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Frontal Sinus –The Future of Growth Prediction: A Review Article

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KEYWORDS

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ABSTRACT:

Every orthodontic treatment planning is dependent on the age of the patient. Skeletal maturity indicators play an important role in assessing the skeletal age. They help in evaluation of stage of maturity in a patient objectively. Thus, they can help in early diagnosis and delivering prompt treatment to the patient so that complex surgical procedures can be avoided in the future which will be less traumatizing to the patient as well. Many methods like radiographs of hand, CVMI asessment on lateral radiographs are used for growth prediction. Frontal sinus is an important parameter which can be studied to evaluate the growth status of an individual. So, the present review aims at exploring the role of Frontal sinus as a growth predictor, its corelation with types of malocclusion, its variability in mouth breathers and cleft patients.

1. Introduction

In orthodontics, treatment of the patient depends on patient's age and growth status. Growth refers to increase in magnitude and development refers to progression in the direction of full growth. The terms growth and age are correlated to each other. Growth spurt is the term given for instantaneous enlargement of general body. Growth increments at the age of puberty provide us with the best opportunity to go for orthodontic and orthopedic treatment which also influences the treatment planning.

Orthodontic treatment does not necessarily focus on dental displacement alone, rather if done during growing years it can be a proven asset for dentofacial orthopedics. Treatment planning during growth period of a patient reduces the duration of treatment and simplifies the procedure. In growing stages, bone remodeling can be done using various myofunctional and orthopedic appliances.

The information whether the patient is in the right growing phase for undergoing these treatments is provided by Skeletal maturity indicators [1]. Methods for assessing skeletal maturity can be grouped as Radiographic and Non-radiographic methods. Hand wrist radiograph is categorized under radiographic method. There are 11 Fishman's maturity indicators located on 6 anatomic sites, i.e., thumb (1), third finger (7), fifth finger (2) and radius (1). Fishman has demarcated 4 stages of bone maturation, i.e., epiphysis as wide as diaphysis, ossification, capping of epiphysis and lastly fusion of epiphysis and diaphysis. Cervical vertebrae maturation is classified as non-radiographic method which has 6 stages that tell about growth status. Frontal sinus is also used as a skeletal maturity indicator. It is formed by the pneumatization of frontal bone. There are four pairs of paranasal sinuses and Frontal sinus is one of them . It is the located behind brow ridges. Radiographically , it is visible only at the age of 5 years till it projects above orbital rims [2]. Frontal sinuses grows in height and width upto 20 years of age. At 2 years of age , the sinus starts growing vertically and at 8 years it can be seen on the cephalograms. . 1 year after the peak of the growth of body , the peak of growth of frontal sinus takes place [3]. For boys , the frontal sinus growth completes at 15.5 years and in girls it complete at 13 years [4]. Thus, the present review aims at exploring the role of Frontal sinus as a growth pattern predictor, types of malocclusions, its variability in mouth breathers and cleft patients.

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2. Frontal Sinus and Growth Patterns

It is important to study the maxillary and mandibular growth patterns to diagnose and treat malocclusion. Study done by Rossouw PE et al studied lateral cephalometric and showed that there was correlation between frontal sinus with length of the maxilla , length of the mandible, width of the symphysis and length of the condyle[5]. All these parameters help in determining growth pattern of mandible. In other studies done , it was showed that the growth rhythm of frontal sinus was same as development of body height [6]. Thus frontal sinus can be used to detect growth pattern of mandible.

Nathani R et al evaluated the Frontal Sinus on lateral cephalograms in 30 children aged 8 - 11 years to assess growth pattern [7]. Frontal sinus correlation with growth patterns and age groups was done using Pearsons's correlation coefficient .It was concluded that the mean yearly increment of frontal sinus growth was maximum in vertical growers and minimum in average growers.

TABLE NO. 1- Results of Nathani R et al research [7]

AGE	FRONTAL SINUS AREA IN HORIZONTAL GROWERS	FRONTAL SINUS AREA IN AVERAGE GROWERS	FRONTAL SINUS AREA IN VERTICAL GROWERS
8 YEARS	Lowest	-	Highest
9 YEARS	Lowest	-	Highest
10 YEARS	Lowest	-	Highest
11 YEARS	-	Lowest	Highest

The study conducted by ***Ruf S et al*** evaluated frontal sinus reliability among paranasal sinuses as a skeletal growth indicator in Angle's class II division I malocclusion [8]. Frontal sinus development was assessed on lateral ceph and radiographs of hand wrist for assessment of skeletal maturity. The research was limited to boys to exclude gender differences. 85% certainty was found on using prediction interval of one year and about 75% using 2 year prediction interval to predict skeletal growth and maturity and it was concluded that frontal sinus gives substantial information during treatment procedure .

Bhangare J et al assessed the co-relation between frontal sinus dimension and craniofacial maturity using lateral cephalograms of 135 patients which were divided on the basis of different skeletal growth patterns [9]. The results showed that horizontal growers had largest frontal sinus size and least was found in average growers. Frontal sinus morphology was related to mandibular plane angle. It was found that growth pattern and frontal sinus dimensions are correlated but it is not necessary that a class III malocclusion patient will always have largest sinus dimension. Average and vertical growers can also have a large frontal sinus.

Valverde Y et al evaluated enlargement of frontal sinus carried out a pilot research on 20 females having Angle's Class III Malocclusion to evaluate the frontal Sinus enlargement as a growth maturity indicator [10]. They reported that after the age of 7 years frontal sinus was detectable on lateral cephalogram and a direct correlation of frontal sinus growth with the body height was observed. So, it was inferred that development of frontal sinus can be proven useful as a growth maturity indicator which can further be used as an asset for orthodontic treatment planning.

Gursoy GM et al in 2020 conducted a study to examine if frontal sinus can be utilized to predict vertical malocclusion [11]. This was a retrospective study that aimed to draw relation between 3-D morphology of frontal sinus and vertical growth patterns. They took CBCT scans (pre-treatment) of 87 patients and 3 groups were formed based on growth pattern. The study concluded that among the patients with vertical craniofacial growth patients the antero-posterior dimension of frontal sinus is decreased. Thus suggesting a significant relation can be drawn among them.

Salehi et al did a study on lateral cephalogram of pre-treatment 71 adult patients and found out that the mandibular final size may be related to surface area of frontal sinus [12]. Also, area of frontal sinus was found to be related to occlusion in anteriors [10].

Abate A et al carried out a study using CBCT to correlate the volumetric morphology of frontal sinus with facial growth patterns [13]. Four groups were made

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comprising 20 patients each g based on age /gender, reconstruction of frontal sinus was done by CBCT and its volume was calculated and correlated with the following cephalometric variables as shown in the table below.

Table No. 2: Shows correlation of different parameters with frontal sinus in study by Abate et al [13]

Parameters	Relation with frontal sinus volume, area and depth calculated by CBCT
Age	No significant correlation
Gender	Volume of frontal sinus was greater in men
ANB angle	Inverse relation with volume of frontal sinus
Length of skull base	Increased with increase in frontal sinus dimension
SNB angle	Direct relation with volume of frontal sinus
Anterior skeletal dimension values	Increased with increase in frontal sinus dimension

It was concluded that there is some significant correlation of volume of frontal sinus with the facial growth pattern despite the fact that there is variation in frontal sinus dimensions. Also, the young adults who have reached a stage of complete sinus growth, vertical growth will continue but in cases with individuals who have a greater volume of sinus will have potential for sinus growth even in future.

Mahmood HT et al conducted a study to determine growth spurt by correlating anatomy of frontal sinus and maturation of cervical vertebrae [14]. Lateral cephalograms were used to assess height width index of frontal sinus and CVMI stages .The results of each of them were tabulated separately for males and females in their pre-pubertal, pubertal, and post-pubertal growth periods. Frontal sinus width and height was found to be more in males whereas, frontal sinus index was greater in females. It is shown that there is relation between morphology of frontal sinus and cervical maturity stages. But these two cannot determine difference in male or females in their pre-pubertal, post-pubertal and growth spurt phase.

3. Frontal Sinus and Gender

Buyuk SK et al evaluated the correlation between morphology of frontal sinus and hand wrist maturation. [15]. Based on hand wrist radiographs, 220 patients were taken and 11 groups were formed. The result showed that in males greater area and width of both frontal sinus than females, highly suggestive in determining the growth and development from the frontal sinus morphology. When different maturation stages were studied, significant differences in al parameters of frontal sinus were found in males.. In females, area of left frontal sinus , height of frontal sinus on right side , width of frontal sinus of right side were correlated with different stages of maturation.

Tehranchi A et al carried out a retrospective study to find the correlation between the dimension of frontal sinus with anatomic variations [16]. The study was performed from 2003-12. PA cephalogram and lateral cephalogram were taken. Sinus area was calculated and the areas were grouped into four based on the upper edge of sinus. The results obtained showed that males have larger dimension of sinus when compared with females and anatomic variation of frontal sinus exists in both the genders.

Shireen A et al conducted a study that aimed to analyse the morphology of frontal sinus using PA skull radiograph in correlation to gender and age [17]. Further, its objective lies in the use of the above information to personal identification in forensic odontology. The methodology included 400 participants whose PA skull radiographs were taken and the left and right sinus height and width were recorded. Yoshino's frontal sinus pattern parameters were taken into account. Following patterns of frontal sinus were recorded in the 400 participants as shown in the Figure 1.

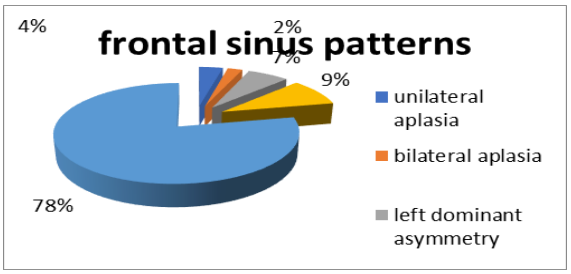

FIGURE 1: Frontal sinus patterns

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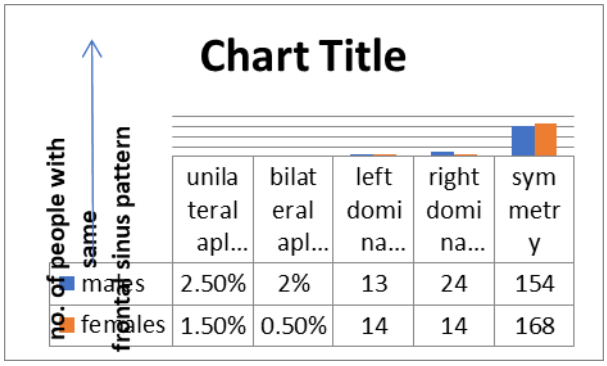

FIGURE 2: Results obtained in study of Shireen et al [17]

The use of frontal sinus patterns proved of a great help in personal identification in forensics. The outcomes reported by this study were that in males , the size of frontal sinus was greater than in females and left frontal sinus was greater in dimension than the right side. One side sinus maybe larger than the other or in some cases it can cross midline to overlap, i.e. Sinus asymmetry is common.

Benghiae AG et al in the year 2017 conducted research with an purpose to find the relation between frontal sinus morphology using CBCT scans with sex determination and assessing its reliability and accuracy level [18]. In this study total of 30 adult CBCT scans (age group 18-65 years) were assessed. The result pointed that an accurate prediction of gender can be done , in females 86.7% ratio and in males 67% on the basis of volume frontal sinus and based on the sagittal dimensions of anterior cortex of the frontal sinus, sex can be estimated with an accuracy of upto 73.3%. The major anatomical variations of frontal sinus which can be considered for sex determination are left unilateral hypopneumatism, right unilateral pluriseptate in males and left unilateral pluriseptate in females. Thus, the study concluded that the CBCT scan of frontal sinus can be used as a valuable resource for sex determination.

Tehranchi A et al based on the sample size of 144 patients in the age group between 13-31 years carried out a study to correlate the frontal sinus dimensions to the various cephalometric indices. [19]. Using Pearsons correlation coefficient, the authors have reported an established relationship between cephalometric indices and the dimension of frontal sinus.

PARAMETERS USED AND ITS CORRELATION WITH THE FRONTAL SINUS:

1. **Gender:**

GONIAL ANGLE: A direct interrelationship was found between frontal sinus and gonial angle in the females.

ANTERIOR FACIAL HEIGHT: In males, direct correlation is seen, with significant increase in frontal sinus dimensions there is increase in the anterior facial height.

2. **SN-FH Angle:** Inverse correlation was seen so as the frontal sinus area increases the anterior cranial base inclination gets reduced..

3. **SNA Angle:** a direct correlation was seen, a significant increase in frontal sinus height was related to maxillary retrognathism.

It was concluded that there exists an negative correlation between area of frontal sinus and the anterior cranial base inclination. A direct correlation was also established between increased gonial angle with the frontal sinus dimensions in females and with increase in frontal sinus dimensions, an appreciable anterior facial height increase was noticed in males.

Elbeshlawy *DM et al* [20] aimed to study the gender prediction using frontal sinus index with the help of lateral cephalogram and CBCT images. Methodology included analyzing 100 cephalograms and 100 CBCT radiographs with age groups divided into two groups- below 18 and above 18 years and each group had 25 males and 25 females. Frontal sinus height (FSH), Frontal sinus width (FSW) and frontal sinus index(FSI) was calculated. Table 3 &4 depict distribution of sample of the study .

TABLE NO. 3: Distribution of sample in study by Elbeshlawy *DM et al* (Below 18 years) [20]

Mode of Radiograph	Ceph	Ceph	CBCT	CBCT
Gender	Male	Female	male	Female
Total number	25	25	25	25
Range of age(in years)	10-17	12-17	9-17	10-17

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Median	14	15	14	15

TABLE NO. 4: Distribution of sample in study by Elbeshlawy *DM et al* (Above 18 years) [20]

Mode of Radiograph	**Ceph**	**Ceph**	**CBCT**	**CBCT**
Gender	Male	Female	male	Female
Total number	25	25	25	25
Range of age(in years)	1-27	18-28	18-27	18-28
Median	24	21	24	21

The result obtained was that FSH values obtained by CBCT in mean of females of age less than 18 years were significant in contrast to FSW and FSI values from ceph in mean of males of 18 years or more were found significant. There was no significant difference when both groups were compared to each other. The study concluded that by using either lateral cephalogram or CBCT, it was not a good indicator for gender prediction due to various anatomic variations of frontal sinus in both the genders.

4.Frontal Sinus and mouth/Nasal Breathers

Al-Sheakli I et al [21] in the year 2013 conducted a study in college of dentistry at Baghdad University which aimed to assess frontal sinus area as a diagnostic aid to recognize mouth breathers or nasal breathers and to determine gender differences in both group and assessed the association of area of frontal sinus to the cephalometric skeletal measurements. Smaller frontal sinus area was present in mouth breathers and larger area is seen in nasal breathers and larger values are seen among males in both the group. So, the nasal breathers and mouth breathers has correlation with facial height, S-N length, ramal length.

5. Frontala Sinus and Malocclusion

Rossouw P.E. et al evaluated the frontal sinus morphology and mandibular growth prediction. 130 random cephalograms were taken and further classified into Angles Class I and Class III malocclusion [22]. The study infers a positive correlation of the maxilla and mandibular length to the area of frontal sinus and a negative correlation was established regarding ANB angle and frontal sinus size suggestive that smaller ANB angle was seen in Class III patients.

Another cepahlometric study conducted by **Yassaei S et al** determined the existing relationship of maxillary sinus morphology and frontal sinus with mandibular size/length in both males and females [23]. A total of 116 digital lateral Cephalogram were studied and divided as follows : 38 patients of Angle class I malocclusion, 40 patients of Angle class II associated with mandibular deficiency and 38 patients of Angle class III having mandibular access. It was concluded from the results that the dimension and frontal sinus area and maxillary sinus was greater in patients with Angle's class III malocclusion. And significant correlation was found between these parameters with mandibular length. The frontal sinus area and dimension except for the frontal sinus width was found to have significant relationship with the anterior and posterior cranial bases and mandibular body length.

Sabharwal A et al carried out a study on the analysis of frontal sinus in various malocclusions. [24]. 120 lateral cephalograms were obtained of the patients between the age group of 16-30 years and were categorized into Angle's Class I, Class II, Class III malocclusion. Post hoc statistical analysis was used.

TABLE NO. 5: Result of study by Sabharwal A et al Based on post hoc analysis [24]

PARAMETERS USED	**CLASS I**	**CLASS II**	**CLASS III**
1.Effective length of the mandible	-	Shortest	Highest
2. Maximum width of frontal sinus	-	-	Highest
3. Maximum frontal sinus area	-	-	Highest

In conclusion, a positive correlation between Class III patients and maximum frontal sinus width and area and effective length of the mandible was found.

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Rossouw P.E. et al carried out a research to evaluate the area of frontal sinus as a predictor of growth pattern of mandible. [22]. They reported that a patient with Class III malocclusion having a larger frontal sinus would obviate the need for orthognathic surgery in the near future besides the usage of orthodontic appliances. Association between large frontal sinus was found with skeletal class III malocclusion, length of condyle and symphysis width.

Another cephalometric study correlated and measured the frontal sinus area in various Skeletal malocclusion that is in Angle's Class I, II and III malocclusions and the results stated that irrespective of mandibular sagittal relationship, a direct correlation was observed between frontal sinus and mandibular length; however, evidence suggested better association between skeletal Class III malocclusions and greater area of frontal sinus [25].

Few authors have also investigated the relationship of individual's height to the frontal sinus development and it was concluded by their research that the frontal sinus can serve as a helpful indicator in the assessment of individual's maturity status [26-28].

Dah-Jouonzo H et al in their study correlated the maxillomandibular relationship with the volume of paranasal sinuses [29]. The findings of the study pointed out that the frontal sinus volume is afflicted greater by vertical rather than changes in anteroposterior direction and concluded that sinus volume was greatest in class III malocclusion compared to class II division 1, and average frontal sinus volume was found in Class II division 2 and Class I cases.

Gupta A evaluated the dimensional analysis of frontal sinus in various skeletal malocclusion [30]. Using 195 samples of lateral cephalograms and further classifying them into three classes of malocclusion this study was carried out. All patients included were of the age group 16 to 30 years.

TABLE NO. 6: Showing correlation between various classes of malocclusion and different parameters of frontal sinus in study by Gupta A [30]

PARAMETERS	**CLASS I**	**CLASS II**	**CLASS III**
Maximum height	Highest	Lowest	-
Maximum width	-	Lowest	Highest
Total frontal sinus area	-	Smallest	Largest
Effective length of mandible	-	Shortest	Greatest

TABLE NO. 7: Showing correlation between different parameters of frontal sinus and gender groups in study by Gupta A [30]

PARAMETERS	**MALE**	**FEMALE**
Maximum height	Greater	Lesser
Maximum width	Greater	Lesser
Area of frontal sinus	Greater	Lesser
Effective length of mandible	Greater	Lesser

TABLE 6 concluded that, largest frontal sinus area and width is seen in Class III and smallest among Class II Patients. A significantly greatest effective mandibular length is observed in Class III and shortest in Class II patients. **TABLE 7** concluded that Male groups have greater maximum height, width and frontal sinus area as compared to female groups.

Dhiman I et al conducted a study to evaluate reliability of Frontal Sinus in malocclusions of various type [31]. 240 patients were divided into 3 categories of Angle's classification of malocclusion; that is : Angle's Class I , Class II , Class III malocclusion. Following tables illustrates the results obtained from the study.

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TABLE NO. 8: Shows correlation b/w angles class of malocclusion and area of frontal and maxillary sinus in study by Dhiman I et al [31]

ANGLES CLASS OF MALOCCLUSION	FRONTAL SINUS AREA (FSA)	MAXILLARY SINUS AREA (MSA)
CLASS I	-	-
CLASS II	-	Larger
CLASS III	Larger	-

Correlation between FSA and Length of Mandibular Body (MBL):

This study shows a positive correlation between skeletal class III and FSA, i.e., individuals with a larger mandibular length tend to show a greater FSA.

Gender:

- Maxillary Sinus Area: No significant difference is observed in males and females.
- Frontal Sinus Area:

TABLE NO. 9: Showing correlation between gender groups and different variables of cephalograms in study by Dhiman I et al [31]

Variables of Cephalogram	Males	Females
1.SNA	Larger	-
2.SNB	Larger	-
3.Saddle Angle	Larger	-
4.Facial Angle	Larger	-
5.Mandibular Body Length (MBL)	-	Larger
6. Total Mandibular Length (TML)	-	Larger

Above study concludes that class III individuals have larger FSA in comparison to class II and III individuals whereas MSA is greater in class II individuals. Larger FSA is also seen is also positively correlated with larger mandibular length, i.e., in class III individuals.MSA proves to show no such significant variations.

6. Frontal Sinus in Cleft Patients

The second most common craniofacial anomaly is Cleft lip and palate (CLCP) . CLCP patient faces various problems such as impaired facial esthetics, malocclusion in skeletal and dental structures, problems in feeding, respiratory, hearing issues and impaired speech. Thus, an early indicator for upcoming skeletal changes is very crucial in cases of CLCP. This will aid in early diagnosis and better treatment plan i.e., orthodontic and surgical both which will also aid in treatment outcome with minimal intervention and can shorten the time period of entire treatment.

The cross sectional and retrospective research conducted by ***Jadhav V et al*** in the year 2021 aimed to evaluate the morphology of frontal sinus as an indicator for future growth pattern and skeletal malocclusion in CLCP patients [32] .A total 30 cases each of skeletal class I, class III and CLCP were selected. Results of the study indicated that in CLCP cases, growth is retarded and so it ruins the growth of frontal sinus. Therefore, the dimensions of CLCP are reduced when compared to skeletal Class III and Class I malocclusion. Dimensions of frontal sinus for class III was found greater and average dimensions for skeletal class III malocclusion. Thus, it was concluded that we can predict the growth pattern and skeletal malocclusion.

7.CONCLUSION

An important factor responsible for treatment planning is the proper estimation of growth. According to the reviewed articles, it has been seen that frontal sinus dimensions and morphology have correlation with growth and development, on gender, skeletal malocclusion, nasal or mouth breathers and also in cleft lip and palate patients. Thus, frontal sinus dimensions and morphology acts as an additional diagnostic aid for more accurate prediction and diagnosis of skeletal malocclusion in growing individuals.

Growth potential plays an indispensible role while planning orthodontic therapy for an individual and the growth spurt stage has significant effect on the treatment procedure as well as on the retention of desired results which are obtained post-orthodontic therapy. So, the early indicators used for estimation of skeletal maturity can prove as a boon in the field of orthodontics which

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helps in avoiding complex procedures and surgeries for the individual who has crossed the pubertal growth spurt.

References

1. Houston WJ. (1980). Relationships between skeletal maturity estimated from hand-wrist radiographs and the timing of the adolescent growth spurt. Eur J Orthod . 2(2):81-93.

2. Chaiyasate S, Baron I, Clement P. (2007). Analysis of paranasal sinus development and anatomical variations: A CT genetic study in twins. *ClinOtolaryngol* , 32:93–7.

3. Guevara YV, Watanabe N, Yamaki M, Saito I. (2013) The frontal sinus enlargement as an indicator of growth maturity in class III patients – A pilot study. *Int J Med Sci Public Health*, 2:451–5.

4. Brown WA, Molleson TI, Chinn S. (1984). Enlargement of the frontal sinus. *Ann Hum Biol* , 11(3):221-6.

5. Rossouw PE, Lombard CJ, Harris AM. (1991). The frontal sinus and mandibular growth prediction. Am J Orthod Dentofacial Orthop;100:542–546.

6. Ruf S. Pancherz H. (1996). Frontal sinus development as an indicator for somatic maturity at puberty. Am J Orthod Dentofac Orthop, 110:476-482.

7. Nathani R, Diagavane P, Shrivastav S, Kamble R, Gupta D, Korde S (2016) .Evaluation of frontal sinus as a growth predictor in horizontal, vertical, and average growth pattern in children from 8 to 11 years: A cephalometric study . J Indian Orthod Soc ,50:101-5.

8. Ruf S, Pancherz H. (1996). Development of the frontal sinus in relation to somatic and skeletal maturity. A cephalometric roentgenographic study at puberty. Eur J Orthod,18:491-497.

9**.** Bhangare J, Ambekar A, Kangane S, Marure P, Deshpande R, Vaprani T. (2019).IOSR Journal of Dental and Medical Sciences (IOSR-JDMS); IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) ,18(4):45-48.

10. Valverde Y, Watanabe N, Yamaki M, Saito I. (2013). The frontal sinus enlargement as an indicator of growth maturity in Class III patients – A pilot study. Int J Med Sci Public Health, 2:451-455.

11.Gürsoy GM, Tuncer G. (2021) Frontal sinus: is it a predictor for vertical malocclusions? Anat Sci Int;96(1):62-69.

12.Oktay H. (1992) .The study of the maxillary sinus areas in different orthodontic malocclusions. Am J Orthod Dentofacial Orthop ;102:143–5.

13. Abate A, Gaffuri F, Lanteri V, Fama A, Ugolini A, Mannina L, Maspero C. (2022) A CBCT based analysis of the correlation between volumetric morphology of the frontal sinuses and the facial growth pattern in caucasian subjects. A crosssectional study. Head & Face Medicine, 18(4):1-12.

14.Mahmood HT, Shaikh A, Fida M. (2016). Association between frontal sinus morphology and cervical vertebral maturation for the assessment of skeletal maturity. Am J Orthod Dentofacial Orthop ,150:637-42.

15. Buyuk SK, Simsek H, Karaman A. (2018) The relationship between frontal sinus morphology and skeletal maturation. Folia Morphol, 77(3):503-508.

16. Tehranchi A, Saedi S, Motamedian SR, Rohani K.(2015). Radiographic Evaluation of Frontal Sinus Dimensions and Anatomic Variation. British Journal of Medicine & Medical Research;8(5):454-462.

17.Shireen A, Goel S, Ahmed IM, Sabeh AM, Mahmoud W. (2019). Radiomorphometric evaluation of the frontal sinus in relation to age and gender in Saudi population. J Int Soc Prevent Communit Dent.9:584-96.

18. Benghiac AG, Budacu C, Moscalu M, Ioan BG, Moldovanu A, Haba D. (2017). CBCT assessment of the frontal sinus volume and anatomical variations for sex determination. Rom J Leg Med;25:174-179.

19.Tehranchi A, Motamedian SR, Saedi S, Kabiri S, Shidfar S. (2017) .Correlation between frontal sinus dimensions and cephalometric indices: A cross-sectional study. Eur J Dent;11(1):64-70.

20.Elbeshlawy DM, Helaly YR. (2020). Frontal sinus index for sex estimation: Is it possible?. Forensic Imaging, 23:1-5.

21. Al-Sheakli I, Mohammed SA, Taha SS. (2013). The frontal sinus dimensions in mouth and nasal breathers in Iraqi adult subjects. J Bagh Coll Dentistry; 25(2):155-163.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(2), 165-173 | ISSN:2251-6727

22.Rossouw PE, Lombard CJ, Harris AM. (1991) .The frontal sinus and mandibular growth prediction. Am J Orthod Dentofac Orthop,100:542-6

23. Yassaei S, Emami A, Mirbeigi S. (2018) .Cephalometric association of mandibular size/length to the surface area and dimensions of the frontal and maxillary sinuses. *Eur J Dent*, 12(2):253-261.

24.Sabharwal A, Patil AS, Shinde S, Swami V. (2019)..Analysis of frontal sinus in various malocclusions. Int J Orthod Rehabil ,10:116-20.

25. Blaney SP. (1990) .Why paranasal sinuses? *J Laryngol Otol*,104:690–3.

26. Ruf S, Pancherz H. (1996) Development of the frontal sinus in relation to somatic and skeletal maturity. A cephalometric roentgenographic study at puberty. *Eur J Orthod,* 18:491–7.

27. Gagliardi A, Winning T, Kaidonis J, Hughes T, Townsend GC. (2004). Association of frontal sinus development with somatic and skeletal maturation in Aboriginal Australians: A longitudinal study. *Homo,* 55:39–52.

28. Guevara YV, Watanabe N, Yamaki M, Saito I. (2013). The frontal sinus enlargement as an indicator of growth maturity in Class III patients – A pilot study. *Int J Med Sci Public Health*,2:451–5.

29.Dah-Jouonzo H, Baron P, Faure J. (2007) Correlations between the volume of the sinuses and the facial bones and parameters of 3D cephalometry. *Orthod Fr*,78:265–281.

30. Gupta A, Giri A, Shrestha RM. (2021). Dimensional analysis of frontal sinus in various skeletal malocclusions. J Nepal Dent Assoc,21(32):7-13.

31.Dhiman I, Singla A, Mahajan V, Jaj HS, Seth V, Negi P. (2015). Reliability of frontal sinus with that of maxillary sinus in assessment of different types of skeletal malocclusions. J Indian Orthod Soc 49:96-103.

32. Jadhav V , Daigavane P, Kamble R , Shrivastav S , Tiwari M. (2021). Broadening the Scope and Utility of Frontal Sinus Morphology for Predicting the Growth Pattern and Skeletal Malocclusion in Cleft Lip and Palate Cases. JPRI, 33(51A):173-179.