

Development of the frontal sinus in relation to somatic and skeletal maturity. A cephalometric roentgenographic study at puberty

Sabine Ruf and Hans Pancherz

Department of Orthodontics, University of Giessen, Germany

SUMMARY The development of the frontal sinus in relation to somatic and skeletal maturity was analysed in 26 male subjects aged 9–22 years by means of longitudinal data obtained from lateral head films, handwrist radiographs and body height growth curves. These were grouped together and analysed in a cross-sectional manner. The results revealed that the final size of the frontal sinus varied considerably. Analogous to body height growth at puberty, the enlargement of the frontal sinus exhibited a similar pattern with a well-defined peak, which on average occurred 1.4 years after the body height peak. In comparison with skeletal maturity, 65 per cent of the subjects reached the sinus peak during the hand radiographic stages MP3-G or MP3-H, while the body height peak coincided with an earlier maturity stage (MP3-FG).

Introduction

The frontal sinus is part of the paranasal sinuses and originates from the anterior ethmoidal cells that start their migration into the frontal bone at the end of the first year of life. With increasing pneumatization the frontal sinus becomes radiographically evident around the age of 8 years, when it projects above the orbital rim (Dolan, 1982; Maresh, 1940).

Several investigations on the enlargement of the frontal sinus from childhood to adulthood and on the physiological variability of the sinus size have been published (Maresh, 1940; Siedband, 1966; Süsse *et al.*, 1968; Ertürk 1968; Hajnis and Pozdenova, 1972; Pobornikova, 1974; Brown *et al.*, 1984; Laude *et al.*, 1986). However, the factors contributing to sinus enlargement have to this date not been completely understood. Individual differences in the growth and resorption processes of the mucosa (Wittmaack, 1918; Süsse, 1964), the quality of the frontal bone which is to be pneumatized (Schloßhauer, 1954), the pressure of the growing brain on the internal lamina of the frontal sinus area (Noetzel, 1949, 1950), the various pressure and hydrodynamic conditions of the endocranium affecting the blood supply of the frontal sinus area (Süsse, 1964) and hereditary

factors (Shea, 1936) are made responsible for sinus enlargement. Furthermore, it has been proposed (Brown *et al.*, 1984) that frontal sinus enlargement follows general bone growth but no proof has been given.

Aim

The aim of the present cephalometric roentgenographic study was to analyse frontal sinus enlargement during the pubertal growth period in relation to body height growth (somatic maturity) and to epiphysial development of the middle phalanx of the third finger and radius (skeletal maturity).

Subjects

From the original male sample of 72 Class II division I malocclusions treated with the Herbst appliance (Hägg and Pancherz, 1988), 26 patients were selected in which the following data existed:

- (i) body height growth records covering the pubertal growth period.
- (ii) lateral head films and handwrist radiographs covering a period from before the pubertal growth peak to the end of pubertal growth.

(iii) clinical records proving that no impairment of the nasal airways existed.

The radiographs were taken at yearly intervals. The average observation period was 7.9 years (range 4–11 years) and was in all cases extended to the end of pubertal growth defined by the handwrist radiographic stages R-IJ or R-J (Hägg and Taranger, 1980).

Methods

Evaluation of lateral head films

The lateral head films were orientated with the nasion–sella line horizontally. The peripheral border of the frontal sinus was traced and the highest (Sh) and lowest (Sl) point of its extension were marked (Ertürk, 1968). Perpendicular to the interconnecting line Sh–Sl the maximal width of the frontal sinus was assessed (Fig. 1). The values measured were not corrected for radiographic enlargement of ~7 per cent. Based upon the sinus width data of the subjects the average growth velocity (mm/year) was calculated. The maximum pubertal sinus growth velocity was assigned as sinus peak (Sp).

Handwrist radiographs

The handwrist radiographs were evaluated according to the method described by Hägg and

Taranger (1980). The epiphyseal development of the middle phalanx of the third finger and of the distal part of the radius were used as indicators of skeletal maturity (Figs. 2 and 3).

Body height growth curves

Growth records of standing body height over a period of 5–10 years were available of all subjects. The body height registrations were made every 3–6 months. By means of a computer program, individual velocity curves of standing

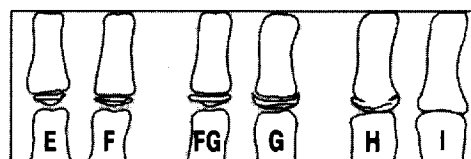


Figure 2 Skeletal maturity stages of the middle phalanx of the third finger (MP3) in progressive order (Hägg and Taranger, 1980):

Stage E: the epiphysis is not yet as wide as the metaphysis.

Stage F: the epiphysis is as wide as the metaphysis.

Stage FG: the epiphysis is as wide as the metaphysis and there is a distinct medial and/or lateral border of the epiphysis forming a line of demarcation at right angles to the distal border.

Stage G: the sides of the epiphysis have thickened and also cap its metaphysis, forming a sharp edge distally at one or both sides.

Stage H: fusion of epiphysis and metaphysis has begun.

Stage I: fusion of epiphysis and metaphysis is completed.

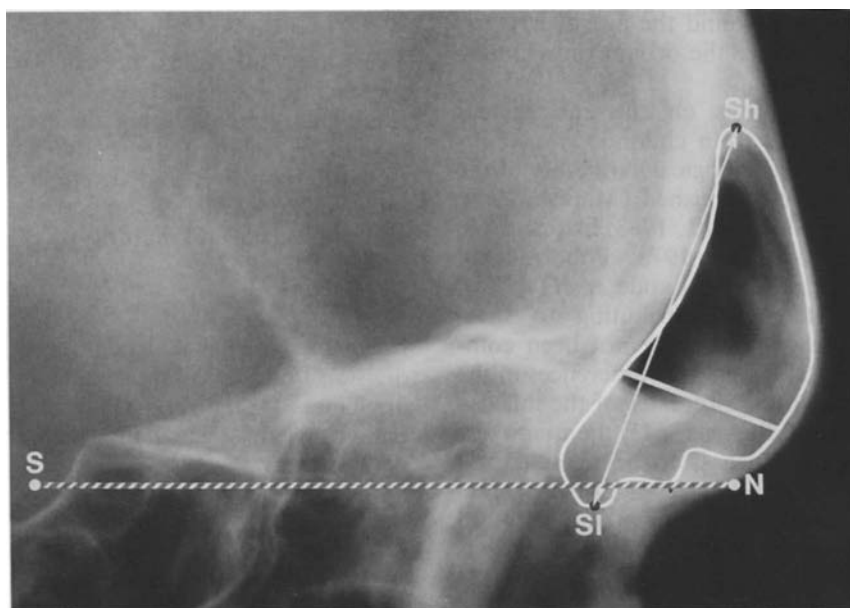


Figure 1 Assessment of the maximal frontal sinus width perpendicular to the interconnecting line Sh–Sl.

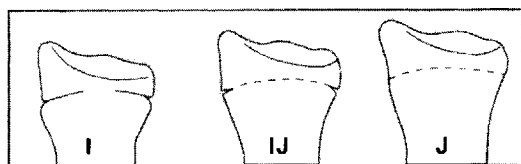


Figure 3 Skeletal maturity stages of the distal epiphysis of the radius (R) in progressive order (Hägg and Taranger, 1980):

Stage I: fusion of epiphysis and metaphysis has begun.

Stage IJ: fusion is almost completed but there is a small gap at one or both margins.

Stage J: fusion of epiphysis and metaphysis is completed.

height were constructed (Pancherz and Hägg, 1985). The age of maximum pubertal body height growth velocity was identified by visual inspection of the curves and assigned as body height peak (Bp).

Statistical methods

For the different variables the arithmetical mean (M), the standard deviation (SD), the maximum (Max) and minimum (Min) were calculated.

The age of the subjects at the attainment of different yearly sinus growth velocities and of different stages of somatic and skeletal maturity was defined as the midpoint of the age interval during which the changes occurred. If more than one skeletal maturity stage was attained during the time interval of two consecutive handwrist radiographs, the interval was divided into equal parts. As the lateral cephalograms were not taken at exactly the same ages in all subjects, sinus growth velocity was calculated for complete years of life. All data were related to sinus peak or body height peak to allow comparison between subjects.

Error of the method

For the assessment of the method error in the calculation of the sinus size, the head films from 10 randomly selected subjects were analysed twice. The following formula was used for the method error (ME) calculation: $ME = \sqrt{(\sum d^2/2n)}$, where d is the difference between two measurements of a pair and n is the number of subjects. The combined ME in tracing the frontal sinus, defining the reference points (Sh and Sl) and measuring the sinus width amounted to 0.22 mm.

The intra-examiner error of skeletal maturity

assessment (Hägg and Pancherz, 1988) was calculated earlier. The frequency of identical ratings was 92 per cent.

Results

Frontal sinus size

At the end of the observation period the frontal sinus had an average width of 15.4 mm (9–28 mm).

Frontal sinus enlargement

Frontal sinus growth velocity varied intra- and inter-individually to a great extent. While some subjects exhibited a smooth increase in sinus size, others showed a more abrupt enlargement. A pubertal peak was, however detectable in all subjects and amounted to an average of 1.9 mm/year (Table 1 and Fig. 4). The sinus enlargement pattern was similar to that of body height development (Figs. 5 and 6). In 84 per cent of the subjects, the peak growth velocity was at least 1.3 mm/year during an observation period of 1 year around the peak. In 70 per cent of the subjects, the peak growth velocity was at least 1.2 mm/year during an observation period of 2 years around the peak.

The pubertal sinus peak (Sp) took place at a mean age of 15.1 years. (12.5–17.5 years) following body height peak (Bp) by an average of 1.4 years. The time relationship between Sp and Bp for the individual cases is shown in Figure 7.

In 17 of the 26 subjects (65%), the pubertal

Table 1 Sinus growth velocity (mm/year) before (–), at and after (+) the pubertal sinus peak (Sp). The arithmetic mean, SD, maximum, minimum and number of subjects (n) with data available are given.

Years	Mean	SD	Maximum	Minimum	n
–5	0.3	0.2	0.5	0	4
–4	0.7	0.4	1.4	0	8
–3	0.7	0.5	1.6	0.2	14
–2	0.7	0.6	2.7	0	21
–1	0.8	0.5	1.7	0	23
Sp	1.9	0.7	3.2	0.5	26
+1	1	0.6	2.5	0	26
+2	0.5	0.5	1.9	0	25
+3	0.4	0.3	1.4	0	21
+4	0.4	0.4	1.4	0	16
+5	0.3	0.2	0.8	0	11
+6	0.4	0.4	1.1	0	9
+7	0.4	0.2	0.7	0.2	2

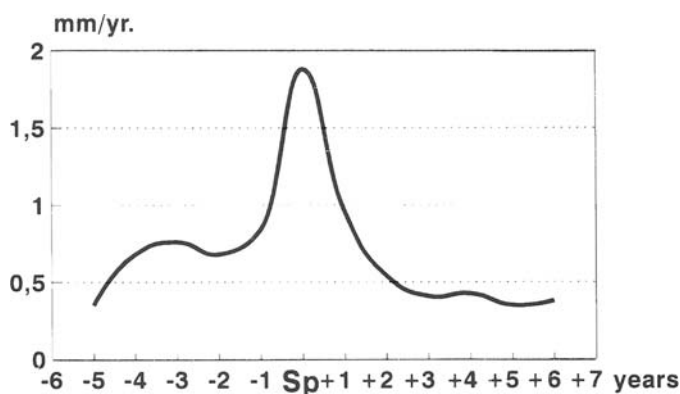


Figure 4 Mean sinus growth velocity (mm/year) before (–), at and after (+) sinus peak (Sp) determined in 26 male subjects.

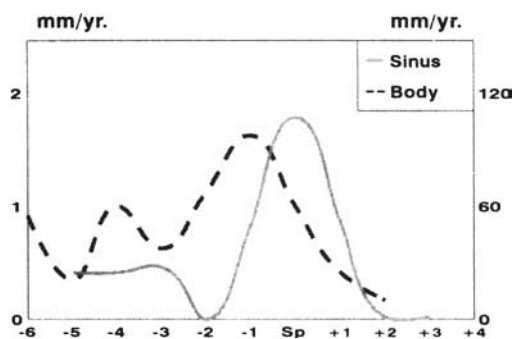


Figure 5 Case 1: Pubertal body height growth velocity and sinus growth velocity (mm/year) in a boy followed from 10–18 years of age.

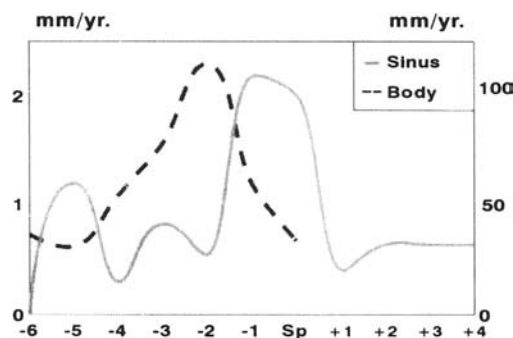


Figure 6 Case 2: Pubertal body height growth velocity and sinus growth velocity (mm/year) in a boy followed from 10–19 years of age.

sinus growth peak coincided with the skeletal maturity stages MP3-G or MP3-H (Fig. 8). The

pubertal body height peak on the other hand took place during an earlier maturity stage (MP3-FG). The time relationship between the skeletal maturity stages and sinus growth peak is given in Table 2 and Figure 9.

End of frontal sinus growth

The end of sinus growth could not be determined by means of the present material. At the skeletal maturity stages R-IJ and R-J no increase in sinus size was found in six of the 26 subjects (23 per cent), while continuous growth was noted in 20 subjects (77 per cent).

Discussion

In agreement with several authors (Maresch, 1940; Siedband, 1966; Süsse *et al.*, 1968; Ertürk 1968; Hajnis and Pozdenova, 1972; Pobornikova, 1974; Brown *et al.*, 1984; Laude *et al.*, 1986) the sinus size exhibited a large variation at the end of body height growth. The cause for this variation is however unknown.

The end of frontal sinus enlargement could not be determined in the present study which was in accordance with other authors (Brown *et al.*, 1984; Leonhardt, 1986; Szilvassy, 1981). While in some cases the sinus growth ceased with the end of pubertal body height growth (R-IT or R-J) in other cases it went on beyond the skeletal maturity stage R-J. Although Szilvassy (1981) observed a period of slow sinus enlargement during childhood (8–12 years) followed by an increased growth rate during ado-

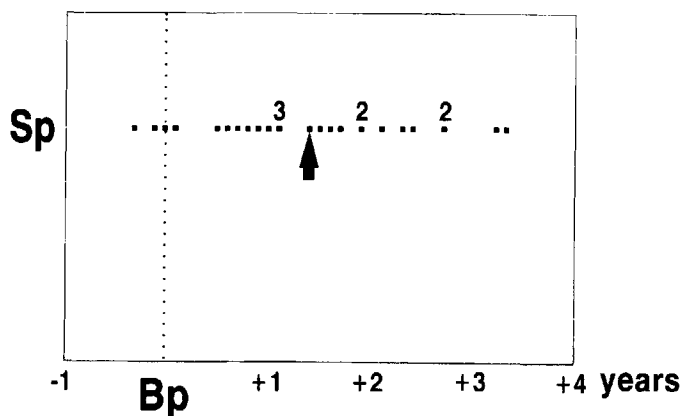


Figure 7 Attainment (years) of the pubertal sinus peak (Sp) in relation to body height peak (Bp) in 26 male subjects. The mean deviation (\rightarrow) of Sp in relation to Bp is marked.

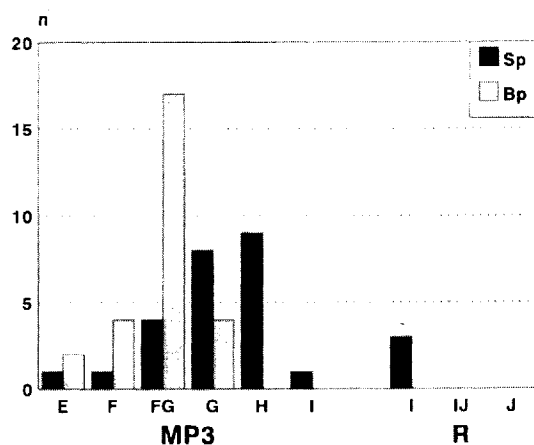


Figure 8 Incidence (number of subjects) of the pubertal sinus peak (Sp) and the body height peak (Bp) in relation to different skeletal maturity stages determined in 26 male subjects.

Table 2 Attainment (in years) of different skeletal maturity ages before (–) and after (+) the incidence of sinus peak (Sp). The arithmetic mean, SD, maximum and minimum are given.

	MP3-F	MP3-FG	MP3-G	MP3-H	MP3-I
Mean	–2.1	–1.3	–0.3	+0.4	+1.4
SD	1.3	1.3	1.2	1.3	1.2
Maximum	+0.4	+1.8	+2.8	+3.8	+4.8
Minimum	–3.9	–3.3	–2.3	–1.7	–0.3

lescence (12–17 years) he did not report a sinus growth peak.

Previous investigations have shown a relationship between skeletal and somatic development (body height growth) on the one hand (Björk and Helm, 1967; Helm *et al.*, 1971; Grave and Brown, 1976; Hägg and Taranger, 1980) and facial growth on the other hand (Nanda, 1955; Hunter, 1966; Bergensen, 1972). The comparison of sinus enlargement with skeletal maturity stages revealed that in the majority of the cases sinus peak occurred during the skeletal stages MP3-G or MP3-H, while body height peak coincided with a less mature stage (MP3-FG). Furthermore the sinus peak on average occurred 1.4 years after body height peak. Thus sinus enlargement was delayed in comparison to somatic and skeletal development.

Waldeyer and Mayet (1979) stated that the frontal sinus enlarges through resorption of functionally unused areas. This developmental process of the frontal sinus as an adaptation to the changing functional demands could render a possible explanation for the relative delay of a sinus peak.

Baer and Harris (1969) interpreted the development of the frontal sinus as a process of structural adaptation to the forward and downward growth of the midface with the forward growth of the external lamina of the frontal bone being essential to keep the contact with

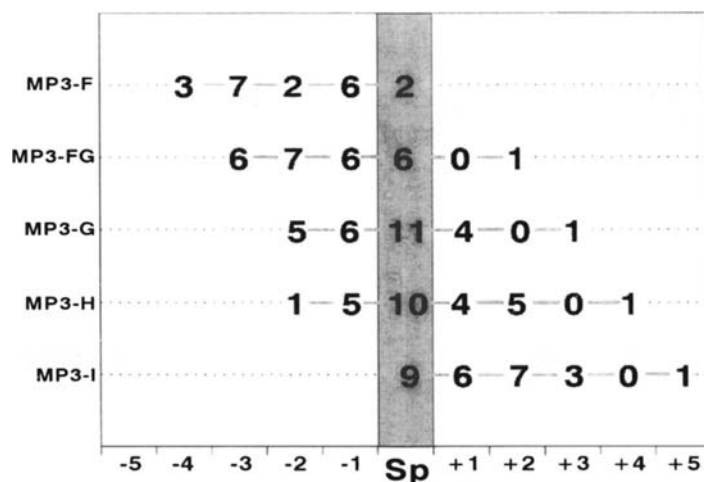


Figure 9 Attainment (years) of different skeletal maturity stages in relation to the pubertal sinus peak (Sp) determined in 26 male subjects. The number of subjects who had reached a certain skeletal maturity stage at different time intervals before (-), at and after (+) the sinus peak (Sp) is shown.

the nasal bone and the maxilla. Therefore orthodontic therapy could theoretically affect sinus enlargement. As all subjects of the present investigation were orthodontically treated with a Herbst appliance (Herbst, 1934), which has a marked headgear effect on the maxilla (Pancherz and Anchus-Pancherz, 1993), the restraint of maxillary growth induced by the Herbst appliance could thus possibly inhibit frontal sinus enlargement. However, sinus growth did follow body height growth even during the active period of orthodontic treatment, so that an influence of Herbst therapy on the enlargement of the frontal sinus does not seem likely.

Conclusion

Analogous to body height growth at puberty, the enlargement of the frontal sinus exhibited a similar pattern with a well-defined peak which occurred on average 1.4 years after body height peak. In comparison with skeletal maturity, 65 per cent of the subjects reached the sinus peak during the skeletal maturity stages MP3-G or MP3-H, while body height peak coincided with a less mature stage (MP3-FG).

Further investigations are in progress to elucidate if frontal sinus growth renders a possibility for predicting somatic and skeletal maturity.

Address for correspondence

Dr. Sabine Ruf
Abteilung für Kieferorthopädie
Zentrum für ZMK
Justus-Liebig-Universität Giessen
Schlangenzahl 14
D-35392 Giessen
Germany

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