Original Article

Evaluation of Frontal Sinus as a Growth Predictor in Horizontal, Vertical, and Average Growth Pattern in Children from 8 to 13 Years: A Cephalometric Study

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Abstract

Aim: This study aims to evaluate the dimensions of the frontal sinus as a growth predictor in horizontal, vertical, and average growth pattern. **Materials and Methods:** Retrospective data in the form of serial cephalometric records of 40 patients obtained at 1 year interval from 8 to 13 years of age were collected for the study. The serial cephalograms of 45 children were digitized, calibrated, and analyzed by software. Based on cephalometric parameters, these children were further divided into 15 horizontal, 15 vertical, and 15 average growth patterns, respectively. These images were then transferred to AutoCAD software for the assessment of dimensions of frontal sinus from 8 to 13 years of age. **Results and Conclusion:** Results of the study showed that there was significant differences in the dimension of frontal sinus among various growth patterns. hence the study concluded that frontal sinus can be a useful predictor for the assessment of growth pattern.

Keywords: Cephalogram, Frontal sinus, Growth pattern, Growth predictor.

Introduction

The growth pattern is influenced genetically, environmentally, and therapeutically. These have long been considered as vital factors in determining the success or failure of orthodontic treatment.[1-4] The ability to predict craniofacial growth pattern accurately improves the reliability of treatment planning and long-term success.[5-7] It is, therefore, necessary for the orthodontist to evaluate the growth pattern meticulously before initiating treatment in growing individual.

Although various indicators are available as a predictor of growth patterns, limited parameters have been shown to enhance the orthodontist's ability to predict the growth pattern. As suggested by Ruf and Pancherz,[8] the somatic maturity stage can be considered rather accurate with the frontal sinus development. Furthermore, Rossouw *et al*.[9] stated that the frontal sinus as seen on a lateral cephalogram is a valuable indicator for assessing mandibular growth. Its role in diagnosis will thereby help the clinician in his attempt to attain excellent treatment results.[10,11]

Frontal sinus is not visible radiographically until the age of 5 years.[4] By the 6th year, they can be demonstrated radiographically and grow larger in size by late adolescence.[12] Rapid growth of the sinuses continues until the age of 12 years when they reach nearly adult size. Tanner[1] found that the annual height (stature) growth increments in children reached a plateau at 16 years in boys and 14 years in girls, and this is also the age at which frontal sinus growth ceases. The development of the frontal sinus is completed by 20 years of age and remains stable until further enlargement of the chambers occurs as a result of bone remodeling with age.

Over the recent diagnostic aids, the dimensions of the frontal sinus, which are easy to identify on lateral radiographs, assist the clinicians to determine post-correction stability in occlusion. The conventional methods still remain the chore for modern research due to unavailability of modern technology, cost, etc.

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Materials and Methods

The following study was performed to evaluate the dimension of frontal sinus with growing age and to correlate it with different growth pattern in children between 8 and 13 years on lateral cephalograms.

The following study was performed in the department of orthodontics where retrospective data in the form of serial cephalometric records of 30 patients taken at 1 year interval from 8 to 13 years of age were collected for the study. The cephalogram of 45 patients was digitized by taking JPEG images from Canon DSLR camera on X-ray viewer at one feet distance.[13] These digitized images were then calibrated and analyzed by software.

The radiographs were further analyzed for the type of growth pattern based on GoGn-SN angle from Steiner's analysis, Frankfort-mandibular plane angle from Tweed analysis, and lower anterior face height from Rakosi analysis, they were then segregated into 15 horizontal (Group 1), 15 vertical (Group 2), and 15 average growth pattern (Group 3) (Figure 1).

These images were transferred to AutoCAD software 2012and calibrated for the assessment of dimension of the frontal sinus. The peripheral border of the frontal sinus was traced manually on AutoCAD software. The highest (H) and lowest (L) point of sinus extension was marked as height of frontal sinus. A perpendicular line drawn to the height of sinus (HL) at the maximum width (AB) of the frontal sinus, which was assessed for every cephalogram (Figure 2).

Area of frontal sinus was then calculated for each interval by multiplying height and yearly growth velocity of the frontal sinus was calculated separately for each of the prediction intervals in horizontal, vertical, and normal growth pattern.

To minimize the measurement error and for unbiased evaluation, assessment was done at an interval of the 2 weeks. Interoperator error was determined to minimize the error for all cephalograms followed by statistical analysis.

The kappa test and reliability test (Cronbach alpha test) were used to determine the reliability of measurement. Descriptive and analytical statistics were performed. The one-way ANOVA with Tukey's *post hoc* test was used to check the mean differences among various groups. Pearson's correlation analysis was done for correlation between the groups. Regression coefficient was performed to compare various parameters used for the prediction of growth pattern.

Results

Average yearly growth increments of mean area of frontal sinus were more in vertical growth pattern than in horizontal and average growth pattern (Table 1).

The one-way ANOVA with Tukey's *post hoc* test showed a significant difference in the mean area of frontal sinus between the groups at all the age interval since $P < 0.05$ in all the groups (Table 2).

Pearson's correlation analysis revealed significant correlation between average with vertical growth pattern and horizontal with vertical growth pattern (Table 3). Regression coefficient confirmed that area of frontal sinus is a better predictor for the assessment of growth pattern.

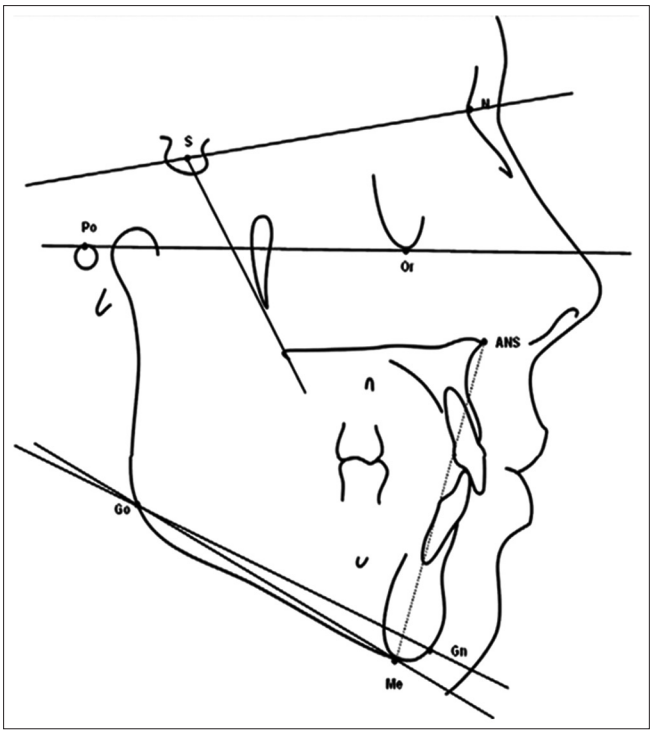

Figure 1: Parameters for evaluation of growth patterns

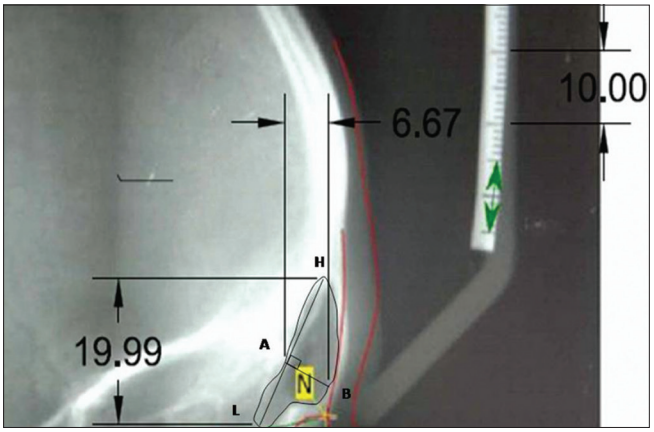

Figure 2: Calibration and evaluation of frontal sinus on AutoCAD software

Discussion

The knowledge of growth pattern and its variation enables the early detection of developing malocclusion in children. Orthodontists now know the importance of analyzing the growth pattern in function and stability of orthodontic

Table 1: Mean area of frontal sinus at yearly interval

	Group Mean±SD (A1–A4)				Average yearly increment
	A1	A2	A3	A4	A5
Horizontal	97.8±58.3	99.5±61.8	137.6±76.5	155.3±89.5	1.96±0.24
Average	110.5±48.2	123.6±56	138.6±64.6	153.3±66.4	1.52±0.71
Vertical	229.6±57.6	264.1±70	288.9±80.0	356.6±73.2	4.30±1.23

Table 2: Difference in area of frontal sinus between the group and within the group

Source	SS	Df	MS	F	*P*
A1					
Between groups	52,756	2	27,300.35	8.74	0.005
Within groups	35,204	12	30,029.56		
Total	87,960	14			
A2					
Between groups	78,992.03	2	39,406.39	9.8	0.003
Within groups	47,496	12	3999.65		
Total	126.88	14			
A3					
Between groups	77,890	2	38,965.56	7.02	0.009
Within groups	65,780	12	5283.63		
Total	143,680	14			
A4				11.3	0.002
Between groups	13,6276.59	2	68,218.29		
Within groups	71,278.73	12	5961.56		
Total	207,555.32	14			

Table 3: Correlation in area of frontal sinus between groups

Dependent variable group	Group	MD	SE	*P*	95% CI lower	Upper
A1	Horizontal	−10.32	39.73	0.95	−103.63	82.03
	Vertical	−130.63	39.73	0.56	−258.45	−85.65
	Average	−120.69	39.73	0.68	−158.7	−58.4
A2	Horizontal	−34.53	46.53	0.58	−89.52	−89.5
	Vertical	−170.25	46.53	0.69	−26.78	−258
	Average	−130.89	46.53	0.95	−65.89	−58.65
A3	Horizontal	−3.52	48.70	0.69	−126.7	−58.63
	Vertical	−168.36	48.70	0.58	−258.4	−58.85
	Average	−169.54	48.70	0.89	−157.25	129
A4	Horizontal	−2.25	49.67	0.65	−145.25	52.78
	Vertical	−125.32	49.67	0.58	−169.45	25.75
	Average	−126.58	49.67	0.75	−123.54	25.56

*Significant at P<0.05. MD: Mean difference, SE: Standard error, CI: Confidence interval

treatment. Several methods of growth predicting given in the literature. Frontal sinus is easily visible on lateral cephalogram and can be as a parameter for prediction of growth pattern as its growth is synchronous with craniofacial growth.

Skeletal growth patterns become evident during early childhood and on average, remain stable with age.[14,15] Bishara and Jakobsen[16] demonstrated that 77% of people maintained their facial types from 5 to 25.5 years of age. Other longitudinal studies comparing the growth of open bite and deep bite subjects have demonstrated that although there are differences in the magnitude and direction of growth changes, they follow similar patterns.

Based on morphologic analysis of frontal sinus which Predicting variation in various skeletal growth patterns, it was an important step in orthodontic diagnosis and treatment planning. The method used to differentiate horizontal, vertical, and average growth pattern is more consistent with the traditionally used methods.[7-20]

Dimensions of frontal sinus were assessed in horizontal, vertical, and average growth patterns for consequent years for age prediction. It was found that at the mean age of 8 years; mean area of frontal sinus was found to be 96.8 ± 58.3 in the horizontal group, 107.5 ± 48.2 for average group, and 227.6 ± 57.6 for vertical group. Similarly, at 9 years of age, mean area of frontal sinus was found to be 99.5 ± 61.8 in horizontal group, 123.6 ± 56.9 for average group, and 264.1 ± 70.1 for vertical group. At 10 years of age, mean area of frontal sinus was found to be 136.6 ± 76.5 in horizontal group, 137.6 ± 64.6 for average group, and 289.9 ± 80.0 for vertical group. At 11 years of age, mean area of frontal sinus was found to be 155.3 ± 89.5 in horizontal group, 153.3 ± 66.4 for average group, and 356.6 ± 73.2 for vertical group (Table 1).

Mean yearly growth increment of frontal sinus was found to be 1.52 ± 0.71 for average growth pattern, 1.86 ± 0.24 for horizontal growth pattern, and 4.30 ± 1.23 for vertical growth pattern, the findings of average growth pattern (Table 2) were similar to the results of Ruf and Pancherz[8] who stated that the frontal sinus peak growth velocity was about 1.3 mm/year rate.

For this study, the calculated average amount of growth increment of frontal sinus for horizontal growth pattern seemed higher than average growth pattern and the average growth increment of frontal sinus for calculated vertical growth in agreement with those of Prashar.[16] They reported that the frontal sinus area did not vary significantly between hypodivergent (243.43 ± 79.21) and normodivergent (221.65 ± 80.74) and hyperdivergent (221.30 ± 67.80) group. The nonsignificance of the frontal sinus area in these groups might be due to the fact that all skeletal classes, that is, skeletal Class I, II, and III malocclusions were distributed in the hypodivergent, normodivergent, and hyperdivergent groups.

Average growth interval of frontal sinus between average and horizontal growth pattern was not significant. The current study demonstrates a definite correlation between average growth increment of frontal sinus and growth pattern and significant

Table 4: Prediction of horizontal growth pattern based on frontal sinus parameter

Jarabak ratio	−0.625	0.452	0.40	0.298
GoGn-SN	−2.183	0.042	0.58	0.255
FMPA	−0.264	0.341	0.58	0.253
A1	0.145	1.176	0.80	0.281
Constant	18.667			
Jarabak ratio	−2.146	0.065	0.52	0.250
GoGn-SN	−3.955	0.019	0.60	0.380
FMPA	−17.8	620.0	00.70	0.376
A2	0.722	2.058	0.80	0.376
Constant	85.327			
Jarabak ratio	−0.523	0.360	0.53	0.39
GoGn-SN	−0.714	0.490	0.60	0.278
FMPA	−3.002	0.050	0.60	0.286
A3	0.113	1.120	0.67	0.04
Constant	19.815			
Jarabak ratio	−0.715	0.391	0.51	0.218
GoGn-SN	−0.914	0.421	0.60	0.126
FMPA	−3.604	0.027	0.40	0.252
A4	0.134	1.144	0.68	0.234
Constant	25.485			

Table 5: Prediction of average growth pattern based on frontal sinus parameters

Jarabak ratio	−0.715	0.391	0.53	0.298
GoGn-SN	−0.914	0.421	0.60	0.255
FMPA	−3.604	0.027	0.60	0.253
A1	0.134	1.144	0.67	0.281
Constant	25.485			
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A4	0.722	1.176	0.67	0.376
Constant	18.667			

difference between average yearly growth increments of each group (Table 3).

Regression coefficient analysis revealed that area of frontal sinus (70%) was found to be a better predictor of growth pattern as compared to GoGn-SN, FMPA, and Jarabak ratio at 8, 9, 10, and 11 years (Tables 4-6).

A recent study has found that frontal sinus is more reliable than maxillary sinus in assessment of different types of skeletal malocclusions.[15] Taking into consideration the cost for other diagnostic tools for predicting growth, frontal sinus can be easily evaluated on the lateral cephalogram making the treatment strategy for the growing patients more appropriate.

Table 6: Prediction of vertical growth pattern based on frontal sinus parameter

Jarabak ratio	−0.625	0.452	0.40	0.298
GoGn-SN	−0.914	−0.715	0.60	0.380
FMPA	−3.604	−0.914	0.60	0.376
A2	0.134	−3.604	0.67	0.376
Constant	85.327			
Jarabak ratio	−0.523	0.360	0.53	0.39
GoGn-SN	−0.714	0.490	0.60	0.278
FMPA	−3.002	0.050	0.60	0.286
A4	0.113	1.120	0.67	0.04
Constant	18.667			
Jarabak ratio	−2.146	0.065	0.51	0.218
GoGn-SN	−3.955	0.019	0.60	0.126
FMPA	−17.8	620.0	0.40	0.252
A3	0.722	2.058	0.68	0.234
Constant	19.815			
Jarabak ratio	−0.715	0.391	0.40	0.250
GoGn-SN	−0.914	0.421	0.58	0.380
FMPA	−3.604	0.027	0.58	0.376
A1	0.134	1.144	0.80	0.376
Constant	25.485			

Conclusion

Frontal sinus can thus be used as a predictor for evaluation of growth pattern. Further studies are required to correlate this parameter with the growth of maxilla and mandible in various growth patterns.

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