximating its centre.
- ***M-Point.*** The midpoint of the premaxilla.
- ***G-Point.*** The centre of the largest circle that is tangent to the internal inferior, anterior, and posterior surfaces of the mandibular symphysis.
- ***Sh-Point.*** The highest point on the peripheral borders of the frontal sinus.
- ***Sl-Point.*** The lowest point on the peripheral borders of the frontal sinus.

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- ***Sa- Point.*** The most anterior point on the peripheral borders of frontal sinus.
- ***Sp- Point.*** The most posterior point on the peripheral borders of frontal sinus.
- ***An-Point.*** The most anterior point on the peripheral borders of maxillary sinus.
- ***Po'-Point.*** The most posterior point on the peripheral borders of maxillary sinus.
- ***Su-Point.*** The most superior point on the peripheral borders of maxillary sinus.
- ***In-Point.*** The most inferior point on the peripheral borders of maxillary sinus.

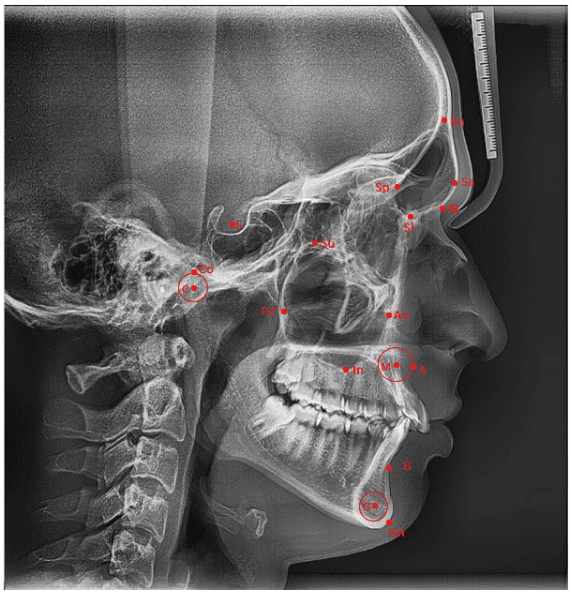

Figure 1. Reference points used in cephalometric measurements.

Cephalometric variables used in study:

A) Linear Measurement (Figure 2)

- **Wits Appraisal** – A perpendicular line was drawn from Point A and Point B to the functional occlusal plane and was named as AO and BO respectively. The linear distance between AO and BO is Wits Appraisal.

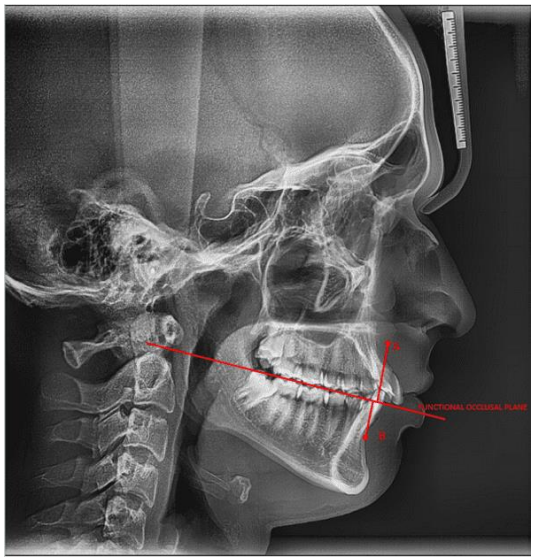

Figure 2. Linear measurements used in the study.

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B) Angular Measurement (Figure 3)

- **SNA angle** – The angle formed between SN line and NA line.
- **SNB angle** – The angle formed between SN line and NB line.
- **ANB angle** – The angle formed between NA line and NB line.
- **Beta angle –** Firstly draw a line connecting the centre of condyle C with B point , then draw a line from point A perpendicular to C-B line. The Beta angle is angle formed between the perpendicular and the A-B line.
- **Yen angle –** The angle formed by joining the S-M line and M-G line.
- **W angle –** The angle formed between the perpendicular line from point M to S-G line and the M-G line.

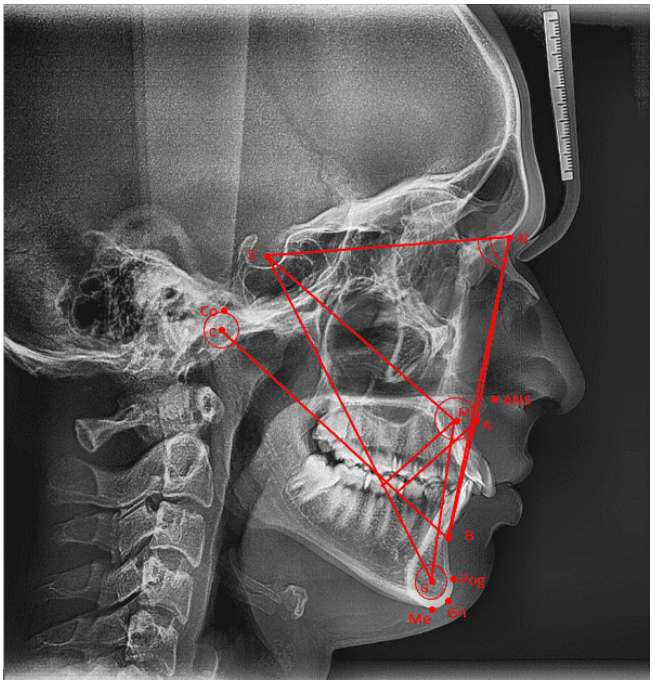

Figure 3. Angular measurements used in the study.

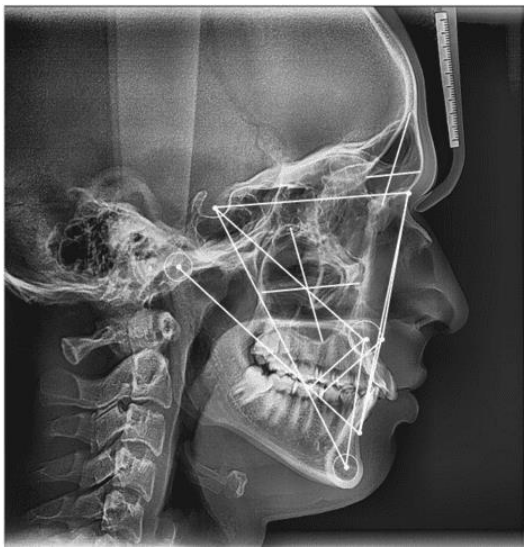

Figure 4. Measurements done in AutoCAD 2024 software.

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Frontal sinus measurements (Figure 5 and 6)

- **Frontal sinus area (FSA)** – The frontal sinus area was measured by tracing the area of high radiopacity as the peripheral border in AutoCAD 2024 software and the area confined within these boundaries represents frontal sinus area.
- **Frontal sinus height (FSH)** – The linear distance between Sh and Sl points.
- **Frontal sinus width (FSW)** – The linear distance between Sa and Sp points.
- **Frontal sinus index (FSI)** – The frontal sinus index (FSI) was calculated as ratio of frontal sinus width to frontal sinus height.

$$FSI = \frac{\text{Frontal sinus width}}{\text{Frontal sinus height}}$$

- **Frontal sinus perimeter (FSP)** – The frontal sinus perimeter was measured by tracing the area of high radiopacity as the peripheral border in AutoCAD 2024 software and the total length around the frontal sinus represents frontal sinus perimeter.

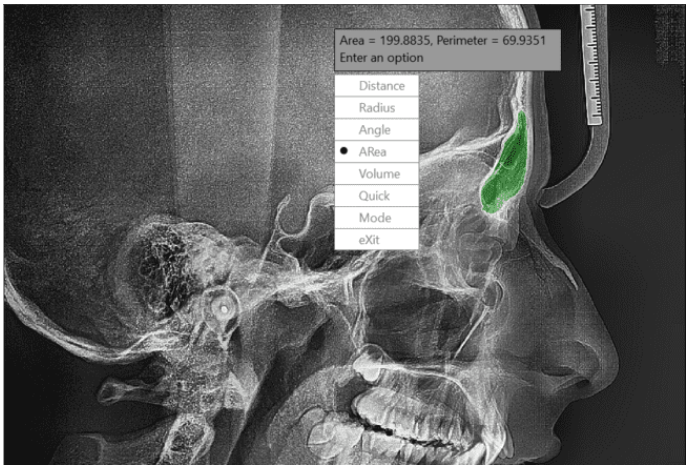

Figure 5. Measurement of frontal sinus area and perimeter.

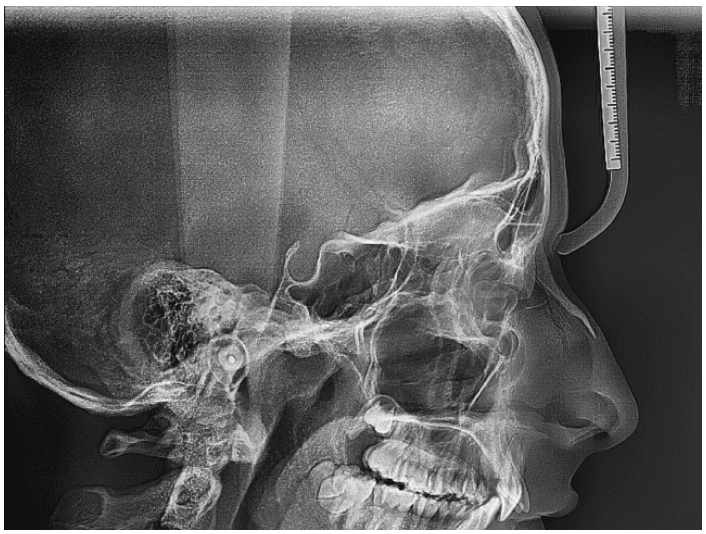

Figure 6. Measurement of frontal sinus height and width.

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Maxillary sinus measurements (Figure 7 and 8)

- **Maxillary sinus area (MSA)** – The maxillary sinus area was measured by tracing the area of high radiopacity as the peripheral border in AutoCAD 2024 software and the area confined within these boundaries represents maxillary sinus area.
- **Maxillary sinus height (MSH)** – The linear distance between Su and In points.
- **Maxillary sinus width (MSW)** – The linear distance between An and Po' points.
- **Maxillary sinus index (MSI)** – The maxillary sinus index (MSI) was calculated as ratio of maxillary sinus width to maxillary sinus height.

$$MSI = \frac{\text{Maxillary sinus width}}{\text{Maxillary sinus height}}$$

- **Maxillary sinus perimeter (MSP)** – The maxillary sinus perimeter was measured by tracing the area of high radiopacity as the peripheral border in AutoCAD 2024 software and the total length around the maxillary sinus represents maxillary sinus perimeter.

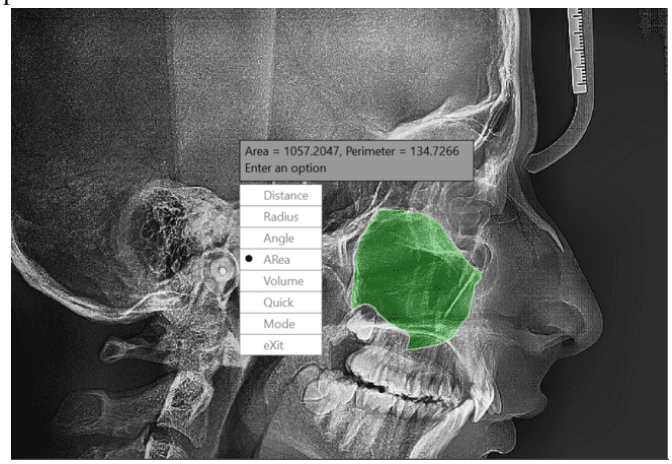

Figure 7. Measurement of maxillary sinus area and perimeter.

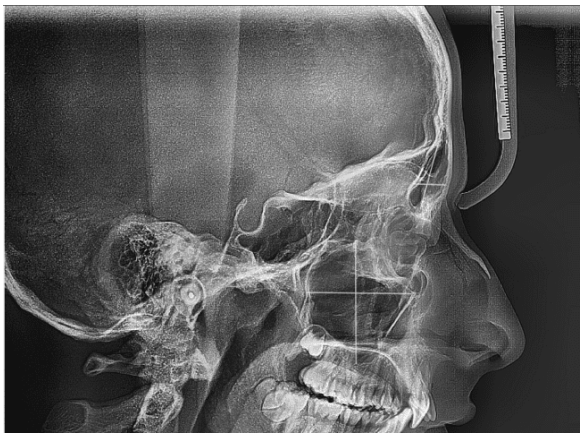

Figure 8. Measurement of maxillary sinus height and width.

RESULTS

Data was analysed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed

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using Shapiro-Wilk test. Inferential statistics to find out the difference between the malocclusion group was done using one-way ANOVO test followed by Bonferroni post hoc test (Table 3 and 4). Independent T test was used for comparison between gender (Table 5 and 6).

Table 1 – Mean values of frontal sinus dimensions in different skeletal malocclusions.

FRONTAL SINUS DIMESIONS	SKELETAL MALOCCLUSION	MEAN	SD
FRONTAL SINUS HEIGHT (mm)	CLASS I	28.53	2.87
	CLASS II	29.29	2.94
	CLASS III	31.97	2.66
FRONTAL SINUS WIDTH (mm)	CLASS I	11.15	3.77
	CLASS II	12.55	3.15
	CLASS III	14.35	3.42
FRONTAL SINUS AREA (mm^2)	CLASS I	223.45	10.27
	CLASS II	276.75	12.35
	CLASS III	281.87	10.84
FRONTAL SINUS INDEX	CLASS I	0.42	0.28
	CLASS II	0.41	0.10
	CLASS III	0.59	0.08
FRONTAL SINUS PERIMETER (mm)	CLASS I	71.44	15.64
	CLASS II	76.29	17.22
	CLASS III	77.84	14.63

Table 2 – Mean values of maxillary sinus dimensions in different skeletal malocclusions.

MAXILLARY SINUS DIMESIONS	SKELETAL MALOCCLUSION	MEAN	SD
MAXILLARY SINUS HEIGHT (mm)	CLASS I	36.25	4.76
	CLASS II	36.27	3.79
	CLASS III	36.08	5.05
MAXILLARY SINUS WIDTH (mm)	CLASS I	37.70	3.35
	CLASS II	38.64	3.82
	CLASS III	36.41	3.71
MAXILLARY SINUS AREA (mm2)	CLASS I	997.85	189.17
	CLASS II	1066.35	193.81
	CLASS III	980.69	209.85
MAXILLARY SINUS INDEX	CLASS I	1.05	0.15
	CLASS II	2.27	0.93
	CLASS III	1.009	0.11
MAXILLARY SINUS PERIMETER (mm)	CLASS I	132.24	12.26
	CLASS II	132.05	12.28
	CLASS III	125.49	11.80

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Table 3 – One-Way ANOVA followed by Bonferroni post-hoc test to compare frontal sinus dimensions in different skeletal malocclusions.

FRONTAL SINUS DIMENSIONS	CLASS I (mm)	CLASS II (mm)	CLASS III (mm)	P VALUE	BONFERRONI POSTHOC TEST
FRONTAL SINUS HEIGHT (mm)	28.53±2.87	29.29±2.94	31.97±2.66	0.03*	CLASS I vs CLASS III 0.01*
FRONTAL SINUS WIDTH (mm)	11.15±3.77	12.55±3.15	14.35±3.42	0.02*	CLASS I vs CLASS III 0.01*
FRONTAL SINUS AREA (mm^2)	223.45±10.27	276.75±12.35	281.87±10.84	0.0001*	CLASS I vs CLASS III 0.0001*
FRONTAL SINUS INDEX	0.42±0.28	0.41±0.10	0.59±0.08	0.02*	CLASS I vs CLASS III 0.01*
FRONTAL SINUS PERIMETER (mm)	71.44±15.64	76.29±17.22	77.84±14.63	0.06	-

Table 4 – One-Way ANOVA followed by Bonferroni post-hoc test to compare maxillary dimensions in different skeletal malocclusions.

MAXILLARY SINUS DIMESIONS	CLASS I	CLASS II	CLASS III	P VALUE	BON-FERRONI POSTHOC TEST
MAXILLARY SINUS HEIGHT (mm)	36.25±4.76	36.27±3.79	36.08±5.05	0.29	-
MAXILLARY SINUS WIDTH (mm)	37.70±3.35	38.64±3.82	36.41±3.71	0.57	-
MAXILLARY SINUS AREA (mm^2)	997.85±189.17	1066.35±193.81	980.69±209.85	0.62	-
MAXILLARY SINUS INDEX	1.05±0.15	2.27±0.93	1.009±0.11	0.88	-
MAXILLARY SINUS PERIMETER (mm)	132.24±12.26	132.05±12.28	125.49±11.80	0.24	-

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Table 5- Mean values and Independent T-test of frontal sinus dimensions between males and females in different skeletal malocclusion.

FRONTAL SINUS DIMENSIONS	SKELETAL MALOCCLUSION	MALE (mm)	FEMALE (mm)	T VALUE	P VALUE
FRONTAL SINUS HEIGHT (mm)	CLASS I	29.33±5.82	27.72±5.91	1.50	0.13
	CLASS II	29.63±7.01	30.96±6.91	1.04	0.29
	CLASS III	31.95±6.02	27.05±5.23	4.75	0.0001*
FRONTAL SINUS WIDTH (mm)	CLASS I	12.44±3.85	9.87±3.29	3.93	0.0001*
	CLASS II	13.85±2.79	11.24±2.93	4.99	0.0001*
	CLASS III	14.58±2.45	10.43±3.19	7.99	0.0001*
FRONTAL SINUS AREA (mm^2)	CLASS I	260.85±10.05	186.06±8.72	43.53	0.0001*
	CLASS II	304.53±13.48	248.99±12.4	23.48	0.0001*
	CLASS III	325.33±12.65	176.65±10.56	69.88	0.0001*
FRONTAL SINUS INDEX	CLASS I	0.42±0.09	0.43±0.39	0.19	0.84
	CLASS II	0.48±0.09	0.36±0.06	8.59	0.0001*
	CLASS III	0.63±0.25	0.35±0.09	8.16	0.0001*
FRONTAL SINUS PERIMETER (mm)	CLASS I	74.82±16.04	68.07±14.74	2.40	0.01*
	CLASS II	75.83±15.97	72.47±18.64	1.06	0.29
	CLASS III	79.88±10.65	66.67±10.47	6.85	0.0001*

Table 6 - Mean values and Independent T- test of maxillary sinus dimensions in males and females in different skeletal malocclusion.

MAXILLARY SINUS DIMENSIONS	SKELETAL MALOCCLUSION	MALE (mm)	FEMALE (mm)	T VALUE	P VALUE
MAXILLARY SINUS HEIGHT (mm)	CLASS I	39.93±3.27	32.56±2.71	13.44	0.0001*
	CLASS II	37.17±3.61	33.62±4.52	4.75	0.0001*
	CLASS III	36.06±3.18	33.62±4.53	3.41	0.0009*
MAXILLARY SINUS WIDTH (mm)	CLASS I	37.41±3.69	38.01±3.01	0.97	0.33
	CLASS II	39.24±3.72	35.27±3.71	5.85	0.0001*
	CLASS III	36.12±3.18	35.28±3.71	1.33	0.18
	CLASS I	1090.52±191.21	905.19±135.94	6.11	0.0001*
	CLASS II	1110.73±191.91	850.23±148.49	8.31	0.0001*

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MAXILLARY SINUS AREA (mm^2)	**CLASS III**	**978.24±157.75**	**850.23±148.48**	**4.43**	**0.0001***
MAXILLARY SINUS INDEX	**CLASS I**	**0.94±0.10**	**1.17±0.10**	**0.59**	**0.0001***
	CLASS II	**3.47±0.23**	**1.05±0.11**	**1.41**	**0.15**
	CLASS III	**0.92±0.43**	**1.05±0.11**	**0.88**	**0.0001***
MAXILLARY SINUS PERIMETER (mm)	**CLASS I**	**138.73±9.45**	**125.76±11.39**	**6.78**	**0.0001***
	CLASS II	**135.83±12.41**	**119.99±11.72**	**7.18**	**0.0001***
	CLASS III	**126.49±9.26**	**119.99±11.71**	**0.41**	**0.001***

Discussion

The paranasal sinus are air-filled bony cavities that surround and open into nasal cavity. [1]. Among these paranasal sinuses, frontal sinus and maxillary sinus occupy significant amount of space within craniofacial bones. The growth of paranasal sinus very closely follows a growth trend similar to other craniofacial bones and may get affected and have variations in size and shape in different skeletal malocclusion. [4,5]

It was observed by **Rossouw et al**[7] that individual with prognathic mandible exhibited enlarged frontal sinus. Studies conducted by **Prashar et al**[22], **Yassaei et al**[14], **Sabharwal et al**[3], **and Gupta et al**[1] who observed increased frontal sinus dimension in skeletal Class III as compared to skeletal Class I and Class II malocclusion.

The maxillary sinus is a part of nasomaxillary complex, largest of paranasal sinuses and is the first paranasal sinus to develop. [9] It is pyramidal in shape and plays an important role in facial contour formation. The floor of the maxillary sinus is formed by the alveolar process of the maxilla and has a close anatomical and functional relationship with the posterior maxillary teeth. [11] It is also observed by **Alberti et al** [23] that in individuals with small and narrow maxillary sinus with concave anterior wall have a dish face appearance and individuals with large maxillary sinus and a convex anterior wall have a rounded face. Thus, variation in maxillary sinus may affect adjacent structures thereby causing various skeletal malocclusion. However, studies conducted by **Oktay et al** [4], **Endo et al**[10], **and Qadir et al**[8] who observed no significant difference of maxillary sinus dimension in different skeletal malocclusion. Therefore, the purpose of the study is to evaluate the reliability of frontal sinus with that of maxillary sinus in assessing different types of skeletal malocclusion.

Frontal sinus height (FSH) to be smallest frontal sinus height in skeletal Class I followed by skeletal Class II and skeletal Class III malocclusion. One-way ANOVA shows statistically significant difference between them ($p = 0.03$). Bonferroni post-hoc test was carried out to rule out the false positive and it verifies statistically significant difference between skeletal Class I and Class III malocclusion ($p = 0.01$).

Frontal sinus width (FSW) shows smallest frontal sinus width in skeletal Class I followed by skeletal Class II and skeletal Class III malocclusion. One-way ANOVA shows statistically significant difference between them ($p = 0.02$). Bonferroni post-hoc test was carried out to rule out the false positive and it verifies statistically significant difference between skeletal Class I and Class III malocclusion ($p = 0.01$).

Frontal sinus area (FSA) shows smallest frontal sinus area in skeletal Class I followed by skeletal Class II and skeletal Class III malocclusion. One-way ANOVA shows statistically highly significant difference between them ($p = 0.0001$). Bonferroni post-hoc test was carried out to rule out the false positive and it verifies statistically highly significant difference between skeletal Class I and Class III malocclusion ($p = 0.0001$).

Frontal sinus index (FSI) shows smallest frontal sinus index in skeletal Class II followed by skeletal Class I and

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skeletal Class III malocclusion. One-way ANOVA shows statistically significant difference between them (p = 0.02). Bonferroni post-hoc test was carried out to rule out the false positive and it verifies statistically significant difference between skeletal Class I and Class III malocclusion (p = 0.01).

Frontal sinus perimeter (FSP) shows smallest frontal sinus perimeter in skeletal Class I followed by skeletal Class II and skeletal Class III malocclusion. One-way ANOVA shows no statistically significant difference between them (p = 0.06). (Table 3)

One-Way ANOVA was conducted to analyse the difference of maxillary sinus dimension in different skeletal malocclusion. The test shows **maxillary sinus height (MSH), maxillary sinus width (MSW), maxillary sinus area (MSA), maxillary sinus index, and maxillary sinus perimeter (MSP)** shows no statistically significant difference in different skeletal malocclusion (Table 4). Maxillary sinus dimensions exhibit variation among individuals due to factors like age, sex, and genetics.

Emirzeoglu et al[2] observed age was the most important factor and maxillary sinus size tends to decrease after the age of 20 years. The anatomical variability of maxillary sinus makes it unreliable to establish a standard for comparison in different skeletal malocclusion. Skeletal Class II malocclusion can be due to mandibular deficiency rather than maxillary excess, so similar dimension of maxillary size can be observed between skeletal Class I and Class II malocclusion. Similarly skeletal Class III malocclusion can be due to mandibular excess rather than maxillary deficiency and similar maxillary sinus dimension can be observed between Class I and Class III malocclusion.

Having observed frontal sinus dimension, variation between skeletal Class I, Class II, and Class III malocclusion, this was tested for gender variation (Table 5). The mean value of **frontal sinus height (FSH)** of ***males*** in Class I, Class II, and Class III were 29.33±5.82 mm, 29.63±7.01 mm, and 31.95±6.02 mm, respectively. The mean value of frontal sinus height of ***females*** in Class I, Class II, and Class III were 27.72±5.91 mm, 30.96±6.91 mm, and 27.05±5.23 mm, respectively. The frontal sinus height was greater in males as compared to females both in skeletal Class I and Class III malocclusion, while it was greater in females as compared to males in skeletal Class II, however, the difference between them was statistically not significant (p = 0.13, p = 0.29, respectively). There was highly significant difference between frontal sinus height in males and females in skeletal Class III malocclusion (p = 0.0001). Studies conducted by **Yassaei et al**[14] observed no statistically difference of frontal sinus height between males and females. However, study conducted by **Gupta et al**[1] who observed statistically significant difference of frontal sinus height between males and females (p = 0.022).

The mean value of **frontal sinus width (FSW)** of ***males*** in Class I, Class II, and Class III were 12.44±3.85 mm, 13.85±2.79 mm, and 14.58±2.45 mm, respectively. The mean value of frontal sinus width of ***females*** in Class I, Class II, and Class III were 9.87±3.29 mm, 11.24±2.93 mm, and 10.43±3.19 mm, respectively. The frontal sinus width was greater in males as compared to females in all skeletal malocclusion. There was highly significant difference between males and females in skeletal Class I (p = 0.0001), Class II (p = 0.0001) and Class III (p = 0.0001) malocclusion. Study conducted by **Gupta et al**[1] **and Hassan et al**[15] who observed statistically significant difference of frontal sinus width between males and females (p<0.001, p<0.001, respectively). However, study conducted by **Yassaei et al**[14] who observed no statistically significant difference of frontal sinus width between males and females.

The mean value of **frontal sinus area (FSA)** of ***males*** in Class I, Class II, and Class III were 260.85±10.05 mm^2, 304.53±13.48 mm^2, and 325.33±12.65 mm^2, respectively. The mean value of frontal sinus area of ***females*** in Class I, Class II, and Class III were 186.06±8.72mm^2, 248.99±12.4 mm^2, and 176.65±10.56 mm^2, respectively. The mean frontal sinus area was greater in males as compared to females in all skeletal malocclusion. There was highly significant difference between males and females in skeletal Class I (p = 0.0001) and Class II (p = 0.0001), and Class III (p = 0.0001) malocclusion. This was in accordance with study conducted by **Yassaei et al**[14] and **Gupta et al**[1] who observed statistically significant difference between males and females (p=0.0001, p=0.030, respectively).

The mean value of **frontal sinus index (FSI)** of ***males*** in Class I, Class II, and Class III were 0.42±0.09, 0.48±0.09, and 0.63±0.25mm, respectively. The mean

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value of frontal sinus index of ***females*** in Class I, Class II, and Class III were 0.43±0.39, 0.36±0.06, and 0.35±0.09, respectively. The frontal sinus index was greater in males as compared to females in skeletal Class II and Class III malocclusion and the difference between them was highly significant statistically (p = 0.0001). Although the frontal sinus index was greater in males, no statistically significant difference was observed between males and females having skeletal Class I malocclusion (p = 0.84).

The mean value of **frontal sinus perimeter (FSP)** of ***males*** in Class I, Class II, and Class III were 74.82±16.04 mm, 75.83±15.97 mm, and 79.88±10.65 mm, respectively. The frontal sinus perimeter of ***females*** in Class I, Class II, and Class III were 68.07±14.74 mm, 72.47±18.64 mm, and 66.67±10.47 mm, respectively. The mean value of frontal sinus perimeter was greater in males as compared to females in all skeletal malocclusion except for Class II malocclusion. There was significant difference between males and females in skeletal Class I (p = 0.01) and highly significant difference between males and females in skeletal Class III (p = 0.0001) malocclusion. There was no statistically significant difference between males and females in skeletal Class II (p = 0.29) malocclusion.

Table 6 exhibits mean value of **maxillary sinus height (MSH)** of ***males*** in Class I, Class II, and Class III were 39.93±3.27 mm, 37.17±3.61 mm, and 36.06±3.18 mm, respectively. The mean value of maxillary sinus height of ***females*** in Class I, Class, and Class III were 32.56±2.71 mm, 33.62±4.52 mm, and 33.62±4.53 mm, respectively. The maxillary sinus height was greater in males as compared to females in all skeletal malocclusion. There was highly significant difference between males and females in skeletal Class I (p = 0.0001), Class II (p = 0.0001) and, Class III (p = 0.0009) malocclusion. This was in accordance with study conducted by **Urabi et al**[16] who observed statistically significant difference between males and females in Class I, Class II, and Class III (p=0.012, p=0.005, p=0.022).

The mean value of **maxillary sinus width (MSW)** of ***males*** in Class I, Class II, and Class III were 37.41±3.69 mm, 39.24±3.72 mm, and 36.12±3.18 mm, respectively. The mean value of maxillary sinus width of ***females*** in Class I, Class II, and Class III are 38.01±3.01 mm, 35.27±3.71 mm, and 35.28±3.71 mm, respectively. The maxillary sinus width was greater in males as compared to females in skeletal Class II and Class III malocclusion, while it was greater in females as compared to males in skeletal Class I malocclusion. There was highly significant difference between males and females in skeletal Class II (p = 0.0001) malocclusion and no statistically significant difference between males and females in skeletal Class I (p = 0.33) and Class III (p = 0.18) malocclusion. Study conducted by **Urabi et al**[16] who observed statistically significant difference between males and females in Class I, Class II, and Class III (p=0.0006, p=0.044, p=0.04, respectively).

The mean value of **maxillary sinus area (MSA)** of ***males*** in Class I, Class II, and Class III were 1090.52±191.21 mm^2, 1110.73±191.91 mm^2, and 978.24±157.75 mm^2, respectively. The mean value of maxillary sinus area of ***females*** in Class I, Class II, and Class III were 905.19±135.94 mm^2, 850.23±148.49 mm^2, and 850.23±148.48 mm^2, respectively. The maxillary sinus area was greater in males as compared to females in all skeletal malocclusion. There was highly significant difference between males and females in skeletal Class I (p = 0.0001) and Class II (p = 0.0001), and Class III (p = 0.0001) malocclusion. This was in accordance with study conducted by **Urabi et al**[16] who observed statistically significant difference between males and females in Class I, Class II, and Class III (p=0.017, p=0.007, p=0.012, respectively). Study conducted by **Muslim et al**[17] who observed statistically significant difference between males and females in skeletal Class I and Class III malocclusion (p=0.000).

The mean value of **maxillary sinus index (MSI)** of ***males*** in Class I, Class II, and Class III were 0.94±0.10, 3.47±0.23, and 0.92±0.43, respectively. The mean value of maxillary sinus index of females in Class I, Class II, and Class III were1.17±0.10, 1.05±0.11, and 1.05±0.11, respectively. The maxillary sinus index was greater in ***females*** as compared to males in skeletal Class I and Class III malocclusion and there was highly significant difference between males and females in skeletal Class I (p = 0.0001) and skeletal Class III (p = 0.0001), while it was greater in males as compared to females in skeletal Class II malocclusion and no statistically significant difference between males and females in skeletal Class II (p = 0.15) malocclusion.

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The mean value of **maxillary sinus perimeter (MSP)** of ***males*** in Class I, Class, and Class III were138.73±9.45 mm, 135.83±12.41 mm, and 126.49±9.26 mm, respectively. The mean value of maxillary sinus perimeter of ***females*** in Class I, Class II, and Class III were 125.76±11.39 mm, 119.99±11.72 mm, and 119.99±11.71 mm, respectively. The maxillary sinus perimeter was greater in males as compared to females in all skeletal malocclusion. There was highly significant difference between males and females in skeletal Class I (p = 0.0001) and Class II (p = 0001), and Class III (p = 0.001) malocclusion.

The present study was conducted with an objective to evaluate the reliability of frontal sinus with that of maxillary sinus in assessing different types of skeletal malocclusion. It was observed that frontal sinus height, frontal sinus width, frontal sinus area and frontal sinus index shows statistically significant difference between different skeletal malocclusion. This suggests that frontal sinus dimensions and area were more predictable in assessing skeletal malocclusion.

The frontal sinus was observed to be greater in skeletal Class III malocclusion, and this may be attributed to the absence of anterior occlusion, which prevents the transmission of masticatory forces to the frontal sinus region. The development of paranasal sinuses is a result of the skull's biomechanical requirements. It is important to consider the amount and direction of the masticatory forces because they significantly contribute to mechanical stress and the amount of pneumatization of frontal sinus.[18]

It was observed that maxillary sinus height, maxillary sinus width, maxillary sinus area, and maxillary sinus index show no statistically significant difference in different skeletal malocclusions. This suggests that maxillary sinus dimensions and area were not predictable in assessing skeletal malocclusion. **Sassouni**[19] discovered that maxillary sinus does not have an impact on facial harmony or skeletal malocclusions. Skeletal Class II and Class III malocclusions are extreme variations of skeletal malocclusion, so it was rational to look for significant difference them. However, the results showed no significant difference between them. The possible explanation is that skeletal Class II malocclusion can be due to mandibular deficiency rather than maxillary excess, so similar maxillary sinus dimension can be observed between skeletal Class I and Class II malocclusions[20]. Similarly skeletal Class III malocclusion can be due to mandibular excess rather than maxillary deficiency, so similar maxillary sinus dimension can be observed between skeletal Class I and skeletal Class III malocclusions. Having compared frontal and maxillary sinus dimension between skeletal malocclusion, it was investigated for gender variation. It was observed that frontal sinus width and frontal sinus area showed statistically significant difference between males and females in different skeletal malocclusions suggesting that frontal sinus dimensions can be used for gender determination. **Brown et al**[21] observed larger frontal sinus in males as compared to females. This may be attributed to the morphological differences in the cranium between males and females and explains why frontal sinus was larger in males as compared to that in females.

It was observed that maxillary sinus height, and maxillary sinus area showed statistically significant difference between males and females in different skeletal malocclusions suggesting that it can be used for gender determination. Statistically significant difference was observed in all frontal sinus dimensions and maxillary sinus dimension, when males were compared to females. **Dibbets**[11] and **Hopkins et al**[12] also detected similar findings which can be attributed to larger cranial base. Hence, larger sinus was found in males as compared to females and can be used for gender dimorphism.

Conclusions

- The frontal sinus dimensions were reliable in assessing skeletal malocclusions.
- The maxillary sinus dimensions were not predictable in assessing skeletal malocclusions.
- Frontal sinus width and frontal sinus area exhibits gender dimorphism suggesting frontal sinus can be used to for gender determination.
- Maxillary sinus height and maxillary sinus area exhibits gender dimorphism suggesting maxillary sinus can be used for gender determination.

Limitation of the study

The limitations of the study was using two-dimensional lateral cephalogram to assess three-dimensional frontal sinus and maxillary sinus anatomy. The variation in

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JCHR (2024) 14(6), 2113-2128 | ISSN:2251-6727

frontal sinus and maxillary sinus may be attributed to racial difference and anatomic variation. A larger sample size with different growth pattern would be more conclusive.

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