Norms of Size and Annual Increments of the Sphenoid Bone from Four to Sixteen Years

SHINJI NAKAMURA, D.D.S., D.D.Sc.

BHIM S. SAVARA, D.M.D., M.S.

DONALD R. THOMAS, B.S.

INTRODUCTION

The cranial base has been studied by many investigators. This interest is due partially to the cranial base being the dividing zone between the neurocranium and the facial skeleton, two areas of the head which grow at different rates. The growth changes in size, shape and position of the individual bones forming the cranial base must therefore exhibit a unique pattern of differential growth. Furthermore, many researchers in facial growth feel that some portion of the cranial base offers the most stable landmarks for use in superimposition of serial cephalograms. The extent of growth changes in the cranial base would obviously affect the usefulness of this practice.

The purpose of this investigation was to evaluate growth changes in one anatomical component of the cranial base, the sphenoid bone, which constitutes the middle part of the craniofacial structure. Norms of size and annual increments of nine anatomical measurements of the sphenoid bone of boys and girls from four to sixteen years of age are established and characteristics of the growth of the sphenoid bone are discussed.

REVIEW OF LITERATURE

Sicher[1] stated that the growth curve of the facial skeleton is widely different from that of the neurocranium. At birth the latter overshadows the former because of the advanced development of the brain and the lack of function of the masticatory apparatus. The brain and its capsule has reached ninety per cent of its final volume by the age of ten years and thereafter the annual increment is almost negligible. After the first year of life the facial skeleton grows not only faster than the brain case, but also retains a considerable rate of growth to the eighteenth year and probably ceases its growth much later. Although the cranial base grows with the growing skull, it furnishes the most convenient "fixed point" for growth studies.

Broadbent[2] also pointed out that landmarks above the face in the cranial base were relatively much more stable than those in the more rapidly growing lower face. He substantiated the stability of the Bolton-nasion plane of orientation and its registration point in the sphenoid area as the most fixed point in the head or face.

Steiner[3] chose the line sella-nasion as a reference line in analyzing cephalometric x-ray pictures of orthodontic patients.

Björk[4] measured cranial base angles (nasion-sella-articulare, nasion-sella-basion), frontal angle (frontale-nasion-sella) and head balance (angle between nasion-sella plane and a perpendicular to the foramen line) using longitudinal material. He found that the cranial base angle showed a marked individual variation and that the orientation of the face was correlated with the rotation of the cranial base and the brain case.

Brodie, Jr.[5] measured the incremental growth of the cranial base and the rela-

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tive contribution made by each part of the cranial base to the whole using an arc constructed through basion, sella turcica and nasion with projections through spheno-occipital junction and sphenoethmoidal junction. He concluded that the incremental growth curve of the whole cranial base, in general, resembled the neural type and that the relative contribution of any one part, once established, did not change significantly within an individual over the period studied.

Moss[6] investigated the postnatal growth of the human skull base. He measured three angles: the clivocribriform, the clivo-orbital, and the clivopalatal. In his research he mentioned that the basicranial region of the human skull base exhibited a characteristic flexure. The axis about which this bending occurs passes transversely through the body of the sphenoid bone dividing the skull base into pre- and postsella components. A change in the form or position of the components of the sphenoid bone complex will greatly influence the angular relations of the skull base affecting the maturation of both neural and facial skeletons.

Enlow[7] claims that the early cerebral expansion produces a disproportionately enlarged cranial vault relative to the cranial base. The bending of the sphenooccipital complex provides an adaptive adjustment between these two different growing regions of the cranium. The bending also results in the placement of the foramen magnum in a ventral location compatible with vertical posture and consistent with the spheroidal configuration of the whole skull. These factors are associated with the formation of a pocket in front of the cranial base beneath the overhanging prefrontal region of the cranium. This pocket is occupied by the developing facial complex.

Enlow[8] also demonstrated in the morphogenetic study of facial growth that the pattern of development of the entire face obscures actual growth patterns in individual anatomical units. Thus, growth patterns of individual bones must be examined separately if the total facial growth is to be made meaningful.

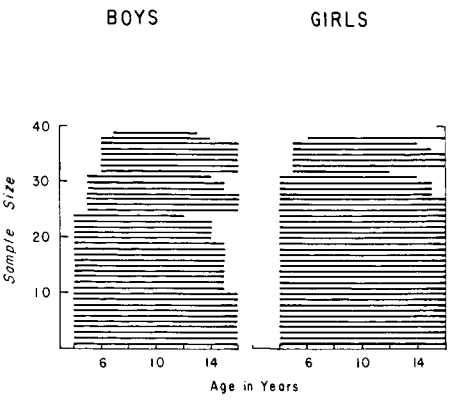

Fig. 1 Sample size and distribution.

Sample

Mixed longitudinal groups of thirty-nine boys and forty girls, who were registered in the Child Study Clinic at the University of Oregon Dental School, were used in this study. The children are predominantly of Northwest European ancestry.

Parents of the children are of middle socioeconomic status and reside in or near Portland. Selection of subjects for this study was based on completeness of records and observations for a minimum of ten years. Sample distributions of the boys and the girls are shown in Figure 1.

The sample size of the boys varied from a maximum of thirty-nine at age 7 through 8, to a minimum of twenty at age 16. The sample size of the girls varied from a maximum of forty at age 6 through 12, to a minimum of thirty-two at age 4.

Materials and Methods

Nine landmarks on the sphenoid bone were located on the serial lateral and

frontal cephalograms of each child.

The landmarks were defined as follows:

1) SE (Sphenoethmoidal suture): the most superior point of the suture in the midsagittal plane.
2) Sa The most anterior point of the anterior contour of sella turcica in the midsagittal plane.
3) SO (Spheno-occipital synchondrosis): The uppermost point of the suture in the midsagittal plane.
4, 5) SOF (Superior orbital fissure, right and left): The most lateral point of the superior orbital fissure where the lesser and greater wings of the sphenoid bone meet.
6, 7) ItC (Infratemporal crest, right and left): The most superior ventral point of the pterygomaxillary fissure is identical to the infratemporal crest of the sphenoid bone.
8, 9) PtP (Pterygoid process, right and left): The most infraventral point of pterygoid process is approximately identical to the most infraposterior point on the contour of the tuberosity of the maxilla.

Figure 2 shows the location of the landmarks used and the dimensions calculated.

All films for a given subject were examined and the age-to-age location of a landmark determined. After one landmark had been located on all films of a series, the same procedure was followed for each of the other landmarks on the lateral cephalograms. Landmarks were similarly located on the frontal cephalograms and all films traced.

Using an analog reader and decimal converter, two coordinates on the lateral tracing and one coordinate on the frontal tracing were measured. The coordinates were then corrected for distortion and enlargement.

Distances between the landmarks for

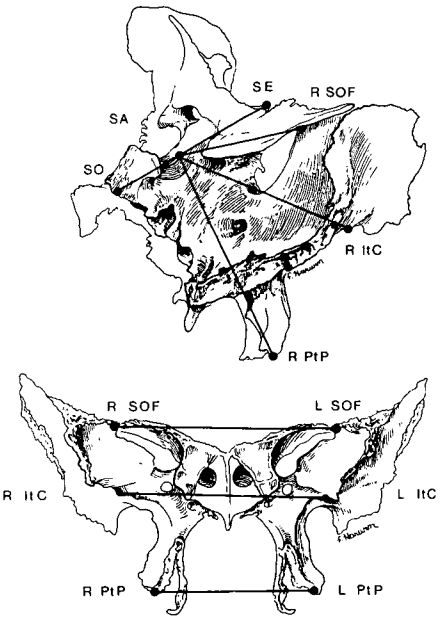

Fig. 2 Sphenoid bone with location of landmarks.

each dimension were computed using the corrected coordinates. The method for three-dimensional correction of landmarks and computation of distances is given in detail by Savara.[9]

The following measurements were obtained at each age: presphenoid length (Sa-SE), basisphenoid length (Sa-SO), maximum body length (SE-SO), lesser wing length (Sa-SOF), greater wing length (Sa-ItC), pterygoid process length (Sa-PtP), width from left to right lesser wing (Lt-Rt SOF), width from left to right greater wing (Lt-Rt ItC) and width from left to right pterygoid process (Lt-Rt PtP).

In this study lesser wing length, greater wing length and pterygoid process length represent the average of right and left side measurements while the other dimensions represent a single measurement. A second-degree polynomial was used to equally space the data and interpolate for any missing observation.

Means and standard deviations for

DIMENSION	AGE(YRS)	4	5	6	7	8	9	10	11	12	13	14	15	16
	N	24	31	37	38	39	39	39	39	39	39	37	31	20
Sa-SO	MEAN	1.61	1.64	1.66	1.71	1.74	1.77	1.80	1.83	1.86	1.90	1.95	2.00	2.03
	S. D.	0.13	0.13	0.11	0.10	0.12	0.11	0.11	0.11	0.11	0.13	0.12	0.11	0.08
	C OF V	8.08	7.81	6.54	6.15	6.85	6.22	6.20	6.14	5.97	6.87	5.96	5.34	3.84
Sa-SE	MEAN	1.91	1.95	1.98	2.00	2.03	2.04	2.05	2.06	2.06	2.06	2.08	2.08	2.10
	S. D.	0.15	0.16	0.16	0.18	0.17	0.18	0.17	0.18	0.18	0.17	0.17	0.16	0.15
	C OF V	7.84	8.35	8.21	9.05	8.57	8.76	8.27	8.67	8.77	8.41	7.98	7.68	6.99
Sa-SOF	MEAN	3.14	3.19	3.25	3.28	3.31	3.34	3.36	3.39	3.40	3.41	3.44	3.48	3.52
	S. D.	0.20	0.19	0.18	0.19	0.18	0.19	0.19	0.20	0.19	0.20	0.20	0.21	0.18
	C OF V	6.29	5.91	5.65	5.83	5.53	5.70	5.67	5.90	5.62	5.93	5.84	6.08	5.02
SE-SO	MEAN	3.40	3.47	3.51	3.58	3.63	3.67	3.70	3.74	3.77	3.80	3.86	3.90	3.94
	S. D.	0.16	0.19	0.17	0.19	0.18	0.18	0.17	0.18	0.18	0.19	0.17	0.20	0.16
	C OF V	4.71	5.38	4.83	5.19	5.03	4.87	4.62	4.90	4.84	4.92	4.42	5.00	4.02
Lt-Rt SOF	MEAN	4.67	4.78	4.87	4.95	5.01	5.06	5.10	5.16	5.20	5.24	5.27	5.39	5.47
	S. D.	0.45	0.42	0.41	0.41	0.40	0.41	0.41	0.42	0.42	0.41	0.42	0.42	0.39
	C OF V	9.73	8.86	8.43	8.36	8.09	8.05	8.03	8.16	8.00	7.92	7.92	7.83	7.22
Lt-Rt Pt P	MEAN	2.64	2.71	2.81	2.94	3.02	3.07	3.15	3.25	3.41	3.51	3.62	3.68	3.76
	S. D.	0.20	0.26	0.27	0.29	0.30	0.30	0.32	0.34	0.34	0.34	0.31	0.34	0.31
	C OF V	7.75	9.45	9.53	9.86	10.01	9.73	10.02	10.37	9.87	9.55	8.62	9.24	8.28
Sa-It C	MEAN	3.75	3.81	3.86	3.93	3.97	4.03	4.07	4.13	4.17	4.23	4.30	4.36	4.38
	S. D.	0.18	0.18	0.18	0.19	0.21	0.21	0.22	0.22	0.23	0.24	0.23	0.25	0.24
	C OF V	4.70	4.63	4.72	4.95	5.21	5.13	5.29	5.37	5.58	5.59	5.42	5.63	5.48
Sa-Pt P	MEAN	4.43	4.52	4.61	4.76	4.86	4.98	5.09	5.19	5.29	5.42	5.55	5.69	5.71
	S. D.	0.25	0.26	0.26	0.24	0.26	0.27	0.28	0.30	0.30	0.30	0.33	0.34	0.29
	C OF V	5.69	5.66	5.58	5.09	5.38	5.36	5.46	5.80	5.73	5.54	5.91	5.93	5.13
Lt-Rt It C	MEAN	6.05	6.16	6.26	6.37	6.44	6.53	6.61	6.72	6.79	6.89	6.97	7.05	7.16
	S. D.	0.42	0.42	0.42	0.45	0.46	0.48	0.49	0.50	0.51	0.52	0.51	0.54	0.46
	C OF V	6.95	6.89	6.73	7.01	7.20	7.28	7.34	7.52	7.58	7.55	7.31	7.60	6.36

Table 1. Means, standard deviations, and coefficients of variation for nine sphenoid bone measurements of boys, aged 4-16 years.

DIMENSION	AGE(YRS)	4	5	6	7	8	9	10	11	12	13	14	15	16
	N	32	37	40	40	40	40	40	40	40	39	39	37	33
Sa-SO	MEAN	1.59	1.62	1.66	1.71	1.73	1.78	1.82	1.85	1.88	1.91	1.93	1.96	1.97
	S. D.	0.12	0.13	0.13	0.13	0.12	0.13	0.14	0.13	0.13	0.13	0.13	0.11	0.13
	C OF V	7.33	8.15	7.73	7.38	7.20	7.37	7.51	7.29	7.00	6.59	6.55	5.84	6.75
Sa-SE	MEAN	1.79	1.85	1.88	1.90	1.93	1.94	1.95	1.97	1.97	1.97	1.98	1.99	1.99
	S. D.	0.16	0.16	0.15	0.15	0.15	0.15	0.16	0.16	0.15	0.16	0.15	0.15	0.15
	C OF V	8.88	8.56	7.99	7.71	7.80	7.97	8.10	7.90	7.81	7.94	7.72	7.64	7.62
Sa-SOF	MEAN	3.04	3.10	3.14	3.18	3.21	3.24	3.26	3.28	3.30	3.32	3.34	3.35	3.37
	S. D.	0.17	0.15	0.16	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.17	0.16
	C OF V	5.46	4.96	4.98	4.76	4.65	4.63	4.81	4.74	4.82	4.91	4.88	5.11	4.85
SE-SO	MEAN	3.29	3.38	3.43	3.49	3.54	3.59	3.64	3.68	3.72	3.74	3.75	3.78	3.79
	S. D.	0.19	0.19	0.19	0.18	0.19	0.19	0.20	0.20	0.19	0.18	0.18	0.18	0.19
	C OF V	5.78	5.69	5.40	5.28	5.40	5.20	5.37	5.36	5.13	4.91	4.86	4.82	5.05
Lt-Rt SOF	MEAN	4.62	4.71	4.79	4.84	4.90	4.96	5.01	5.05	5.10	5.15	5.18	5.20	5.26
	S. D.	0.35	0.35	0.36	0.36	0.35	0.35	0.36	0.36	0.38	0.38	0.40	0.40	0.38
	C OF V	7.62	7.54	7.54	7.40	7.20	7.15	7.13	7.18	7.47	7.33	7.65	7.67	7.24
Lt-Rt Pt P	MEAN	2.63	2.70	2.79	2.91	2.99	3.04	3.10	3.22	3.35	3.47	3.54	3.58	3.61
	S. D.	0.20	0.20	0.22	0.20	0.21	0.20	0.20	0.25	0.26	0.24	0.23	0.26	0.27
	C OF V	7.61	7.42	7.82	6.72	7.04	6.45	6.45	7.76	7.79	6.92	6.61	7.16	7.55
Sa-It C	MEAN	3.65	3.72	3.78	3.84	3.90	3.95	3.98	4.05	4.10	4.15	4.18	4.21	4.23
	S. D.	0.15	0.16	0.18	0.16	0.18	0.16	0.17	0.18	0.17	0.19	0.17	0.17	0.17
	C OF V	4.11	4.31	4.67	4.30	4.61	4.18	4.20	4.38	4.24	4.58	4.14	4.07	4.08
Sa-Pt P	MEAN	4.25	4.40	4.54	4.67	4.79	4.89	4.98	5.11	5.23	5.35	5.46	5.51	5.59
	S. D.	0.19	0.21	0.20	0.19	0.22	0.23	0.26	0.28	0.29	0.30	0.33	0.30	0.32
	C OF V	4.38	4.85	4.45	4.06	4.62	4.70	5.19	5.43	5.54	5.62	6.09	5.46	5.64
Lt-Rt It C	MEAN	5.96	6.09	6.18	6.28	6.38	6.47	6.55	6.65	6.75	6.81	6.85	6.91	6.95
	S. D.	0.34	0.33	0.35	0.34	0.34	0.33	0.33	0.33	0.33	0.34	0.32	0.32	0.35
	C OF V	5.71	5.41	5.65	5.37	5.34	5.13	5.01	4.92	4.87	4.95	4.62	4.70	5.00

Table 2. Means, standard deviations, and coefficients of variation for nine sphenoid bone measurements of girls, aged 4-16 years.

each measurement at each age were calculated for boys and girls. Means and standard deviations of annual increments were also computed.

Findings

The means and standard deviations for size of nine dimensions of the sphenoid bone are presented in Tables 1 and 2 and the means are plotted in Figures 3 and 4. The means and standard deviations of annual increments are presented in Tables 3 and 4, and mean increments are plotted in Figures 5 and 6.

Measurements on dorsal part of sphenoid bone

1) Basisphenoid length (Sa-SO): This is the smallest dimension studied and increases from 1.61 cm at 4 years to 2.03 cm at 16 years for boys, and from 1.59 cm at 4 years to 1.97 cm at 16 years for girls.

The boys' increments are almost constant over the entire age range. The girls' increments are almost constant from the 4th to the 11th year and decrease thereafter.

2) Presphenoid length (Sa-SE): This dimension is the next to smallest in size and increases from 1.91 cm at 4 years to 2.10 cm at 16 years for boys, and from 1.79 cm at 4 years to 1.99 cm at 16 years for girls.

Presphenoid length exhibits less increase than basisphenoid length over the entire period. Increments constantly decrease from the 4th to the 13th year with a very slight increase at 14-16 years in boys and at 13-15 years in girls.

3) Lesser wing length (Sa-SOF): Mean size increases from 3.14 cm at 4 years to 3.52 cm at 16 years for boys, and from 3.04 cm at 4 years to 3.37 cm at 16 years for girls.

The boys' increments decrease slowly through the 12th year, increase slightly during the 13th year, then decrease again. The girls' increments decrease slowly throughout the age range.

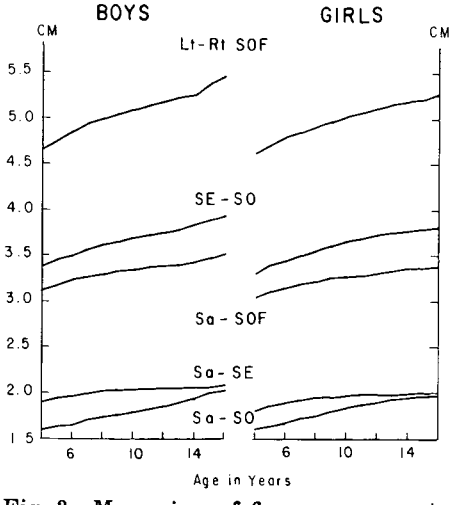

Fig. 3 Mean sizes of five measurements of dorsal part of sphenoid bone.

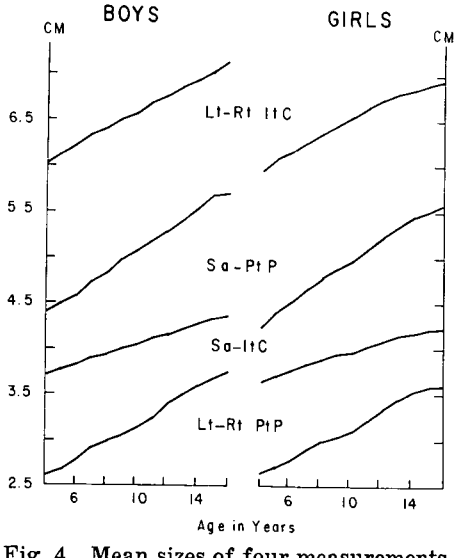

Fig. 4 Mean sizes of four measurements of ventral part of sphenoid bone.

4) Maximum body length (SE-CO): This dimension increases from 3.40 cm at 4 years to 3.94 cm at 16 years for boys, and from 3.29 cm at 4 years to 3.79 cm at 16 years for girls, growing more during the earlier part of the age range than the later part.

DIMENSION	INTERVAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
	N	24	31	37	38	39	39	39	39	39	37	31	20
Sa-SO	MEAN	0.047	0.027	0.044	0.032	0.028	0.036	0.032	0.027	0.043	0.035	0.047	0.022
	S. D.	0.043	0.052	0.047	0.047	0.049	0.041	0.040	0.044	0.059	0.054	0.044	0.050
Sa-SE	MEAN	0.046	0.039	0.035	0.021	0.011	0.013	0.005	0.000	0.007	0.001	0.007	0.016
	S. D.	0.035	0.027	0.042	0.027	0.028	0.037	0.033	0.029	0.029	0.025	0.024	0.022
Sa-SOF	MEAN	0.047	0.052	0.036	0.031	0.029	0.022	0.025	0.017	0.012	0.023	0.020	0.018
	S. D.	0.035	0.028	0.031	0.036	0.031	0.023	0.034	0.028	0.033	0.035	0.039	0.064
SE-SO	MEAN	0.088	0.050	0.074	0.049	0.036	0.038	0.036	0.029	0.030	0.041	0.038	0.030
	S. D.	0.043	0.041	0.052	0.043	0.047	0.039	0.043	0.046	0.043	0.050	0.050	0.038
Lt-Rt SOF	MEAN	0.075	0.075	0.074	0.057	0.054	0.039	0.063	0.036	0.038	0.045	0.023	0.036
	S. D.	0.082	0.048	0.058	0.049	0.047	0.032	0.066	0.039	0.041	0.054	0.055	0.134
Lt-Rt Pt P	MEAN	0.079	0.116	0.119	0.085	0.046	0.084	0.102	0.155	0.102	0.123	0.053	0.043
	S. D.	0.066	0.082	0.092	0.088	0.036	0.075	0.101	0.120	0.099	0.133	0.077	0.118
Sa-It C	MEAN	0.078	0.052	0.071	0.056	0.054	0.043	0.062	0.035	0.064	0.067	0.056	0.056
	S. D.	0.051	0.038	0.048	0.043	0.038	0.040	0.047	0.042	0.046	0.046	0.036	0.065
Sa-Pt P	MEAN	0.135	0.128	0.130	0.103	0.113	0.115	0.099	0.102	0.127	0.135	0.137	0.107
	S. D.	0.083	0.097	0.092	0.085	0.063	0.069	0.100	0.089	0.075	0.121	0.080	0.051
Lt-Rt It C	MEAN	0.110	0.093	0.114	0.089	0.097	0.082	0.105	0.073	0.096	0.096	0.068	0.076
	S. D.	0.065	0.050	0.059	0.052	0.061	0.058	0.062	0.056	0.062	0.066	0.053	0.059

Table 3. Means and standard deviations of annual increments for nine sphenoid bone measurements of boys, aged 4-16 years.

DIMENSION	INTERVAL	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16
	N	32	37	40	40	40	40	40	40	39	39	37	33
Sa-SO	Mean	0.038	0.038	0.050	0.028	0.044	0.037	0.032	0.038	0.021	0.020	0.017	0.019
	S. D.	0.067	0.042	0.041	0.048	0.046	0.039	0.041	0.046	0.052	0.052	0.044	0.046
Sa-SE	Mean	0.051	0.033	0.023	0.024	0.014	0.013	0.012	0.007	0.003	0.008	0.007	0.000
	S. D.	0.041	0.041	0.026	0.030	0.024	0.027	0.025	0.026	0.023	0.030	0.029	0.029
Sa-SOF	Mean	0.048	0.045	0.034	0.037	0.023	0.026	0.018	0.022	0.018	0.012	0.016	0.009
	S. D.	0.041	0.035	0.031	0.030	0.027	0.024	0.024	0.026	0.028	0.027	0.027	0.024
SE-SO	Mean	0.088	0.066	0.060	0.049	0.052	0.047	0.040	0.037	0.017	0.012	0.020	0.015
	S. D.	0.075	0.056	0.047	0.047	0.041	0.044	0.040	0.043	0.047	0.040	0.030	0.046
Lt-Rt SOF	Mean	0.064	0.073	0.048	0.058	0.054	0.050	0.049	0.044	0.042	0.033	0.037	0.021
	S. D.	0.050	0.040	0.041	0.044	0.039	0.045	0.036	0.041	0.042	0.053	0.031	0.034
Lt-Rt Pt P	Mean	0.053	0.114	0.114	0.077	0.050	0.066	0.122	0.125	0.121	0.063	0.046	0.013
	S. D.	0.059	0.075	0.079	0.084	0.076	0.081	0.115	0.101	0.119	0.103	0.093	0.040
Sa-It C	Mean	0.057	0.057	0.063	0.061	0.045	0.038	0.063	0.055	0.043	0.037	0.026	0.002
	S. D.	0.052	0.053	0.056	0.049	0.039	0.039	0.036	0.051	0.041	0.054	0.039	0.029
Sa-Pt P	Mean	0.122	0.139	0.133	0.117	0.102	0.092	0.126	0.129	0.118	0.106	0.056	0.060
	S. D.	0.079	0.076	0.066	0.083	0.076	0.084	0.078	0.135	0.101	0.097	0.094	0.072
Lt-Rt It C	Mean	0.097	0.094	0.104	0.100	0.087	0.081	0.104	0.098	0.062	0.043	0.054	0.023
	S. D.	0.076	0.060	0.064	0.066	0.052	0.042	0.048	0.063	0.043	0.058	0.044	0.052

Table 4. Means and standard deviations of annual increments for nine sphenoid bone measurements of girls, aged 4-16 years.

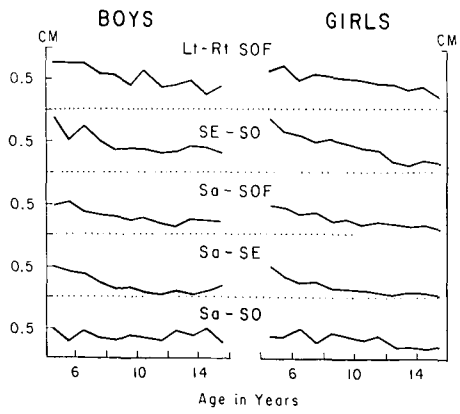

Fig. 5 Mean annual increments of five measurements of dorsal part of sphenoid bone.

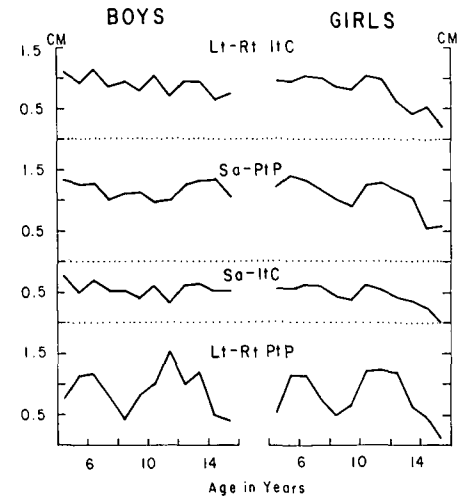

Fig. 6 Mean annual increments of four measurements of ventral part of sphenoid bone.

The boys' increments diminish from the 4th through the 12th year, increase slightly in the 13th and 14th years, and then decrease. The rate of growth for the girls decreases throughout the age range.

5) Width from left to right lesser wing (Lt-Rt SOF): Mean size increases from 4.67 cm at 4 years to 5.47 cm at 16 years for boys, and from 4.62 cm at 4 years to 5.26 cm at 16 years for girls.

The mean increments for both boys and girls appear to decrease slightly throughout the age range.

Measurements on ventral part of sphenoid bone

1) Width from left to right pterygoid process (Lt-Rt PtP): This dimension, the smallest width measurement, increases from 2.64 cm at 4 years to 3.76 cm at 16 years for boys, and from 2.63 cm at 4 years to 3.61 cm at 16 years for girls.

The increment curves for boys and girls show a definite childhood increase at the 5th and 6th years (preceding eruption of the first molars). An adolescent spurt is apparent between the 11th and 14th years in boys and between the 10th and the 13th years in girls (preceding eruption of the second molars).

2) Greater wing length (Sa-ItC): This dimension increases from 3.75 cm at 4 years to 4.38 cm at 16 years for boys, and from 3.65 cm at 4 years to 4.23 cm at 16 years for girls.

Mean increments for boys decrease slightly with an adolescent increase at 12 to 14 years. The girls' increments show a childhood increase at the 6th and 7th years, an adolescent increase at 10 to 12 years, and then a sharp decrease thereafter.

3) Pterygoid process length (Sa-PtP): Mean size increases from 4.43 cm at 4 years to 5.71 cm at 16 years for boys, and from 4.25 cm at 4 years to 5.59 cm at 16 years for girls.

The mean increments exhibit a childhood increase from the 4th to the 6th year in both boys and girls. Adolescent spurts are apparent between the 12th and 14th years in boys and between the 10th and 13th years in girls.

4) Width from left to right greater wing (Lt-Rt ItC): This dimension, the largest dimension studied, increases from 6.05 cm at 4 years to 7.16 cm at 16 years for boys, and from 5.96 cm at 4 years to 6.95 cm at 16 years for girls.

The increment curve for the boys is irregular; however, the growth rate appears to decrease slightly with age with a possible adolescent spurt between the 12th and 14th years. The mean increments for girls show a childhood increase at the 6th and 7th years and an adolescent increase between the 10th and 12th years.

Discussion

Each dimension used in this study represents a region of the sphenoid bone. All dimensions are measured three-dimensionally using Savara's method and represent the actual sizes of the parts of the sphenoid bone. Traditional two-dimensional cephalometric measurements are not directly comparable with the findings of this study; however, the general trends are similar.

Björk[4] divided the head into four distinct zones for the purpose of growth and developmental studies. These are the brain case, the upper facial structure, the mandible, and the intermediate zone formed by the cranial base. The growth of the brain case is governed by the growth of the brain and is slight after the age of ten or twelve years. The facial skeleton, comprising the bones of the upper facial structure and mandible, continues its growth up to the age of twenty and beyond. The cranial base, which from a functional

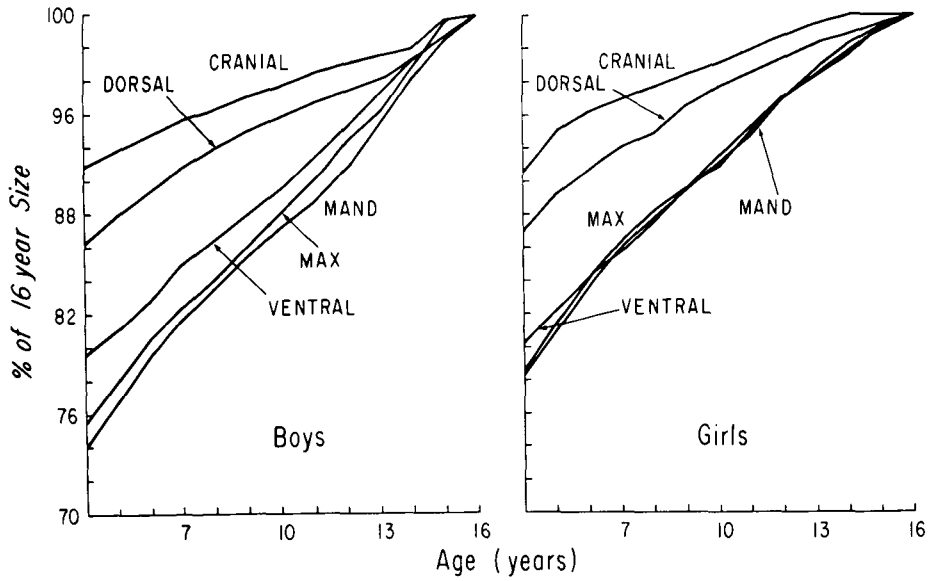

Fig. 7 Mean growth patterns of cranium, maxillae, mandible, ventral part of sphenoid bone and dorsal part of sphenoid bone. Each growth pattern is the average of several dimensions of that region of the head with the dimensions represented as the percentage of the 16th year size obtained at each age.

point of view may be regarded as the border between the brain and the facial structure, must develop in conformity with the brain case on the dorsal side and the facial structure on the ventral side. The dorsal and ventral surfaces of the sphenoid bone must, therefore, exhibit differential growth patterns in order to compensate for the difference in growth rates of these adjacent structures.

Brodie, Jr.[5] found that the incremental growth of the cranial base conforms quite closely to the neural pattern of growth, which is characterized by a gradual deceleration from birth to 7-10 years at which time ninety per cent of final growth has been attained. He also states that in a less striking manner cranial bone growth is allied to general body growth patterns. A plateau occurs around puberty and is followed by a parapubertal acceleration in most cases.

The results of our investigation support this concept. Figure 7 shows the growth patterns of the cranium, maxillae, mandible, ventral part of the sphenoid bone and the dorsal part of the sphenoid bone. These growth patterns represent the percentage of the sixteen year size obtained at each age. Each curve is the average of all the growth patterns available of that area of the head, e.g. (six cranial, six maxillary, five mandibular, four ventral (sphenoid), and five dorsal (sphenoid) dimensions.[10, 11, 12, 13, 14] These average growth patterns show quite clearly the resemblance between the growth of the cranium and the dorsal part of the sphenoid bone and between the growth of the ventral part and that of the mandible and maxillae.

An examination of the increments plotted in Figures 5 and 6 shows the same pattern. The dimensions of the dorsal surface (basisphenoid length, presphenoid length, maximum body length, lesser wing length, and width from left to right lesser wing) have small increments throughout the age range. The increments are larger in the

earlier years (4-9) than in the later years (except for basisphenoid length which has almost constant increments throughout). A small parapubertal acceleration occurs around thirteen to fifteen years in boys but no such acceleration is apparent in girls, possibly due to the girls' acceleration being so small that it is obscured by measurement error and the spreading effect caused by puberty occurring at different times in different individuals. This growth pattern is similar to the neural growth pattern as Brodie, Jr. pointed out.

The dimensions of the ventral surface (greater wing length, pterygoid process length, width from left to right greater wing and width from left to right pterygoid process) have larger annual increments than measurements of the dorsal surface and exhibit childhood and adolescent growth spurts. The adolescent growth spurt occurs from one to three years later in boys than in girls, e.g., between the 10th and 12th years in girls and between the 12th and 14th years in boys. Savara et al.[10, 11, 12, 13] found the same type of growth pattern in the maxillary and mandibular dimensions of boys and girls.

Summary

The sphenoid bone is located in the middle part of the cranial base and is composed of a body and several flattened laterally extended wings. The dorsal surface of the sphenoid bone forms the floor of the cranium and its growth pattern resembles that of the brain and cranium, most of the growth occurring before ten years of age with little or no adolescent growth spurt discernible.

In contrast, the ventral surface forms the posterior boundary of the facial skeleton and is analogous in growth to the facial bones having a distinct adolescent growth phase. It grows at a greater rate than the dorsal surface.

Child Study Clinic
611 S. W. Campus Drive
Portland, Oregon 97201

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