Biennial Size Norms of Eight Measures of the Temporal Bone From Four to Twenty Years of Age

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Effective correction of facial anomalies and malocclusions hinges on adequate understanding of normal form and development. Thus, the plotting of growth trends and norms has a real clinical application which has justified continued attempts to grasp more of the subtle aspects of skeletal growth. Some portions of the face, e.g., the mandible, have been examined thoroughly; others, for good reason, have received less attention. The temporal bone is among the latter. Integral to mandibular development, the temporal bone is of acute interest to research and yet it has remained largely unevaluated because of the difficulty of reproducing it on X-ray films.

Four characteristics of the newborn temporal bone were delineated by Weinmann and Sicher:[1] undeveloped mastoid process, stylomastoid process lying unprotected on the lateral surface, articular fossa facing laterally with almost no downward orientation, and absence of external meatus.

Moss, Noback and Robertson[2] compared growth of the fetal temporal bone with fetal zygomatic, parietal and frontal bones, and the mandible showing that, when plotted against age, each slowed in growth at about 90 days menstrual age. When plotted against each other, development of these bones showed a constant relationship.

Although a good deal of cephalometric work has been done in recent years, cephalographic studies relating to the temporal bone have been limited. This lack may be attributed to the difficulty of determining the image of the temporal bone on cephalograms, e.g., as Enlow[3] pointed out, the squama is seldom clearly visible. For this reason most examinations have considered only the position of the glenoid fossa in relation to the cranial base, mandible or maxillae. For instance, Björk[4] explained the relation of the glenoid fossa to other portions of the face and head as interrelated response of all locations to change at any one point. Droel and Isaacson[5] presented a method for obtaining cephalograms that yield a sharp image of the glenoid fossa with the aim of judging the relation of the mandible to the cranium and localizing deviant variables in facial development. Coben,[6] in his article on the integration of the facial skeleton, treats the temporal bone briefly noting only that his material suggests that the position of the glenoid fossa relative to basion changes little through time.

Ricketts[7] recognized that backdoor techniques have been used for years to come to grips with the organization of the glenoid fossa and, through it, the relationship of the temporal bone and the mandible. Using vertex-view cephalograms along with frontal

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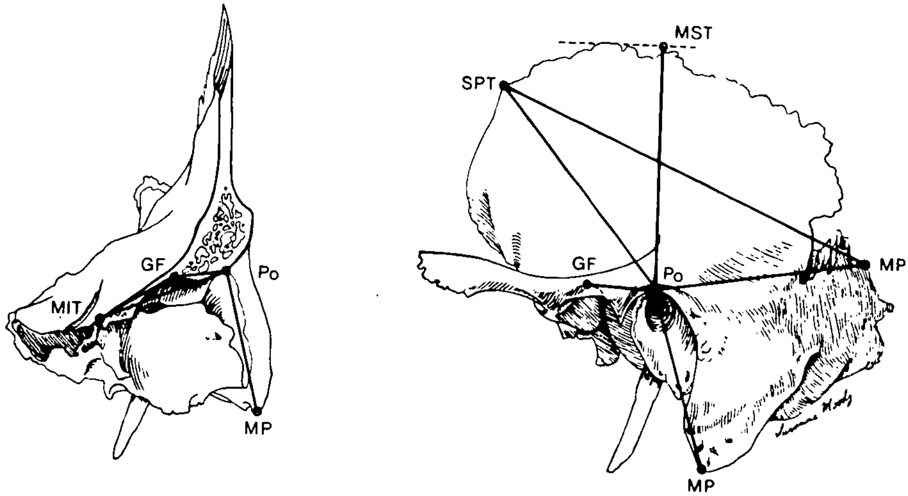

Fig. 1 Temporal bone with location of landmarks and dimensions measured.

and lateral films, he re-examined the growth of the face. However, his focus still did not include the entire temporal bone.

This paper attempts to overcome the problems of working with the temporal bone on cephalograms and presents norms of size.

Materials and Methods

The research material consists of two longitudinal samples from the files of the Child Study Clinic, School of Dentistry, University of Oregon Health Sciences Center. In the first sample (Sample A) 25 boys and 25 girls were observed from 4 to 16 years of age, and the second (Sample B) 25 boys and 25 girls were observed from 16 to 20 years of age. Five boys and five girls were in both samples. The children were Caucasian, predominately of Northwest European ancestry, residing in or near Portland, Oregon. Their parents were of middle and upper-middle socioeconomic status. Selection of subjects was based on completeness of records with no missing observations.

Seven landmarks of the temporal bone (defined below, Fig. 1) were located on sets of lateral and frontal cephalograms obtained biennially.

1. MST (most superior point of the temporal bone): The highest point of the squamoparietal suture observed on the frontal film and the perpendicular height at porion observed on the lateral film. This landmark is difficult to locate on the cephalograms.
2. MPT (most posterior point of the temporal bone): The point at the junction of the parietomastoid, the lambdoid, and the mastoido-occipital sutures.
3. SPT (spheno-parieto-temporal junction): The point at the junction of the sphenotemporal, sphenoparietal, and squamoparietal sutures.
4. MP (mastoid process): The lowest point on the contour of the mastoid process.
5. MIT (most inner point of the temporal bone): The most inner point of the temporal bone facing the angular spine of the sphenoid bone.
6. GF (glenoid fossa): The uppermost point on the superior margin of the glenoid fossa.
7. Po (porion): The most superior

point on the roof of the external auditory meatus at the border of the external cartilaginous ear canal.

These landmarks were located on the left temporal bone. Details on locating landmarks have been provided by Savara and Takeuchi.[8] Landmarks were marked on 0.003-inch thick acetate film at one sitting for each subject's entire series of cephalograms.[9] Using an Oscar analog reader, decimal converter and card punch, two coordinates from the lateral tracing and one coordinate from the frontal tracing were obtained (excepting MST for which two coordinates were obtained on the frontal and one on the lateral tracing), and transcribed onto IBM cards.

These two sets of two-dimensional data were combined mathematically[10] to recreate three-dimensional cartesian coordinates free from magnification and distortion (where distortion is defined as the error in measurement caused by measuring a three-dimensional object from its two-dimensional projection). Distances between landmarks were calculated using three-dimensional coordinates.

Next, a third-order polynomial equation was used for equal spacing of the data.[11] This was necessary to obtain equal yearly time intervals between examinations.

The following measurements were obtained biennially:

1. MP-SPT: Maximum length.
2. Po-MPT: Petrous length.
3. Po-SPT: Squamous length.
4. Po-GF: Glenoid length.
5. Po-MP: Mastoid length.
6. Po-MST: Maximum height.
7. Po-MIT: Maximum length.
8. GF-MIT: One depth component.

Means, standard deviations, and coefficients of variation for each measurement and biennial increments were calculated for both boys and girls.

Reliability of Measurements

Twenty cephalograms were chosen randomly. Landmarks were located and all measurements made twice, on separate occasions, by the same locator. The mean difference, standard error of the mean, absolute error, and the range of differences were calculated on each dimension. Po-MST showed the largest absolute error (1.34 mm), and GF-MIT the smallest (0.45 mm). A paired t-test indicated that the mean difference in Po-MST between the first and second measurements was statistically significant at the 2.5% confidence level, but the remaining dimensions showed no significant difference between two measurements. The average annual increment for temporal bone measurements was approximately 1 mm, or less; and for some *yearly* periods, little or no growth could be detected on the cephalograms. Therefore, it was decided to use biennial increments.

Results

The means, standard deviations, and coefficients of variation of eight temporal bone measurements of boys and girls at each age level in both Samples A and B are shown in Tables I and II. At age 16 there are discrepancies of measurement between Samples A and B. Accordingly, Student's t-test was applied to examine whether significant difference existed between each measurement in the two samples. No statistically significant difference was found between any measurements.

The important findings are as follows:

(1) The temporal bone continues growing until at least 20 years of age.

(2) At age 4 Po-GF showed that

		SAMPLE A							SAMPLE B		
DIMENSION	AGE (YRS)	4	6	8	10	12	14	16	16	18	20
MPT-SPT	Mean	8.28	8.44	8.58	8.69	8.83	8.95	9.03	9.09	9.14	9.19
	S.D.	0.32	0.30	0.29	0.29	0.30	0.33	0.31	0.43	0.43	0.41
	C of V	3.82	3.56	3.41	3.39	3.45	3.64	3.48	4.74	4.66	4.44
Po-MPT	Mean	4.93	5.01	5.07	5.16	5.22	5.30	5.36	5.43	5.45	5.48
	S.D.	0.29	0.28	0.29	0.28	0.30	0.30	0.29	0.45	0.45	0.44
	C of V	5.94	5.64	5.74	5.35	5.70	5.70	5.40	8.32	8.20	7.98
Po-SPT	Mean	4.55	4.63	4.74	4.81	4.94	5.03	5.11	5.28	5.32	5.35
	S.D.	0.31	0.31	0.32	0.32	0.31	0.30	0.29	0.16	0.17	0.18
	C of V	6.82	6.79	6.70	6.57	6.18	6.02	5.72	2.98	3.29	3.28
Po-GF	Mean	0.77	0.86	0.93	1.01	1.09	1.19	1.24	1.21	1.28	1.32
	S.D.	0.20	0.18	0.16	0.15	0.14	0.15	0.17	0.14	0.14	0.13
	C of V	25.76	20.87	17.45	14.52	12.75	12.23	13.46	11.45	10.70	9.93
Po-MP	Mean	2.91	3.02	3.15	3.25	3.33	3.47	3.55	3.31	3.39	3.43
	S.D.	0.28	0.26	0.23	0.24	0.24	0.26	0.27	0.29	0.28	0.26
	C of V	9.75	8.61	7.35	7.32	7.16	7.44	7.70	8.83	8.32	7.54
Po-MST	Mean	4.79	4.85	4.91	5.01	5.10	5.17	5.24	5.31	5.35	5.39
	S.D.	0.43	0.43	0.45	0.43	0.44	0.45	0.45	0.41	0.42	0.42
	C of V	9.03	8.91	9.26	8.61	8.73	8.60	8.56	7.64	7.85	7.78
Po-MIT	Mean	2.30	2.46	2.62	2.77	2.91	3.08	3.18	3.09	3.19	3.25
	S.D.	0.21	0.19	0.18	0.17	0.17	0.19	0.21	0.28	0.28	0.27
	C of V	9.21	7.84	6.91	6.30	5.78	6.04	6.48	9.02	8.75	8.30
GF-MIT	Mean	1.69	1.77	1.86	1.94	2.02	2.10	2.15	2.03	2.08	2.10
	S.D.	0.10	0.11	0.11	0.10	0.12	0.12	0.13	0.19	0.19	0.19
	C of V	5.76	6.45	5.68	5.17	5.84	5.90	6.24	9.50	9.22	9.13

TABLE I

Means, Standard Deviations, and Coefficients of Variation for Eight Temporal Bone Measurements of Boys Aged 4-16 Years in Sample A and 16-20 Years in Sample B.

DIMENSIONS	AGE (YRS)	SAMPLE A 4	6	8	10	12	14	16	SAMPLE B 16	18	20
MPT-SPT	Mean	7.73	7.96	8.17	8.36	8.49	8.62	8.72	8.58	8.65	8.70
	S.D.	0.44	0.40	0.41	0.44	0.44	0.42	0.42	0.37	0.37	0.36
	C of V	5.69	5.06	5.05	5.27	5.17	4.93	4.83	4.31	4.22	4.19
Mo-MPT	Mean	4.47	4.63	4.74	4.85	4.95	5.05	5.10	5.09	5.13	5.16
	S.D.	0.36	0.29	0.28	0.29	0.30	0.31	0.32	0.30	0.31	0.30
	C of V	8.00	6.32	6.00	6.06	6.00	6.08	6.29	5.88	6.00	5.81
Po-SPT	Mean	4.36	4.50	4.62	4.75	4.86	4.95	5.04	5.08	5.13	5.16
	S.D.	0.34	0.34	0.33	0.33	0.32	0.32	0.30	0.34	0.34	0.34
	C of V	7.90	7.45	7.17	6.85	6.51	6.38	6.05	6.73	6.55	6.66
Po-GF	Mean	0.73	0.81	0.92	1.01	1.10	1.17	1.25	1.15	1.19	1.23
	S.D.	0.16	0.15	0.14	0.12	0.13	0.14	0.15	0.21	0.20	0.21
	C of V	21.38	18.50	15.26	12.20	12.02	11.99	12.16	18.18	17.17	16.89
Po-MP	Mean	2.62	2.72	2.87	2.99	3.11	3.17	3.21	2.98	3.03	3.05
	S.D.	0.22	0.19	0.19	0.19	0.21	0.19	0.19	0.23	0.23	0.23
	C of V	8.30	7.08	6.53	6.35	6.65	5.97	5.87	7.59	7.47	7.60
Po-MST	Mean	4.63	4.75	4.87	4.98	5.06	5.15	5.23	5.14	5.18	5.22
	S.D.	0.51	0.51	0.47	0.46	0.44	0.46	0.45	0.43	0.44	0.43
	C of V	11.11	10.66	9.74	9.16	8.65	8.90	8.67	8.42	8.50	8.26
Po-MIT	Mean	2.17	2.33	2.52	2.69	2.81	2.94	3.07	2.87	2.95	3.00
	S.D.	0.22	0.23	0.27	0.26	0.25	0.24	0.25	0.31	0.31	0.31
	C of V	10.09	9.88	10.56	9.63	8.95	8.22	8.32	10.66	10.68	10.19
GF-MIT	Mean	1.55	1.68	1.77	1.84	1.89	1.97	2.03	1.91	1.95	1.96
	S.D.	0.15	0.15	0.15	0.16	0.17	0.17	0.17	0.16	0.17	0.17
	C of V	9.49	9.11	8.58	8.84	8.96	8.51	8.34	8.53	8.49	

TABLE II

Means, Standard Deviations, and Coefficients of Variation for Eight Temporal Bone Measurements in Girls Aged 4-16 Years in Sample A and 16-20 Years in Sample B.

more than 40% of growth remained, and Po-MIT and GF-MIT indicated that more than 20% of growth remained in both boys and girls. Po-MPT in boys has the least growth potential at age 4.

(3) At age 10 MPT-SPT, Po-SPT, Po-MP (length measurements), Po-MST (maximum height), and GF-MIT (one depth component) had attained more than 90% of growth; Po-GF (glenoid length) showed that the least growth had been completed in boys, only 79%, whereas 81.5% had been completed in girls. Po-MIT (maximum depth) attained an intermediate degree of growth with 96.2% in boys and 88.7% in girls.

(4) Po-MP showed a significant sex difference in size (0.055 level) in both Samples A and B at age 16. MPT-SPT showed no significant difference in Sample A at age 16 while it showed significant difference in Sample B at age 16. The remaining measurements did not show any significant difference between boys and girls at age 16 in both Samples A and B.

Discussion

Our findings support earlier statements by Weinmann and Sicher[1] and Scott[12] that the growth of the temporal bone was well-advanced in the first decade of life and has almost reached adult size by age 20. In our study less than 20% of growth remained at age 4 in five of eight measurements, ranging from 9% in Po-MPT to 16.6% in Po-MP in boys, and from 11.3% in Pg-SPT to 16.3% in Po-MP in girls. Moreover, six of eight dimensions reached more than 90% of growth at age 10, ranging from 91.3% of GF-MIT to 95.3% of Po-MPT in boys and from 92.3% of GF-MIT to 96% of MPT-SPT in girls. It suggested that these six dimensions follow the *neural growth pattern.*[13] Po-GF showed the least growth at age 10 (within 79% of age 20 size in boys and 81.5% in girls).

On the other hand, Po-MIT attained 86.2% of growth in boys and 88.7% of growth in girls at age 10, which is somewhat intermediate between neural and physical growth patterns. It is possible that growth of Po-MIT is influenced by growth of the neurocranium and mandible due to its positional and functional relationship to them, and surface deposition at porion directly changed this dimension. Enlow[3] mentioned, "the distance from the external auditory meatus to the anterior temporal margin increases to a much greater extent during postnatal growth than the distance from the meatus to the temporoparieto-occipital junction." This statement is consistent with our findings. Po-GF is equivalent to the distance from the meatus to the temporoparieto-occipital junction, has 9% of growth left in boys and 12.9% in girls at age 4; but Po-SPT, which dimension is similar to the distance from the meatus to the anterior temporal margin, has 13% of growth left in boys and 14.5% in girls. Thus, Po-SPT increases to a greater extent from age 4 to 20 years than Po-MPT. Boys are consistently larger in size than girls excepting Po-GF. These findings are in agreement with those of Bambha[14] and Nakamura et al.[15] in the measurements of the cranial base, and by Sekiguchi et al.[16] in those of the cranium.

Po-MP shows a significant sex difference. The growth of this dimension is strongly related to the physical and neural growth and development of the human head.

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