

## Enlargement of the frontal sinus

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**Summary.** The enlargement of the frontal sinus has been analysed in a longitudinal study of 49 males and 47 females for whom a first lateral cephalogram was available at from 2 to 5 years of age for 88 subjects and from 6 to 11 years for 8 subjects. Thereafter the cephalograms were taken at approximately yearly intervals and in 28 subjects a last cephalogram was taken at 24 years or older. In only six subjects was enlargement of the sinus still proceeding at the time of the last cephalogram.

The enlargement was assessed by a standardized measurement of the maximum vertical height of the sinus. The median age for the first appearance of the frontal sinus was 3.25 years for the boys and 4.58 years for the girls. It enlarged on average to 32.60 mm (SD 9.10) in the males and 26.60 mm (SD 7.50) in the females.

The median age at which the main increase in size of the sinus ceased was 15.68 years for boys and 13.72 years for girls, thus suggesting that the enlargement of the frontal sinus, a mainly osteoclastic activity, follows very closely the trends for growth in bone lengths.

### 1. Introduction

Logan Turner (1901) reported the frequent absence of the frontal sinus in Australian aboriginals, while Brothwell, Molleson and Metreweli (1968) noted that modern African negroes usually have well-developed frontal sinuses. Wolfowitz (1974) suggested from an examination of the frontal sinus among Bantus and Europeans in South Africa that there might be a genetic basis to the diversity of frontal sinus development in different races. An important prerequisite to any genetic study would be to know at what age the frontal sinus size and shape ceased to change.

The annual height (stature) growth increments in children reach a plateau at 16 years in boys and 14 years in girls (Tanner 1962) and it was thought that these too are the ages that the frontal sinus enlargement ceased. This view is supported by Maresh's (1940) observation that the frontal sinus reached full size soon after puberty, but the oldest subject in Maresh's sample was only 17 years, and so what took place in later years could only be a surmise. Furthermore, Weinmann and Sicher (1955) referred to a senile enlargement of the frontal sinus, suggesting that some growth may still take place after puberty, but gave no indication of how much or in how many subjects this occurred. Because the data on when sinus enlargement ceased are imprecise, an analysis has been made of the lateral cephalograms from the longitudinal studies undertaken and reported by Leighton (1971), Bhatia and Leighton (1971), and Bhatia, Wright and Leighton (1979), of subjects who had been followed for up to 24 years of age. It has been possible to determine when sinus enlargement ceases, the earliest age the sinus may be observed and mean length of the growth period as well as the final height of the frontal sinus.

## 2. Subjects and methods

### Sample

The cephalograms for this study were derived from over 500 children who were born in hospital and were normal at birth. Their dental status was recorded from birth and cephalograms were taken on a yearly basis from two years old or later until the taking of cephalograms for research purposes was stopped by the King's College Hospital Ethical Committee in 1975. Since then, 28 of the subjects agreed to the taking of a final cephalogram to complete the longitudinal series. The cephalograms of 49 males and 47 females have been analysed.

Table 1. The data available for estimation of the age (years) of appearance of the frontal sinus in 49 boys and 47 girls.

Age at cephalogram before sinus observed	Age at which sinus first observed on a cephalogram										
	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	
(censored observation)	1/-	10/11	13/5	5/4	2/1	1/1			2/-	1/-	
2+											
3+			2/-	2/3							
4+				2/4		2/2					
5+					1/3	1					
6+						3/4					
7+						1/-	1/2	1			
8+								1/1		1	
9+								1	2		
10+										1	
11+											

Each result shows boys/girls.

Table 1 gives the number of male and female subjects in each age group for whom the frontal sinus was present in the first available or subsequent cephalograms. For over half of the boys and almost half of the girls the frontal sinus was observed on the first cephalogram. For each of these children the data on age at appearance of the frontal sinus was expressed as less than the age at the first cephalogram, 'censored' data in statistical terminology. For each of the remaining children, the age at the last cephalogram on which the frontal sinus was not observed and the age at the cephalogram

Table 2. The data available for estimating the age (years) for the cessation of the main enlargement of the frontal sinus in 49 boys and 47 girls.

Age at cephalogram before cessation of enlargement	Age at cephalogram at which sinus is known to have ceased its main enlargement											
	10+	11+	12+	13+	14+	15+	16+	17+	18+	19+	20+	†
7+												
8+												
9+												
10+	1/-	1/-										
11+		1/3	-2	-3								
12+		-1	-3	-1	-1	-1						
13+				2/8	1/2							
14+				5/-	-5	1/1	-1					
15+						5/2	1/1					
16+						1/-	10/7					2/-
17+								5/4				2/-
18+								1/-	3/-	2/-		1/-
19+										1/-	1/-	1/-
												-1

Each result shows boys/girls.

† Censored observation at penultimate cephalogram.

following, on which it was first observed, provided an age range in which the frontal sinus appeared, a confined observation. The data for estimating the age for the cessation of the main enlargement of the frontal sinus were treated in a similar manner, table 2.

#### Frontal sinus measurement

Only lateral cephalograms taken at approximately yearly intervals were available, and though not all the cephalograms were equally easy to interpret, the frontal sinus could be clearly seen when it was present. For this study, to assure comparability between the cephalograms, tracings were made on Rocky Mountain tracing paper. Sella *S*, the centre of the sella turcica, and nasion *N*, the junction between nasal and frontal bones, were aligned on a straight line previously drawn onto the tracing paper, and onto this the complete outline of the frontal sinus on and above the sella-nasion line and the related part of the frontal bone were traced. The height of the sinus was measured by dropping a line from the most superior point of the sinus perpendicularly to the sella-nasion line (figure 1). For each subject, the heights of the frontal sinuses for a longitudinal series of cephalograms were plotted against age on graph paper. Measurements were made to the nearest millimetre; a cephalogram would give 6.8% to 8.6% enlargement of head size.

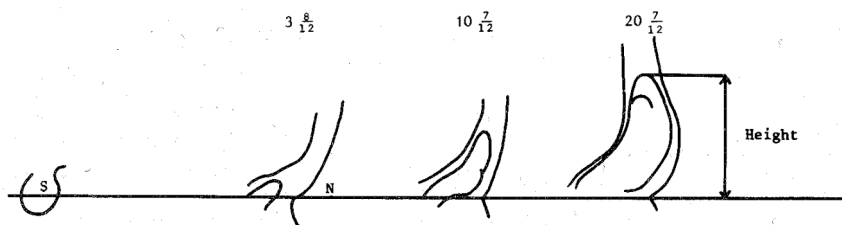


Figure 1. Selected tracings of Case No. 342 at 3 years 2 months, 10 years 7 months and 20 years 7 months. For all the tracings Sella (*S*) and Nasion (*N*) were aligned on a straight line and the outlines of the frontal sinus and the frontal bone were drawn. The height of the sinus was measured by dropping a line from the top of the sinus perpendicular to the sella-nasion line.

#### Analysis

The median age at appearance, a 95% confidence interval for the median age, and a range of age in which the frontal sinus could be expected to appear in 95% of children were estimated on the assumption of a log-normal distribution of the age of appearance. A maximum likelihood estimation procedure (Wolynetz 1979) was used to obtain for the boys and girls separately the mean age at appearance, standard deviation and standard error of the mean on the log-age scale. Confidence intervals and 95% ranges were calculated and transformed back to age in years.

The median ages at cessation of the main enlargement and total enlargement were estimated in a similar manner. The main enlargement of the frontal sinus is the increase in size which has taken place by the age of puberty. Around this age, for varying periods of from one or more years, there is frequently a quiescent period. This is then followed by a prolonged period of very slow increase in size until the sinus reaches its total enlargement when two cephalograms indicated that enlargement had ceased or temporarily ceased, the age at the first of these cephalograms and the age at the one before this provided confined data for age at cessation of total enlargement or main enlargement. Where the last two cephalograms indicated that enlargement was continuing, the age at the first of these was used as the censoring point. A log-normal distribution was again assumed.

The mean duration of the enlargement period was estimated in a similar way, but a normal distribution was assumed for years of enlargement as there was no reason to think that this distribution was skewed. The length of the enlargement period was confined between minimum age of cessation less maximum age of appearance, and maximum age of cessation less minimum age of appearance, or zero. The data were censored if a maximum age of cessation of enlargement was not known. If the maximum age of appearance was greater than the minimum age at cessation the lower limit was taken as zero.

### 3. Results

The results are given in tables 3 and 4. The mean duration of enlargement periods, and the differences between median ages at appearance of frontal sinus and cessation of enlargement differ slightly because of the log-normal assumption in the calculation of

Table 3. The median age, 95 % confidence interval for median and the 95 % range for the appearance of the frontal sinus, the end of the main enlargement, and completion of enlargement. Note that for six of the boys the sinus was still enlarging at time of last cephalogram.

	Boys (N=49)	Girls (N=47)
<i>First appearance</i>		
Median age (years)	3.25	4.58
95% confidence interval for median	2.52- 4.18	3.83- 5.49
95% range	1.18- 8.95	1.63-12.92
<i>End of main enlargement period</i>		
Median age (years)	15.68	13.72
95% confidence interval for median	15.03-16.36	13.14-14.32
95% range	11.76-20.91	10.29-18.28
<i>Completion of enlargement</i>		
Median age (years)	17.51	14.94
95% confidence interval for median	16.69-18.38	14.08-15.85
95% range	12.68-14.18	10.02-22.26

Table 4. The mean + SE, 95% confidence interval for mean and 95% range for the duration of (a) the main enlargement period and (b) the total enlargement period for the frontal sinus.

	Boys (N=49)	Girls (N=47)
<i>Duration of main enlargement period</i>		
Mean ± SE (years)	12.20 ± 0.38	8.78 ± 0.52
95% confidence interval for mean	10.24 - 14.16	7.77 - 9.79
95% range	8.09 - 16.31	2.39 - 15.17
<i>Duration of total enlargement period</i>		
Mean ± SE (years)	14.10 ± 0.50	10.24 ± 0.60
95% confidence interval for mean	13.13 - 15.08	9.07 - 14.14
95% range	8.35 - 19.86	2.70 - 17.79

Table 5. The mean, standard deviation and range for the final height of the frontal sinus in males and females.

	Number	Height (mm) on last observation		
		Mean	SD	Range
Males	49	32.60	9.10	13.00-55.00
Females	47	26.60	7.10	14.00-48.00

the latter. The results show that the frontal sinus appears later in girls ( $P < 0.05$ ) but both main enlargement and total enlargement cease at an earlier age in girls on average ( $P < 0.001$ ). Hence the length of the growth period in girls is much shorter than in boys, but from the direct analysis it was found to be slightly more variable. The mean final size of the frontal sinus is larger in males than females (table 5).

#### 4. Discussion

##### *The age of first appearance*

The early age at which the frontal sinus may be identified confirms the findings of Maresh (1940) who gave an age range of from two to six years. The later age of first participation in this growth study of some of the sample, 18 of whom were five years or older, but who already had a measurable frontal sinus suggests that for most of the sample an early commencement of frontal sinus enlargement is the norm. Nevertheless, there were eight boys and 15 girls for whom there was no readily detectable evidence of the frontal sinus above the sella to nasion line until they were seven years or older. The average final sinus height achieved by these males was 25.10 mm, 7.50 mm less than the male average sinus height, and for the females 22.70 mm, 3.90 mm less than the female average (table 6).

Table 6. The mean, standard deviation (s.d.) range for the age of the frontal sinus when first observed for males and females for whom there was a delayed appearance of the frontal sinus (more than 1 SD).

	Number	Mean	SD	Range
Age (years) sinus first observed	8 (M)	8-40	1-50	7-20-11-50
Height (mm) on final observation	15 (F)	8-00	1-70	7-40-12-50
Age (years) sinus height mainly achieved	8 (M)	25-10	5-70	17-00-36-00
Height (mm) on final observation	15 (F)	23-70	7-10	7-00-36-50
Age (years) sinus height mainly achieved	8 (M)	16-80	1-60	14-70-19-00
Height (mm) on final observation	15 (F)	14-60	2-60	11-00-20-00

No correlation was found between the age of onset and the final sinus height for whole sample. M, Males; F, Females.

##### *Completion of sinus enlargement*

The findings confirm that the main enlargement of the frontal sinus is completed at around 16 years and 14 years for boys and girls, respectively, which is very similar to Tanner's (1962) figures for the plateauing of annual growth increments in children. There are insufficient data in our sample to detect with confidence a pubertal growth spurt.

After the main enlargement of the sinus had taken place, there was for 15 of the males and 10 of the females a mean additional enlargement of 4.33 mm and 3.70 mm, respectively (table 7). This is in addition to the six males for whom sinus enlargement appeared not to have finished. Among the 28 cases for whom cephalograms were available at 24 years or older, only seven subjects showed any additional increase in size

Table 7. The mean (mm), standard deviation and range of increase of frontal sinus size for 15 males and 10 females for whom there was a measurable increase of sinus height after the main enlargement had taken place.

	<i>N</i>	Mean	SD	Range
Males	15	4.30	3.20	1.00-12.00
Females	16	3.70	2.40	1.00- 8.00

from the time of their penultimate cephalogram and the amount of this increase was less than 3-Omm in all of these.

It is apparent that there is in some subjects a small additional increase in frontal sinus height, several years after it may be assumed that full body height has been reached; but whether or not this continues into old age as suggested by Weinmann and Sicher (1955) is not known.

#### *Duration of frontal sinus enlargement*

The median age at which the sinus appears for the girls is one year later than the boys, and yet the duration of enlargement for the girls is shorter by four years, which may explain why the mean final height for the sinus of the females is 6 mm less than for the males.

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**Résumé.** L'agrandissement du sinus frontal a été analyse dans une étude longitudinale de 49 hommes et de 47 femmes pour qui un premier céphalogramme lateral était disponible à un age de deux a cinq ans pour 88 sujets et de six à onze ans pur 8 sujets. Ensuite les céphalogrammes étaient pris a des intervalles d'environ un an et, chez 28 sujets, un dernier Cephalogramme fut pris à 24 ans ou a un age plus avancé. Chez 6 sujets seulement l'agrandissement du sinus était encore en cours au moment du dernier céphalogramme.

L'agrandissement a été constaté par une mesure standardisée de la hauteur verticale maximum du sinus. L'age médian a la premiere apparition du sinus frontal était de 3.25 ans pour les garçons et ue 4,58 ans pour les filles. Il s'agrandissait en moyenne jusqu'a 32,60 (SD 9,10) mm chez l'homme et 26,60 (SD 7,50) mm chez la femme.

L'age median auquel l'agrandissement majeur du sinus cessait était de 15,68 ans chez les garçons et 13.72 ans chez les filles, suggerant ainsi que l'agrandissement du sinus frontal, une activité surtout osteoclastique, suit de très pres les tendances de croissance en longueur des os.