Original Article

Reliability of Frontal Sinus with Different Variables in Predicting Different Skeletal Jaw Relations

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ABSTRACT

Aim and objective: The aim of study was to assess the reliability of frontal sinus with different variables in predicting different skeletal jaw relations.

Material and method: 120 orthodontic patients of age group 18 years to 30 years and above who came for orthodontic treatment were assessed by using pre-treatment records. After taking radiographs, frontal sinus, maxillary sinus and cephalometric landmarks were traced and further divided into three groups depending of ANB angles. Statistical analysis using ANOVA and independent sample t-test was used to analyze the results. Pearson's coefficient correlation was used to find reliability between frontal sinuses and various variables in different skeletal patterns.

Result: A statically significant correlation was found between frontal sinus with skeletal malocclusion $P < 0.05$) in all the groups. Class III malocclusion showed the largest frontal sinus area when compared to skeletal Class I and Class II malocclusion. There was significant clinical correlation in varitiaons of maxillary sinus obtained on comparison between males and females.

Conclusion: As frontal sinus area was larger in class III and significantly correlating with mandibular length, symphysial width, it is more reliable as compared to maxillary sinus in predicting skeletal relations.

Key words: Maxillary sinus, Frontal sinus, Malocclusion, Prediction, Cephalometrics

INTRODUCTION

Skeletal pattern prediction has been a controversial and progressing topic ever since it was advocated by Ricketts.[1] Prediction would involve forecasting a change in direction or different growth rates for two patients having the same age, sex, and race on the basis of some prior knowledge, such as a cephalometric measurement.[2] The understanding of skeletal morphology and its changes helps us to detect developing malocclusion in children. There were changes in skeletal morphology depending upon was genetics, environmental factors, and therapeutics. For determining the success or failure of orthodontic treatment these have been considered to be the determinant factors. There has been improvement in orthodontic diagnosis and treatment palnning by correlating the indicators of maxillary and mandibular growth.

Five measurements proposed by Ricketts (1982)[3] were helpful to find the presence of abnormal mandibular growth: Cranial Deflection, Porion Location, Ramus Position, Symphysis Width, Condylar Axis. Schulhof, Nakamura, Williamson (1977)[4] claimed 73% prediction accuracy with these four factor. The ANB Angle (Steiner 1953)[5] is still widely accepted as an indicator of maxillo-mandibular harmony.[6] Dibbets[7] and Hopkin[8] et al. reported that the patients with larger cranial bases tended to have larger maxillary sinuses. Many studies were found in which maxillary sinus was related with skeletal malocclusions.

Lateral cephalograms have become a vital tool in orthodontic assessment and treatment planning since the introduction of radiography by Broadbent in 1931.[9,10] Various anatomical points are used in assessment of different malocclusions,[11,12] one of these landmarks are the paranasal sinuses which can be easily assessed by radiographic methods. There are four anatomical sinus present in head and neck region which are maxillary sinus, ethmoidal sinus, frontal sinus, and sphenoidal sinus.

Joffe,[13] Rossouw, Lombard and Harris[14] found frontal sinus enlargement to be associated with prognathic subjects. However, there is lack of anteroposterior relation classification specificity in these studies, therefore, additional data was necessary. Research was performed using frontal sinus to assess vertical skeletal pattern while only few studies has been performed to determine sagittal pattern.The objective of the present study was to assess the reliability of frontal sinus with different variables in predicting different skeletal jaw relations.

MATERIAL AND METHOD

This prospective cephalometric study was performed on 120 patients who came for orthodontic treatment in the the Department of Orthodontics and Dentofacial Orthopedics in collaboration with the Department of Oral Medicine and Radiology, Surendera Dental College and Research Institute, Sri Ganganagar. The sample size was determined by power analysis based on:

$$\eta = \frac{\{Z_{1-\alpha/2}\sqrt{P(1-P_\alpha)} + Z_{1-\beta}\sqrt{P_0(1-P_\alpha)}\}^2}{(P_\alpha - P_0)^2}$$

P_0 = Population Proportion, P_α = Sample Proportion, α = Significance Level, $1 - \beta$ = Power

With a permissible significance level of 0.05, β was 0.2, a sample size of 120 was sufficient for the study to have 80% power and be clinically significant to find reliability of frontal sinus with various variables.

The patients fulfilled following inclusion and exclusion criteria to be included as study sample:

Inclusion Criteria

- Age 18 years to 30 years at the time of pre-treatment records.
- All permanent teeth should be present
- No history of orthodontic treatment
- No pathological changes in paranaal sinuses
- No visible facial asymmetry
- No congenital tooth anomalies
- Absence of growth and development related significant medical history.

Exclusion Criteria

- Pregnant patients
- Syndromic maxillo-facial area
- History of bony dysplasia
- Patients with any history of immune-compromised diseases
- Patients with malignancy
- Patients with or history of injury/trauma in maxillary anterior segment

One-hundred and twenty patients were categorized into three groups, depending on the different types of skeletal malocclusion based on the ANB angle[15] as follows:

Group 1: n = 47, ANB angle between 2° and 4° (skeletal Class I)
Group 2: n = 42, ANB >4° (skeletal Class II)
Group 3: n = 31, ANB <2° (skeletal Class III)

An informed consent was taken from the patient and parents prior to treatment followed by lateral cephalometric radiographs of adequate diagnostic quality.

In a standard cephalostat, the exposure was maintained at 72 kvp and current 10 mA with filtration of 2.5 mm of Al eq. All the exposed films were developed and fixed under standardized conditions to achieve uniformity. The radiographs were taken on KODAK 8000 c panoramic/cephalogram combination unit X-ray machine and 8/10 inches films were used. The radiographs were taken with patient positioned in normal head position.

Tracings of frontal sinus, maxillary sinus and cephalometric landmarks were done with the help of 0.5 mm lead pencil.

The following reference points and cephalometric variables were examined in the study:

Reference Points and Cephalometric Planes (Figure 1)

ANS: Anterior nasal spine, most anterior point on the tip of the anterior nasal spine in midsagittal plane.

PNS: Posterior nasal spine, constructed radiographic point, posterior limit of bony palate or maxilla.

Ar: Articulare, point of intersection of posterior margin of the ramus and the outer margin of cranial base.

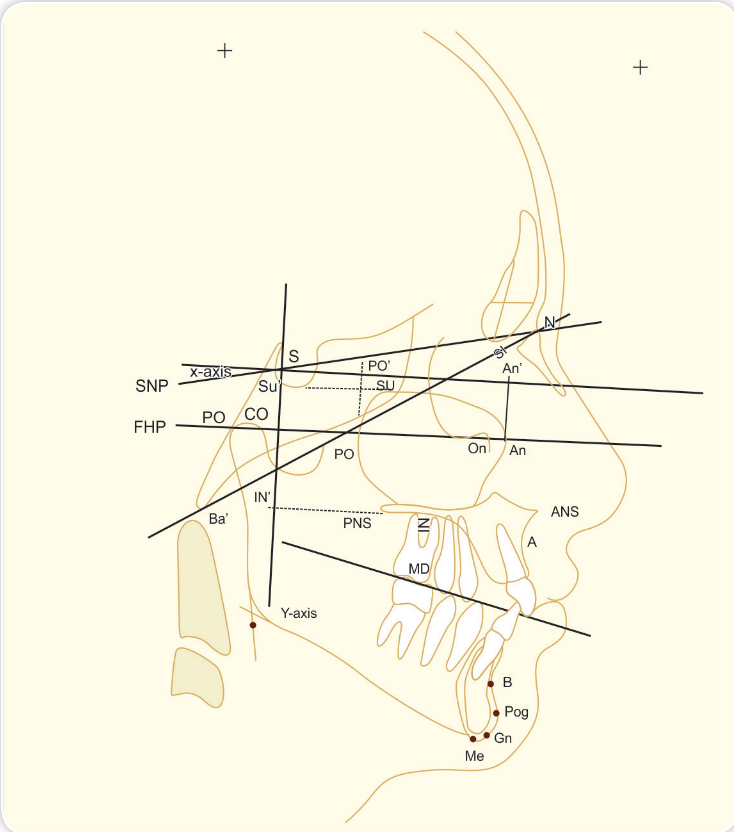

Figure 1 Reference points and cephalometric planes

Ba: Basion, the lowest point on the anterior margin of the foramen magnum in median plane.

N: Nasion, most anterior point on frontonasal suture in midsagittal plane.

S: Sella turcica, midpoint of sella turcica in median plane.

A: Point A, deepest midline point on maxillary alveolar process between ANS and prosthion.

B: Point B, most posterior point in concavity between infradentale and pogonion.

Or: Orbitale, lower most part on the bony orbit.

Me:.Menton, most inferior point on the bony chin in the midsagittal plane.

Po: Porion, midpoint on upper edge of porus acusticus externus.

Go: Gonion, constructed point at the junction of ramal plane and mandibular plane.

Sh: Point Sh, most highest point on the peripheral borders of the frontal sinus.

Sl: Point Sl, most lowest point on the peripheral borders of the frontal sinus.

An: Point An, most anterior point of maxillary sinus.

An′: Point An′, point projected vertically from An to the x-axis.

Po: Point Po, most posterior point of maxillary sinus.

Po′: Point Po′, point projected vertically from Po to the x-axis.

Su: Point Su, most superior point of maxillary sinus.

Su′: Point Su′, point projected vertically from Su to the y-axis.

In: Point In, most inferior point of maxillary sinus.

In′: Point In′, point projected vertically from into the y-axis.

FHP: Frankfort horizontal plane-extends from porion to orbitale.

SN plane: Sella nasion plane—it is cranial line between center of sella tursica (sella) and anterior point of frantonasal suture (nasion).

Ba-N:

- Basion-nasion plane—extends from basion to nasion
- Occlusal plane—plane passing posteriorly through mesiobuccal cusp of first permanent molar and anteriorly bisecting the overbite.

METHOD OF MEASUREMENTS

Angular Measurements (Figure 2A)

ANB angle: Angle formed between point N to point A and point N to point B.

Saddle angle: This angle is formed by joining sella nasion and articulare (S-N-Ar).

Gonial angle: This angle is formed by joining Articulare- Gonion and Menton (Ar-Go-Me).

Cranial deflection: Angle formed by FHP and Ba-N plane.

Linear Measurements (Figure 2B)

Maxillary Sinus

Maxillary sinus length: The line extends from An to Po.
Maxillary sinus height: The line extends from Su to In
Upper maxillary sinus area (UMSA): The area above maxillary plane
Lower maxillary sinus area (LMSA): the lower area of maxillary sinus from the palatal plane
Total maxillary sinus area (MSA): The sum total of UMSA and LMSA.

Frontal Sinus

Upon tracing the areas of high radiopacity on periphery, the highest (Sh) and lowest (Sl) points of its extensions were marked. A perpendicular to the interconnecting line Sh-Sl was drawn to determine the maximal width of the frontal sinus. Frontal sinus area (FSA) was then calculated by multiplying height with width.

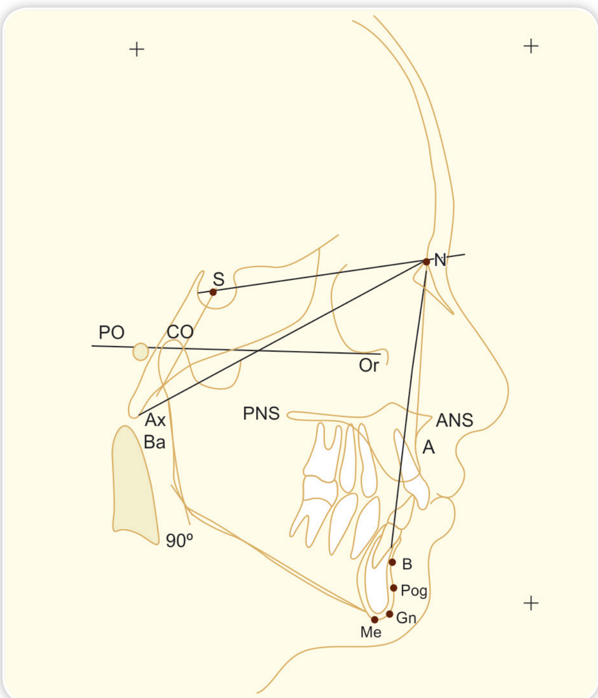

Figure 2A Angular measurements used in the study

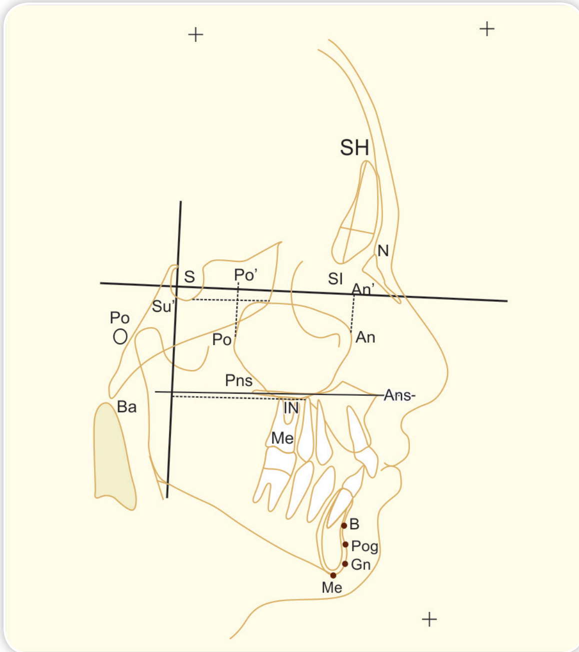

Figure 2B Linear measurements used in the study

Symphysis Width

Distance from anterior to posterior limit of the grid.

Mandibular Body Length (MBL)

Distance from menton to gonion (Me-Go)
Tracings were done to check the reliability of frontal sinus with maxillary sinus in different type of skeletal malocclusions.

Error of Method

To determine the error associated with measurement, 10 radiographs were selected at random. Their measurements were repeated 4 weeks after the first measurement and the random method was assessed as described by Dahlberg. The mean difference between the first and second measurement, the standard error of a single measurement, and the percentage of total variance attributable to measurement error were calculated for each measurement. The casual error according to Houston's formula ($ME = \sqrt{\Sigma d^2/2n}$) and the systemic error with dependent t test at $p < 0.05$ were calculated. The reliability was found to be 92%.

Statistical Analysis

Statistical analysis were applied. The collected data as a whole was statistically analyzed by descriptive analysis for mean, range and standard deviation using SPSS software (SPSS version 23 for window, release 7.5.1, Chicago, USA). The difference between males and females were tested using parametric student's *t*-test. The significant changes within the group were determined by non-parametric paired't' test and the mean difference among the groups was compared by student 't' test. ANOVA test was used to find the clinical significance between size of frontal sinus and maxillary sinus in males and females. Pearson's correlation coefficient was used to find reliability between frontal sinus, maxillary sinus and variables in different skeletal patterns.

RESULTS AND DISCUSSION

Demographic data for male and females in different classes were given in **Table 1**. The descriptive statistics of frontal sinus area and maxillary sinus area in different skeletal malocclusions was given in **Table 2**. Mean and standard deviation of frontal sinus area in skeletal class III for male and female were found to be largest followed by class II and class I, whereas for maxillary sinus area mean and standard deviation of both gender was highest in class II followed by class III and class I as shown in **Table 2**. ANOVA test showed that there were statistically significant gender differences in frontal and maxillary sinus area ($p<0.05$).

Correlation of frontal sinus area and maxillary sinus area with other variables in skeletal classes between both genders was assessed by Pearson's correlation coefficient **(Tables 3 and Table 4)**. Frontal sinus area and maxillary sinus area showed significant correlation in skeletal classes with other variables.

Mandibular Body Length (MBL) showed significant positive correlation with frontal sinus in skeletal class III in males and skeletal class I and III in females. Whereas maxillary sinus area did not show any significant value for any variable except symphysial width in class III. Symphysis width had clinically significant positive correlation with maxillary sinus and frontal sinus in class III males and positive correlation with frontal sinus in class III females ($p<0.05$).

Discussion

Orthodontic treatment corrects the dental malocclusions and facial disproportions to provide esthetic, psychosocial and functional improvements. Numerous radiographs, individual findings and analysis, which allow a broad-based decision to be made for the particular patient, are a prerequisite for correct diagnosis in orthodontics.

Table 1

Mean and standard deviation of male and female in different classes

Relation	*Male*		*Female*	
	N	*%*	*N*	*%*
Class I	26	44.83	21	33.87
Class II	13	22.41	29	46.77
Class III	19	32.76	12	19.36
Frontal sinus (Mean ± SD)	267.51 ± 104.83 (mm^2)		154.98 ± 57.98 (mm^2)	
Maxillary sinus (Mean ± SD)	1249.5 ± 355.66 (mm^2)		934.38 ± 172.86 (mm^2)	

Table 2

Mean and standard deviation of frontal sinus and maxillary sinus area in different classes

Relation	*Frontal sinus: Mean ± SD*			*Maxillary sinus: Mean ± SD*		
	Male (mm^2)	*Female (mm^2)*	*p value*	*Male (mm^2)*	*Female (mm^2)*	*p value*
Class I	217.38 ± 53.96	142.55 ± 56.01	<0.01*	1137.35 ± 236.21	840 ± 102.11	<0.01*
Class II	253.79 ± 87.45	146 ± 47.8	<0.01*	1389.32 ± 490.58	1003.2 ± 180.03	<0.01*
Class III	331.36 ± 127.31	178.4 ± 61.68	<0.01*	1269.46 ± 254.89	925.97 ± 175.11	<0.01*
Anova test	13.73	7.88		7.64	16.86	
Statically significant * (p<0.05)						

Table 3

Pearson's correlation coefficient test of different variables of males in skeletal classes I, II, and III

Variables	*Skeletal classes*	*Male*			
		Frontal sinus		*Maxillary sinus*	
		r value	*p value*	*r value*	*p value*
Saddle Angle	Class I	-0.07	0.69	0.28	0.13
	Class II	-0.51	0.13	-0.25	0.49
	Class III	-0.03	0.93	-0.19	0.59
MBL	Class I	-0.15	0.39	-0.06	0.74
	Class II	0.17	0.64	0.08	0.82
	Class III	0.46	0.03*	-0.4	0.25
ANB	Class I	0.06	0.73	-0.01	0.96
	Class II	-0.33	0.35	-0.41	0.24
	Class III	0.03	0.93	-0.1	0.78
Gonial Angle	Class I	0.21	0.23	0.05	0.78
	Class II	-0.31	0.38	-0.35	0.32
	Class III	0.43	0.21	0.43	0.21
Cranial deflection	Class I	0.09	0.61	0.011	0.95
	Class II	0.15	0.72	-0.52	0.12
	Class III	0.35	0.09	0.19	0.59
Symphysis width	Class I	0.06	0.73	-0.19	0.28
	Class II	0.38	0.28	-0.12	0.74
	Class III	0.39	0.04*	0.38	0.041*

Statically significant * (p<0.05)

Table 4

Pearson's correlation coefficient test of different variables of females in skeletal classes I, II, and III

Variables	*Skeletal classes*	*Female*			
		Frontal sinus		*Maxillary sinus*	
		r value	*p value*	*r value*	*p value*
Saddle Angle	Class I	0.14	0.5	-0.14	0.5
	Class II	0.09	0.8	-0.27	0.45
	Class III	-0.37	0.29	-0.08	0.76
MBL	Class I	0.57	0.0002*	0.16	0.44
	Class II	0.35	0.32	0.14	0.48
	Class III	0.41	0.02*	-0.43	0.09
ANB	Class I	0.28	0.17	0.18	0.39
	Class II	-0.04	0.91	-0.18	0.62
	Class III	0.12	0.73	-0.45	0.08
Gonial Angle	Class I	0.24	0.25	-0.08	0.7
	Class II	0.4	0.25	-0.002	0.99
	Class III	-0.37	0.29	-0.06	0.83
Cranial deflection	Class I	-0.18	0.39	0.25	0.23
	Class II	0.35	0.32	0.06	0.98
	Class III	0.31	0.11	0.32	0.22
Symphysis width	Class I	-0.06	0.78	-0.35	0.09
	Class II	0.06	0.92	0.31	0.38
	Class III	0.37	0.042*	-0.002	0.99

Statically significant * (p<0.05)

Ages ago study models, photographs, radiographic imaging and cephalometric tracing were used to determine the inter-relationships of the dentition, maxillofacial skeleton and soft tissues in all phases of treatment from diagnosis to, treatment planning and further assessing treatment progress, outcomes and retention.

Pranasal sinuses like maxillary sinus, ethmoidal sinus, frontal sinus and sphenoidal sinus are the bony chambers embedded into the bone around the nasal cavity.[17]

Among all maxillary sinuses is the largest of paranasal sinuses. It is pyramidal in shape with base directed medially towards the lateral aspect of nose and apex directed laterally in the zygomatic process of maxilla .the floor is formed by the alveolar process of the maxilla[18, 19]. Average size being 3.5 cm in height, 2.5 cm in width, 3.2 cm anteroposteriorly. Its growth ceases by 15th year of age. Its average volume is approximately 15 ml which continues to enlarge throughout life.

The frontal sinus originates from the anterior ethmoidal cells that migrate into the frontal bone at the end of the first year of life.[20] Development of frontal sinuses begins from 5thto 6thyear of age. Brown, Molleson and Chinn[20] found that during a study using lateral cephalograms the enlargement of the frontal sinuses ceased at 15½ years in boys and 13¾ years in girls. In adults, the frontal sinuses are usually seen as two asymmetric cavities located above the level of the supraorbital ridges and the nasion.

Various techniques for determination of growth pattern were given in the literature. Study done by Sabina Ruf[21] suggested that frontal sinus is an indicator for assessing the somatic maturity stage. AI-Bustani AI (2004)[22] showed a significant correlation between the frontal sinus width and maxillary base length in class II subjects and highly significant correlation class III subjects. These studies showed that frontal sinus can be used as a predictor to assess different skeletal discrepancies in growing patients. Anil prashar (2012)[23] also found frontal sinus area to be larger in skeletal class III malocclusion.

Despite of research on the development of the frontal sinus, few studies have evaluated the relationship of frontal sinus with other skeletal parameters using lateral cephalogram.

Joffe[13] found frontal sinus enlargement to be associated with prognathic subjects. In a similar study reported by Rossouw et al. (1991)[14] who compared area of the frontal sinus between adult skeletal Class III and Class I growth pattern cases excluding Class II growth pattern. No study had been peformed to evaluate the reliability of paranasal sinuses for depicting the skeletal pattern taking that into note the present study was done to evaluate the reliability of frontal sinus in assessment of different types of skeletal malocclusions and other skeletal features such as maxillary sinus area saddle angle, Gonial angle, and MBL.

In the present study, Class III malocclusion showed largest FSA. Class III and Class II malocclusion showed the excessive and deficient mandibular growth pattern respectively. The FSA was found to be increased with mandibular prognathism in skeletal Class III. Skeletal Class I malocclusion showed decreased FSA when compared to class II malocllusion. The findings of the present study were in agreement with those of Rossouw et al. (1991).[14]

Assessment of correlation of frontal sinus area with various variables in different skeletal malocclusions.

Correlation with saddle angle: The negative correlation suggested that large frontal sinus and maxillary sinus is not related with large cranial base, and was not clinically significant. Scott[24] and Brenda M Wilhelm[25] also stated that cranial base growth patterns are similar for different malocclusions and a more obtuse “saddle angle” or cranial base angle in Class II skeletal patterns was not depicted.

Correlation with MBL: Males and females both showed significant correlative result with MBL in skeletal Class III for frontal sinus, where as maxillary sinus showed negative correlation with MBL in skeletal class III cases. This was evidenced by the study of Guyer, Ellis, McNamara (1986)[26] who reported larger mandibular length in skeletal class III sample as compared to skeletal class I sample. MBL showed negative correlation with both frontal sinus and maxillary sinus in skeletal class I cases, and positive in cases of females. In cases of skeletal class II malocclusion both showed positive correlation in males as well as in females, but it was not clinically significant.

Correlation with ANB: The positive correlation was found between frontal sinus area and ANB in males and female skeletal class I and class III, whereas maxillary sinus had negative correlation with ANB in males, but in females ANB had positive correlation with maxillary sinus only in class I. But none of these had any clinical significance. The increase in the thickness of the Nasion accounted for the enlargement of the frontal sinus. Baer and Harris[27] interpreted the structural adaptation of frontal sinus with the forward and downward growth of the midface keeping external lamina of frontal bone in contact with nasal bone and the maxilla.

Correlation with gonial angle: The positive correlation was found between frontal sinus area and maxillary sinus area with gonial angle in male skeletal class I and class III, whereas in female only frontal sinus area showed positive correlation with skeletal class I and class II. In our study, the frontal sinus area showed no significant correlation with gonial angle in any skeletal class in both males and females. This is supported by Prashar et al[21] who found poor correlation of frontal sinus with gonial angle thereby concluding that large frontal sinus may be present with large mandible irrespective of its growth direction form of the mandible with reference to its relation with body and ramus.

Correlation with cranial deflection: The present study concluded a positive correlation in Class III malocclusion between cranial deflection and frontal sinus area and the value was weakly statistically significant in cases of males. The results showed that a large frontal sinus area was associated with a large cranial deflection in skeletal Class III malocclusion. Schulhof, Nakamura and Williamson (1977)[4] in their study on Class III malocclusion have reported that large cranial deflection is associated with prognathic mandibles. This is mainly due to descend of the posterior cranial base resulting in the anterior positioning of the mandible.

Correlation with symphysis width: Our study concluded a significant positive correlation between Symphysis width and fontal sinus area in skeletal Class III malocclusion in both genders and with maxillary sinus in class III females. In case of skeletal Class II malocclusion positive correlation was found between symphysial width and frontal sinus area. The values being statically insignificant but clinically important. These findings suggested that large frontal sinus area was associated with large mandible with large symphysis width. Ricketts (1982)[1] reported that large symphysis width was associated with large mandibles. Todd, Aki and Nanda (1994)[28] assessed the symphyseal dimensions to determine the direction of mandibular growth.

The lateral cephalogam is part and parcel of everyday orthodontic analyses, and this study indicates that a large frontal sinus as seen on the lateral cephalograms may give an indication to excessive mandibular growth. Although this method seems to be reliable, there are some inherent limitations in its present study. The use of two-dimensional radiographic modality along with smaller sample size is the limiting factor, which is statistically demonstrated in our study between maxillary sinus and frontal sinus. Frontal sinus is a valuable indicator for assessment of skeletal malocclusion. Further research would be required to minimize the limiting factor for a better diagnosis and treatment planning.

Clinical implication: The frontal sinus can serve as an additional diagnostic aid, enabling the orthodontist to make more accurate prediction and diagnosis for the skeletal jaw malocclusion in growing individuals. Subjects with skeletal malocclusions who can be properly treated by orthodontic tooth movement alone must be distinguished from subjects with skeletal malocclusion that requires functional modification.

CONCLUSION

MSA was more in skeletal Class II malocclusion as compared to skeletal Class I and Class III malocclusion in both genders, whereas FSA was found to be larger in skeletal Class III malocclusion. Skeletal Class III and Class II malocclusion are the extreme variations of the facial developmental process.

From the observations, the following conclusions were drawn:

1. Frontal sinus is more reliable as compared to maxillary sinus for the prediction of skeletal malocclusion and can be used as an indicator of skeletal malocclusion in growing individual.
2. Frontal sinus area, as seen on a lateral cephalogram, tends to be larger in individuals having skeletal Class III malocclusion as compared to skeletal Class I and Class II malocclusions.

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