Original Article

Height width ratio of frontal sinus in different stages of cervical vertebrae maturation in subjects with normal occlusion

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ABSTRACT

Background & Objectives: The recognition of pubertal growth spurt is an important aspect of Orthodontics. Morphological changes of the frontal sinus during adolescent growth spurt have evoked the interest of many authors. The present study aimed to evaluate the height-width ratio of frontal sinus in different stages of cervical vertebral maturation (CVM) and if possible, to determine the clinical relevance of frontal sinus morphologic variations in assessing the developmental status of an individual. **Method:** A cross-sectional study was performed on pretreatment lateral cephalograms of 115 subjects aged 7 to 22 years. The sample was divided into six groups based on the cervical vertebral maturation stages and five groups based on chronological age. The height-width ratio of the frontal sinus was calculated and CVM stages were evaluated on the same radiograph. The comparison of height-width ratios with the different CVM stages was done using one-way ANOVA. A pair-wise comparison was done by Duncan's post-hoc test. Student's t-test was used for comparison of the frontal sinus parameters with gender. Correlations of the parameters with CVM stages gender-wise were done using Kendall's tau_b test. **Results:** Results showed that the height-width ratio of the frontal sinus in the study population does not differ with different age groups or the CVM stages. The height-width ratio failed to show any significant change with age or cervical maturation stages in the sample. **Conclusion:** The frontal sinus height-width ratio failed to show a specific pattern among the different CVM stages and hence, could not characterize an adolescent growth spurt.

Key words: Cervical Vertebrae, Frontal Sinus, Height Width Ratio

The knowledge of craniofacial growth and development has become a prerequisite in Orthodontics. It has become essential for the orthodontist to evaluate the stage of growth of a patient, estimate how much growth is remaining, and accordingly plan the treatment [1, 2]. If favorable, an attempt can be done to either modify or assess the potential adverse effects of future craniofacial growth.

Craniofacial growth and development demonstrate large individual variations with respect to chronological age at which similar developmental events such as sexual maturation, dental development, and peak statural height take place [3]. Different methods to assess the stage of growth and maturation have been investigated by many authors [4-9]. Due to the wide variation in maturity with chronological age, the assessment of physiological maturity has been stated to be a better indicator in the assessment of the developmental status of an individual. Various methods of assessing developmental status include somatic, dental, skeletal, and sexual maturity indicators as predictors.

Initially introduced by Bergersen [10], Fishman [11] presented the skeletal maturity index (SMI) in 1982, in response to, conflicting evidence from Houston [12] and Hagg [7]. Due to the additional radiation exposure and specific skill for its interpretation alternatives to hand-

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wrist radiographs were developed. These included assessment of skeletal maturity using cervical vertebrae maturation (CVM) staging from the routine lateral cephalograms [5, 9, 13-15]. Studies by various authors assessed the relationship between CVM and mandibular growth and concluded that the CVM method is a valid indicator for the assessment of skeletal maturity and is comparable with the use of hand-wrist radiographs [13, 16, 17]. The cervical vertebrae maturation method is currently the most widely used and accepted method for the assessment of the growth status of an individual. However, it carries certain limitations such as poor reproducibility [18, 19].

The frontal sinus is regarded as the last of the sinuses to develop, postnatally. A number of studies have reported great physiologic and gender variability of the frontal sinus size and its development from childhood to adolescence [20-23]. Moderate associations between somatic maturity and frontal sinus development from lateral head films have been demonstrated earlier [24]. Even though there are several reports on the development of the frontal sinus, few studies have investigated the relationship of the frontal sinus with other growth parameters. The present study aimed to find the frontal sinus height, width, and height-width ratio with different age groups and cervical vertebrae maturation in subjects with normal occlusion and if possible, to assess the clinical relevance of frontal sinus morphologic variations in assessing the developmental status of an individual using lateral cephalograms. CBCT was not taken as the radiograph of choice considering the number of data required and also because the study utilized department archive records.

METHODOLOGY

The study was conducted in the outpatient department of Orthodontics & Dentofacial Orthopedics for a period of 18 months. Being a period study, department archive records of subjects with normal occlusion taken for another study from 1st January 2012 to 31st December 2015 were taken. Along with this, cephalograms of patients satisfying the inclusion criteria from the dental outpatient department during the time period 1st January 2016 to 31st December 2016 after obtaining informed consent were also taken. A total of 115 lateral cephalograms were evaluated with approximately 20 cephalograms in each cervical stage of maturation (6 stages).

Inclusion Criteria

Patients satisfying the following criteria were included in the study: Normal occlusion [25]; No history of previous orthodontic or orthopedic treatment; Subjects of growing age with no history of congenital abnormalities affecting growth and development, bone diseases and major illness in the past; Apparently symmetrical face; No history of trauma or surgery in the dentofacial region. Radiographs from department archive records that satisfied the following criteria were taken: Good quality radiographs in which the frontal sinus and the cervical spine (C2-C4) can be viewed. ANB angle between 2 degrees to 4 degrees.

Exclusion criteria: Subjects with a history of paranasal sinus pathology and not willing to participate were excluded from the study.

Study procedure

Pre-treatment lateral head cephalograms of subjects were taken and the chronological age was recorded according to the actual date of birth of the subjects. The lateral cephalograms obtained from previous records were made sure to be from the same cephalostat and same-sized head films. All lateral cephalometric films were traced on a transparent cellulose acetate matte sheet 0.003 inches in thickness with a 0.5mm lead pencil by the same operator. Similar conditions of the lightbox and general illumination were maintained during the viewing and tracing of all head films. All reference points were first identified, located, and marked. The reference planes were drawn and when the bilateral structures cast double shadows on the film, the technique of averaging the bilateral images was used.

Frontal sinus tracing was according to the criteria of Ertürk and Bonn [26]. After the orientation of the S- N line, the frontal sinus was traced by following areas of high radiopacity as peripheral areas. The highest point and the lowest point (SH and SL respectively) were identified and connected by drawing a line. To calculate the width, a line perpendicular to the SH-SL line is drawn and the line with maximum width extending from the sinus posterior point and the sinus anterior point was taken as the sinus width. The height-width ratio of the frontal sinus was calculated by dividing the frontal sinus height by the frontal sinus width.The three cervical vertebrae (C2, C3, and C4) were also traced on the same tracing sheet. The presence or absence of curvature in the inferior borders of the C2, C3, and C4, the general shape of the bodies of C3 and C4 and intervertebral spacing were visualized. On the basis of these findings, the patients are placed in each CVMI category using the modified version of Baccetti et al [15].

The data were tabulated and analyzed by statistical software (IBM SPSS Statistics version 22). The null hypothesis was stated as the frontal sinus parameters of males and females do not differ significantly. Descriptive statistics (mean, standard deviation, range, and confidence intervals) were calculated for all variables. The data followed a normal distribution. Hence, the statistical tool which was used for comparing the sinus height width ratios with the different CVM stages was one-way ANOVA (Analysis of Variance). A pair-wise comparison was done by Duncan's post-hoc test. The statistical tool used for the comparison of the frontal sinus parameters with gender was the Student t-test. Correlations between the parameters with different age groups and CVM stages gender-wise were done using Kendall's tau_b test. A p-value of < 0.05 was considered statistically significant. Correlations were significant at 0.01 level (2-tailed).

RESULTS

The study included 115 subjects (total population) of which 40 were males and 75 were females. The subjects were categorized into 5 age groups namely 7-10 years, 11-13 years, 14-16 years, 17-19 years, and 20-22 years. The cervical vertebrae maturation (CVM) stages were grouped into six cervical stages namely CS1, CS2, CS3, CS4, CS5, and CS6.

Frontal sinus height width ratio according to different age groups in males, in females, and in the total population is presented in the table above (Table 1). The height-width ratio of the frontal sinus does not change with the different age groups in males, females, or the total population. Hence, the height-width ratio of the frontal sinus in comparison to the different age groups was statistically insignificant (p>0.05). The height-width ratio according to the different CVM stages is presented in the table above (Table 2). In males, females, and the total population, the frontal sinus height-width ratio did not show a significant difference with the different cervical maturation stages. Thus, the frontal sinus height-width ratio according to different CVM stages showed no significance (p>0.05). Correlation between CVM stages and frontal sinus height, CVM stages and frontal sinus width, and CVM stages and frontal sinus height width ratio was done gender-wise using Kendall's tau_b test. Correlations were significant at 0.01 level. The test results suggested a strong positive correlation between CVM stages and frontal sinus height in both males and females. There was a strong positive correlation between CVM stages and frontal sinus width in the case of males and females. The frontal sinus height-width ratio showed no significant correlation with CVM stages in both males and females.

DISCUSSION

The relationship of somatic growth, skeletal maturity, and frontal sinus parameters, if established, could be of great significance in orthodontic treatment which requires determination of growth spurt. A systematic review by Cozza et al [27] reported the determination of peak growth which occurs at adolescent growth spurt helps in supplementary growth mandible in skeletal Class II cases if intervened at the correct time. The study aimed to measure the height-width ratios of the frontal sinus in different stages of cervical vertebrae maturation in subjects with normal occlusion.

Among the various maturation indices, the CVM method was proved effective in determining the adolescent growth spurt in relation to body height and mandibular size. A study by Mitani H [1] reported the change in cervical vertebrae to be positively correlated with an increase in mandibular size. The CVM index was developed by Lamparski [5], modified by Hassel and Farman [9], and further modified thrice by Baccetti and co-workers [13-15]. The modified version by Baccetti et al. was used in the present study for the evaluation of CVM stages.

Ruf and Pancherz [8] presented the mean sinus growth velocity in mm/year, before, at, and after the sinus peak in 26 males between the age group 9-22 years. They reported the peak enlargement of the frontal sinus was seen by 15.1 years. In other words, the enlargement of the frontal sinus exhibited changes with growth spurts which is reported to be on an average of 1.4 years after the peak in body height [28]. A longitudinal study by Brown WA [20] on the enlargement of the frontal sinus by measuring maximal vertical height concluded that the median age for the first appearance of the frontal sinus was 3.25 years for boys and 4.58 years for girls. In the present study, the addition of subjects in or close to the circumpubertal period was ensured by the inclusion of subjects whose age ranged from 7-22 years. They were further segregated into 5 different age groups which were 7-10 years, 11-13 years, 14-16 years, 17-19 years, and 20-22 years. Because of the difference in the onset of the circumpubertal period, males and females were taken as 2 different study groups.

Patil and Revankar [29] suggested that if chronological age was compared with skeletal maturity assessment to evaluate the frontal sinus index, the results would have been more useful from the age estimation point of view. The subsequent cross-sectional study performed by Mahmood et al [30] included subjects from Karachi aged 8-21 years, divided into 6 groups based on CVM stages but the grouping was not based on age groups. In order to assess the level of skeletal maturity, they assessed the frontal sinus morphological variations using the sinus index derived by dividing the frontal sinus height by the frontal sinus width. They preferred this ratio rather than individually taking the height and width because they expected the size of the frontal sinus to vary according to the physical size of the patient and also to avoid possible magnification errors in the cephalograms. Hence, in the present study, height width ratio was taken as the parameter for comparison with different age groups as well as the different CVM stages. Mahmood et al [30] reported a significant difference (p<0.001) between males (n=126) and females (n=126) of their study group in the frontal sinus index/height-width ratio. The mean value reported by them for the frontal sinus index for males of the study group was 2.67±0.51 and for females of the study group was 2.98±0.58. They found that the sinus index when compared between the genders showed a statistically significant difference, with females having a larger value for the index when compared to males. The mean frontal sinus height-width ratio for the males and females of the present study group were 2.45±0.27 and 2.57±0.25 respectively (p<0.05, Table 2). The result of the present study was in agreement with the study of Mahmood et al [30] where a significant difference was observed (p<0.05) in comparison of the frontal sinus index between males and females of the study group. Also, the females of the present study group had a larger sinus height width ratio similar to the study reports by Mahmood et al [30].

The height-width ratio of the frontal sinus in the study population (males and females together i.e., total population) of the present study does not differ with different age groups (Table 1). The height-width ratio did not differ with the cervical vertebrae maturation stages in males, females, or the total population of the study population (Table 2). When the height-width ratio was calculated according to different CVM stages, the CS3 stage showed decreased value in females compared to males. The height-width ratio in the other stages was higher in females than that in males. In the study by Mahmood et al [30], the frontal sinus index was found to be higher in all states except the CS1 stage in females when compared to males.

Table 1: Frontal sinus height width ratio according to different age groups in males, females and total population.

Study Population	Frontal sinus height width ratio Mean±SD					P value
	7-10 years	11-13 years	14-16 years	17-19 years	20-22 years	
Males	2.28±0.29	2.58±0.25	2.40±0.20	2.43±0.10	2.45±0.02	0.08
Females	2.55±0.33	2.58±0.23	2.61±0.21	2.59±0.30	2.48±0.24	0.72
Total population	2.41±0.34	2.58±0.23	2.54±0.23	2.55±0.27	2.48±0.22	0.15

Table 2: Frontal sinus height width ratio according to different CVM stages in males, females and total population.

Study Population	Frontal sinus height width ratio Mean±SD						P value
	CS1	CS2	CS3	CS4	CS5	CS6	
Males	2.31±0.31	2.50±0.31	2.59±0.28	2.44±0.23	2.40±0.13	2.40±0.08	0.44
Females	2.50±0.33	2.71±0.18	2.57±0.23	2.67±0.20	2.53±0.23	2.53±0.27	0.41
Total Population	2.41±0.33	2.57±0.29	2.57±0.24	2.59±0.23	2.51±0.22	2.51±0.24	0.27

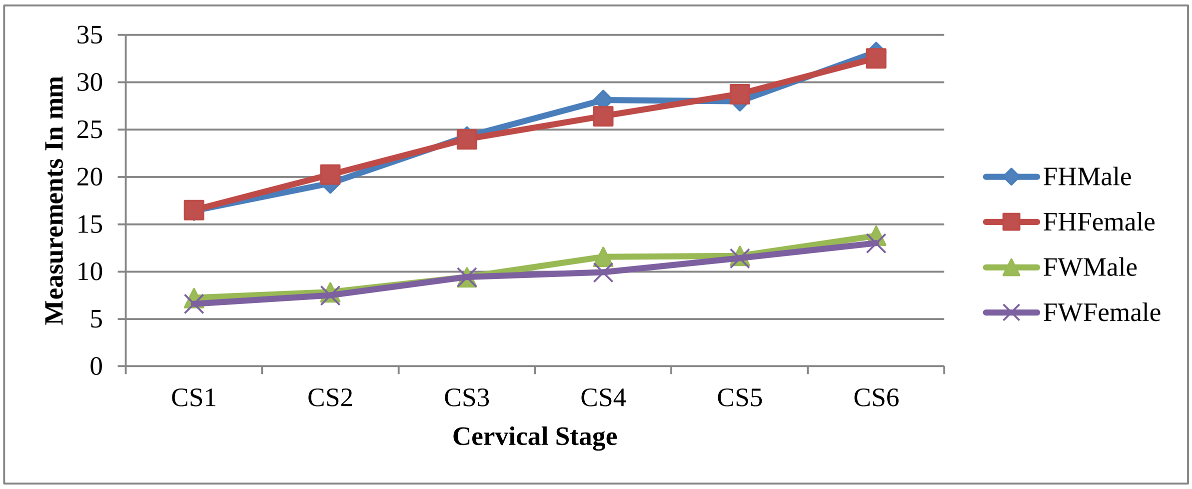

Figure 1: Frontal Sinus Parameters of Males and Females in the different CVM stages.

In the present study, the frontal sinus height in different age groups ranged from 16.9±1.58 mm to 33.00±1.41 mm in males, 17.18±3.09 mm to 32.62±2.06 mm in females and 17.05±2.40mm to 32.67±1.95mm in the total population (Table 1). When compared to study reports by Mahmood et al [30], the frontal sinus height was less in all the CVM stages in males in the present study. In females, with the exception of CS6, their study population showed larger dimensions in frontal sinus height. The frontal sinus width in males of their study population had a higher value in all CVM stages except CS1 and CS4. The width of the frontal sinus in females of the study population of the present study, however, showed a numerically higher value in CS3, CS4, CS5, and CS6 when compared to their study.

According to various past studies [28,31-33], larger frontal sinus dimensions were associated with larger mandibles or in other words, in skeletal Class III patients. However, smaller sinuses were not associated with skeletal Class II patients [32, 33]. Due to this reason, only patients with normal occlusion were included in the study. A statistically significant correlation (0.333) of frontal sinus width with age was observed by Singh et al [34] but an inconsistent correlation was observed in frontal sinus width with CVMI. The study by Mahmood et al [30] showed a weak negative correlation ($p<0.001$) between frontal sinus measurement and CVMI in males and a statistically insignificant correlation in females. In the present study, there was a strong positive correlation of the frontal sinus width as well as height, with CVM in males and females ($p<0.05$) contrary to the study by Mahmood et al [30].

Szilvassy [21] assessed the growth rate of the frontal sinus in 215 subjects from 3-17 years (117 males and 98 females) and found a significant difference between males and females in terms of the growth rate of the frontal sinus. During 3-5 years, males and females showed an even increase in size. The retardation in the growth at 8-12 years in males, when compared to females, was reflected in the frontal sinus dimensions too. Substantial acceleration in the frontal sinus size in males was seen at the age of 14-15 years and it surpassed the female ones with respect to size. The frontal sinus formation ceased by the age of 18 years in their study. In the present study, the frontal sinus height in males was seen to surpass that of females only by the age of 17 years and it extended to 22 years. The frontal sinus width, however, showed an increase in males in all age groups except 11-13 years where the females had a greater measurement in width. In contrast to the study by Szilvassy [21], the formation of the frontal sinus did not finish by 18 years (Table 1).

Tehranchi et al [35] evaluated radiographic variations and dimensions of frontal sinuses in 40 females and 26 males who were older than 12 years and concluded that the frontal sinus dimensions were larger in men than in women even though it was statistically not significant. In another study by Tehranchi et al [33] on the correlation between frontal sinus dimensions and cephalometric indices, 78 females and 66 males with a mean age of 19.26±4.66 years were included and found a similar result to the previous study, i.e., the dimensions of the frontal sinus were larger in males compared to females. Other studies that reported a statistically significantly larger frontal sinus in men compared to women were Harris et al [22] and Ponde et al [36].

This was in agreement with the present study where after 17 years the males have a larger frontal sinus height when compared to their female counterparts. In the case of the frontal sinus width except in the age group 11-13 years, the males have a larger frontal sinus width dimension. The difference, however, is statistically not significant. In the different CVM stages, the females have a greater value for frontal sinus height in CS1 and CS2 but by CS3 to CS6, the males demonstrated a larger dimension. However, when frontal sinus width was considered in different CVM stages, the males had a dimensionally larger frontal sinus in all stages and it was statistically significant in CS4 (Table 2).

Many studies [24, 28, 37] which were done in a longitudinal manner, had assessed the sinus growth velocity with the help of sequential radiographs and hence could determine the frontal sinus growth peak analogous to the adolescent growth spurt. The lack of sequential records in the department and the ethical considerations of exposing subjects to annual radiographs to assess the growth of the sinus were the main reasons for not attempting a longitudinal study.

CONCLUSION

The study has confirmed that there is a close relationship between certain cervical maturation stages and frontal sinus dimensions. We can conclude that as the skeletal maturity of the individual increased with age, the height and width of the frontal sinus also increased in a linear pattern but, the height-width ratio failed to show a specific pattern among the different CVM stages. Hence, even though frontal sinus height and width were statistically significantly associated with the different age groups and cervical stages, the frontal sinus height-width ratio failed to characterize the different stages of the adolescent growth spurt.

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