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Variation in Midfacial Tissue Thickness of African-American Children

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ABSTRACT: Forensic anthropologists use facial reconstruction to develop a likeness of an unknown individual in order to generate public interest that may lead to a positive identification. Tissue thicknesses of the face from living persons or cadavers are an essential part of the reconstruction method. The purpose of this study is to add to the growing database of tissue thicknesses along the facial midline of African-American children and to begin to examine the possibility of geographic differences between children of the same ancestral group. Results indicate that significant differences do not exist between males and females or between African-American females from the Midwest and Southeast U.S. Only age was determined to have a significant effect on mean tissue thickness variation, in our sample, with the majority of change occurring in the facial region.

KEYWORDS: forensic science, forensic anthropology, facial reconstruction

In a death investigation, it is the responsibility of the forensic anthropologist to generate a biological profile of the individual based on the analysis of the skeletal remains. The biological profile includes information pertaining to the sex, age, predominant ancestry, stature, and individualizing traits of the individual and is intended to aid the investigators in the establishment of a positive identification. However, there are times when even the most complete analysis does not lead to the identity of the individual and, therefore, it may be necessary to appeal to the public for assistance.

Two-dimensional and three-dimensional facial reconstructions have been applied to unidentified human skeletal remains to generate a likeness of the unknown individual when alive (1–15). When completed, a photograph is taken of the reconstruction and then published in a newspaper or broadcast over the television. The expectation is that someone will recognize the person and notify the investigators who can then proceed with gathering the necessary materials needed for a positive identification.

Mean tissue thicknesses of the face are essential data for an accurate facial reconstruction and were first recorded for a small number of adult European males and females by His in 1895 and Kollman and Büchly in 1898 (reprinted in Refs 9 and 16). Since then, tissue thickness means have been generated for European-American adults (17,18,19), adult Japanese males and females by Suzuki in 1948 (reprinted in Ref 16), African-American adults (16,19), European-American children (19–22), African-American children (19), and Hispanic children (19).

Significant differences in facial tissue thicknesses and craniofacial morphology have been shown to exist between children of different ancestry (19,23). However, tissue thickness representing children from populations not having European ancestry and suitable for facial reconstruction can only be found in the work of Manhein et al. (19). A review of the orthodontic literature produces only a few studies that have compared individuals of differing predominant ancestry. For example, Richardson (23) compared lateral cephalometric data from a longitudinal study of 41 male and 42 female African-American children to similar data published for European-American children and found statistically significant differences at 14 of 17 measurements. Children of non-European ancestry are also underrepresented in the anthropometric literature regarding craniofacial measurements and are not even included in the classic reference text by Farkas (24).

Comparisons of facial tissue thickness between groups of similar predominant ancestry but from different geographic locations are even more scarce. However, there is reason to expect differences as indicated by the work of Richardson (25) who found statistically significant differences in craniofacial measurements between European-American adults from northern California and the southeastern U.S.

Purpose

The purpose of this study is to add to the growing database of mean tissue thickness measurements along the facial midline of African-American children for use in two dimensional reconstruction, three dimensional reconstruction, and video superimposition, and to examine tissue thickness variation with respect to age and sex. A comparison between female African-American children from the midwest and southeast U.S. will also be made in order to examine the possibility of regional variation.

In addition to increasing the database of tissue thicknesses for African-American children, the data generated from the current study can also provide a means to help determine "closeness of fit" between a photograph of the living individual and the skull during superimposition (26). When the superimposition is performed, basic features such as the eye orbits and nasal aperture may appear to match but, overall, the skull may still seem a bit misaligned. This sometimes happens because the individual in the photograph may

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be over or underweight. Two lines, one indicating the maximum thickness at the landmark and another representing the minimum thickness, can be drawn on the marker. These two lines can form an "acceptable" range of tissue thickness against which the soft tissue outline can be compared. Later when the markers are glued to the skull and the superimposition is performed, the ability to compare the soft tissue outline to the range indicated by the lines can help the forensic anthropologist to be more confident that the result is an acceptable match or exclusion.

Materials and Methods

When children are the focus of study it is difficult to find a sufficient number of individuals for use in measuring facial tissue thickness. One way this can be overcome is to measure the soft tissue image present in lateral craniographs that have been taken in preparation for orthodontic treatment. Lateral craniographs are easily obtained through most orthodontic practices around the country and are taken following a standardized procedure. Expense can be kept at a minimum; the tools necessary include a pencil, tracing acetate, sliding calipers, ruler, and a protractor. One major drawback is the inability to collect data from landmarks lateral to the midline.

The sample for this study consisted of 224 African-American children, 77 males and 147 females of normal weight between the ages of 7 and 12 years. X-rays were obtained from patient records in orthodontic practices in Columbia, South Carolina, Augusta, Georgia, and Indianapolis, Indiana. Demographic information regarding sex, age, and predominant ancestry as reported by the child's parent or guardian were also taken from patient files. Selection of individual X-rays was based on three criteria: 1) the X-ray was taken before any orthodontic treatment, 2) none of the subjects suffered from any maxillofacial deformities such as cleft palate, etc., and 3) both the soft tissue and osseous profiles were easily recognizable.

All craniographs had been taken with the subject's head in the Frankfort horizontal using a cephalostat that maintained a constant distance between the X-ray source and the subject and between the subject and the X-ray film. Subjects had been instructed to hold their mouth closed and keep their lips together with light contact. X-ray source-to-film distance was five feet (60 in.).

X-rays were covered with standard orthodontic tracing acetate, which was taped in place to prevent accidental removal and to aid in replacement of the acetate over the X-ray if additional data collection was necessary later. Landmarks on the skull were located and marked with a pencil. The stationary edge of the sliding calipers was placed along the skull to reproduce where the future depth marker would be glued on the skull and then the thickness was measured. Data were collected using Fowler-Sylvac Ultra-Cal II digital electronic sliding calipers that measured to the exact .01 mm.

Tissue thickness measurements taken directly from orthodontic X-rays must be adjusted for magnification before they can be applied to facial reconstruction. Bergersen (27) has published compensation tables for adjusting measurements to be more representative of the living individual. To account for the distances between the subject and the X-ray source and between the subject and X-ray film used in this study, each measurement was multiplied by .92140.

Comparisons of tissue thickness means were made in two ways. First, the effects of age and sex on tissue thickness within the sample of African-American children from Georgia and South Carolina were determined using two-way ANOVA. In this comparison, ages were grouped by categories consisting of 7 to 9 years (Category 1), 10 to 12 years (Category 2), and 13 to 15 years (Category 3) in order to reflect the type of age ranges that would most likely result from skeletal and dental analysis. Second, the possibility that there are significant differences between African-American children from different geographical regions was tested by comparing females from Indianapolis, Indiana to females from Georgia and South Carolina using two-way ANOVA.

Landmarks and Measurements

Definitions of the landmarks are listed in Table 1, illustrated in Figs. 1 and 2 and follow George (7) and Krogman and Sassouni

TABLE 1—*Landmark definitions.*

Landmark	Abbreviation	Definition	Reference
Supraglabella	Sg	A point on the frontal bone 10 mm superior to glabella	7
Glabella	G	The most anterior point on the frontal bone	28
Nasion	N	The intersection of the naso-frontal suture and the internasal suture, identified as a dark line in lateral X-ray, it may lie above the deepest concavity between the nose and the forehead	28
Midnasal	MN	A point on the superior edge of the nasal bone halfway between the most anterior point on the nasal bones and the nasal root	28
Nasale	Na	The most anterior point on the nasal bones	7
Pronasale	Pro	The most anterior point on the soft tissue nose	7
Anterior nasal spine	ANS	The most anterior point on the anterior nasal spine	28
Point A	Pt. A	The most posterior point on the contour of the maxillary alveolar projection between the spinal root and prosthion, this point may be found at the apex of the maxillary central incisor root	28
Superior labial sulcus	SLS	The most posterior point on the upper lip	7
Prosthion	Pr	The most anterior point of the alveolar portion of the premaxillary bone, usually between the central incisors	28
Point B	Pt. B	The most posterior point on the outer contour of the mandibular alveolar process	28
Inferior labial sulcus	ILS	The most posterior point on the lower lip	7
Pogonion	Pog	The most prominent or most anterior point on the bony chin	28
Gnathion	Gn	Located by taking the midpoint between pogonion and menton	28
Menton	ME	The lowermost point on the symphyseal shadow	28

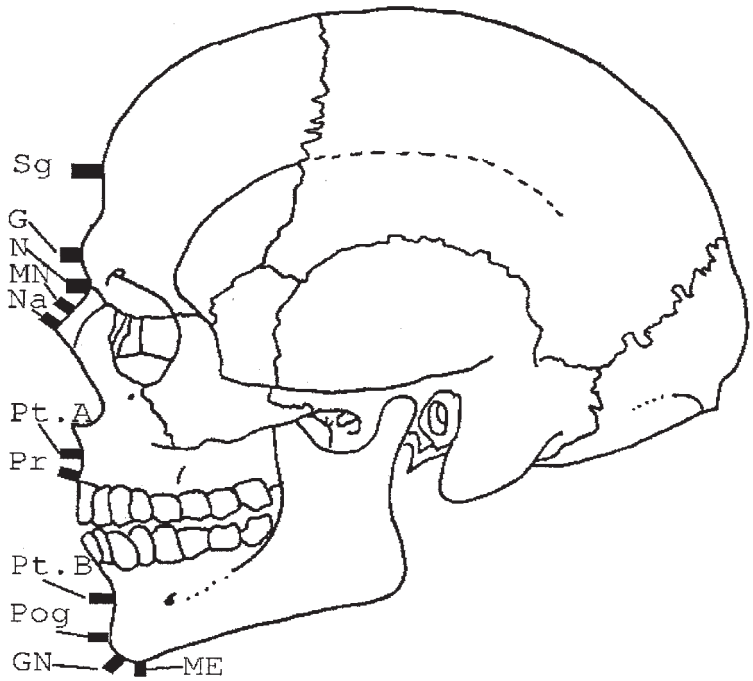

FIG. 1—*Measurement landmarks.*

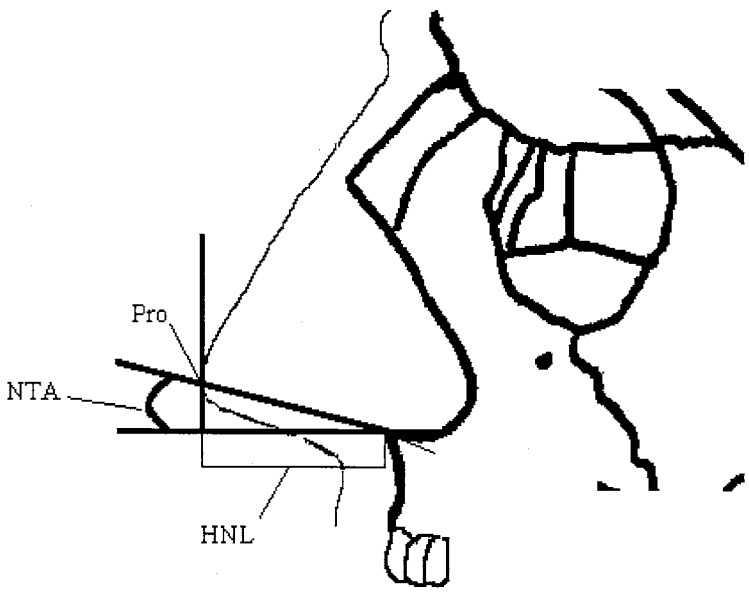

FIG. 2—*Nasal measurements.*

(28). Nasal tip angle (NTA) was measured using the following steps: first, a horizontal line is extended along the inferior nasal spine, then another line is drawn from the anterior nasal spine to pronasale (Pro). Finally, the angle formed by the horizontal line and the line drawn from ANS to Pro is measured with a protractor. This angle can then be reproduced three-dimensionally by placing a protractor along the nasal spine of the skull and adjusting the tip of the block of clay to the desired angle. Horizontal nasal length (HNL) was measured as the distance from ANS to Pro.

Lip thickness was measured for both the upper and lower lips by placing the caliper on the labial surface of the tooth and measuring out perpendicularly to the skin surface. These measurements are listed as upper lip thickness (ULT) and lower lip thickness (LLT).

The length of the eye was included as a measurement in this study and was taken as the distance between the base of the eye orbit and the apex of the cornea. The depth of eye placement in facial reconstruction has traditionally been based on artistic impression (5,11), therefore, the measurements presented here represent a first step toward the quantification of the length of the eye.

Results

Intraobserver error was tested using a sample of 20 cephalometric radiographs; ten males and ten females randomly selected from different age ranges. Data were collected on two consecutive days. Students' t-tests were not significant at any landmark ($p > .05$).

TABLE 2—*Mean midfacial tissue thicknesses of African-American juveniles from Georgia and South Carolina (all measurements in mm).*

	Age	Sex	Sg	G	N	MN	Na	Pt. A-SLS	Pt. A	Pt. B-ILS	Pt. B	Pr	Pog	Gn	ME
	7-9 YRS	M													
Mean			5.31	6.25	6.5	3.63	2.99	14.57	13.44	14.49	13.6	12.26	10.08	6.95	9.21
S.D.			1.08	1.39	1.53	1.04	0.45	2.34	2.51	3.39	2.44	1.65	2.37	1.89	4.07
N=30															
	10-12 YRS	M													
Mean			5.18	6.25	6.41	3.6	2.95	14.87	13.89	13.48	13.98	12.53	11.55	8.06	9.21
S.D.			0.84	1.06	1.67	0.81	0.56	2.06	2.42	2.43	2.55	1.59	2.79	2.41	2.38
N=32															
	13-15 YRS	M													
Mean			6.01	6.78	6.92	4.4	3.45	17.55	15.98	14.31	14.69	13.48	13.07	8.34	10.15
S.D.			1.29	1.57	1.82	0.82	0.56	2.52	1.96	2.34	2.22	1.69	3.17	2.72	4.14
N=15															
	7-9 YRS	F													
Mean			5.08	5.86	5.99	3.69	2.97	13.87	12.51	12.63	12.5	11.26	10.44	7.41	8.41
S.D.			1.13	1.23	1.54	0.88	0.72	1.85	1.66	2.82	2.28	1.34	2.46	1.84	3.50
N=23															
	10-12 YRS	F													
Mean			5.51	6.36	6.22	3.93	3.31	14.84	13.98	13.2	13.49	11.9	11.36	8.24	9.67
S.D.			1.25	1.42	1.21	0.87	0.77	1.75	1.56	3.46	3.23	1.55	2.55	2.04	2.90
N=42															
	13-15 YRS	F													
Mean			5.22	6.11	6.07	3.94	2.88	15.7	14.58	13.79	14.07	11.49	12.16	9.09	9.99
S.D.			0.95	1.29	1.25	1.04	0.30	2.04	2.17	2.64	2.82	1.17	2.58	2.59	2.56
N=18															

TABLE 3—*Means for nasal, lip, and eye measurements of African-American juveniles from Georgia an South Carolina (NTA is in degrees, all others in mm).*

	Age	Sex	NTA	HNL	EYE	ULT	LLT
	7-9 yrs.	M					
Mean			37.80	20.82	21.28	12.29	14.92
S.D.			8.76	1.81	2.70	2.44	2.34
	10-12 yrs.	M					
Mean			30.36	23.52	22.30	12.87	17.00
S.D.			7.82	2.92	2.47	2.60	3.16
	13-15 yrs.	M					
Mean			29.86	27.11	25.17	15.33	17.98
S.D.			13.57	4.80	4.01	3.87	1.59
	7-9 yrs.	F					
Mean			39.83	20.45	21.73	11.42	14.33
S.D.			11.66	2.44	2.14	2.11	1.69
	10-12 yrs.	F					
Mean			33.80	23.81	22.38	12.26	15.63
S.D.			9.96	2.57	2.80	2.59	2.57
	13-15 yrs.	F					
Mean			28.64	26.24	24.76	10.78	14.75
S.D.			9.74	2.14	3.77	1.72	2.99

Interobserver error was tested by using 20 different radiographs; ten males and ten females taken from different age ranges. A second observer, familiar with roentgenographic cephalometry, was instructed on the measurement method used and collected data on all 20 radiographs. Results from each investigator were compared and based on Students' t-tests, were not significantly different for any landmark ($p > .05$).

Mean tissue thicknesses and angular measurements for children from Georgia and South Carolina are presented in Tables 2 and 3 and it can be seen that, in general, thickness increases with age in males and females. However, it appears that growth does not occur in a slow and gradual manner for all landmarks. Some locations only show a statistically significant increase between two age categories, rather than between all three (Table 4). For example, the thickness from Pt. A to SLS is significantly greater for 13 to 15 year olds (Category 3) compared to 7 to 9 year olds (Category 1). This same measurement is also significantly greater for 13 to 15 year olds when compared to 10 to 12 year olds. However, the difference between 7 to 9 year olds and 10 to 12 year olds is not statistically significant. Therefore, the soft tissue at this location only makes a significant advance around the age of 13. The same is true for the length of the eye, which also increases significantly at age 13. Tissue thickness increases around age 13

TABLE 4—*Summary of statistically significant differences between males and females from Georgia and South Carolina ($p < .002$ using the Bonferroni method (28)).*

Landmark or Measurement	Age Category	Sex	Age Category and Sex
Sg	No	No	No
G	No	No	No
N	No	No	No
MN	1 and 3	No	No
Na	No	No	Yes
Pt. A-SLS	1 and 3, 2 and 3	No	No
Pt. A	1 and 2, 1 and 3, 2 and 3	No	No
Pt. B-ILS	No	No	No
Pt. B	No	No	No
Pr	No	Yes	No
Pog	1 and 2, 1 and 3	No	No
Gn	1 and 2, 1 and 3	No	No
ME	No	No	No
NTA	1 and 3, 2 and 3	No	No
HNL	1 and 2, 1 and 3, 2 and 3	No	No
EYE	1 and 3, 2 and 3	No	No
ULT	No	Yes	No
LLT	No	No	No

TABLE 5—*Mean midfacial tissue thicknesses and nasal measurements of African-American juvenile females from Indiana (all measurements in mm except for NTA which is in degrees).*

	Sg	G	N	MN	Na	Pt.A-SLA	Pt.A	Pt.B-ILS	Pt.B	Pr	Pog	Gn	ME	NTA	HNL
7–9 Yrs															
Mean	4.65	5.54	5.77	3.91	3.15	13.67	12.73	12.79	13.36	11.22	12.24	7.17	8.73	18	23
S.D.	0.517	0.55	0.61	0.41	0.29	0.92	0.83	1.2	1.13	0.64	1.1	1	1.3	2.8	1.2
N = 5															
10–12 Yrs															
Mean	4.95	5.71	5.99	3.99	3.4	14.93	13.54	13.71	13.42	11.84	11.87	7.3	8.36	22	23
S.D.	0.231	0.234	0.25	0.17	0.12	0.38	0.36	0.54	0.49	0.274	0.49	0.44	0.6	1.2	0.53
N = 28															
13–15 Yrs															
Mean	5.29	5.93	6.2	4.21	3.31	15.09	13.9	13.98	13.8	12.44	12.56	7.77	8.86	20	26
S.D.	0.223	0.227	0.24	0.17	0.12	0.37	0.35	0.53	0.48	0.26	0.47	0.42	0.58	1.1	0.51
N = 30															

may be explained by a circumpubertal growth spurt (30). Two landmarks, pogonion (Pog) and gnathion (Gn), exhibit a significant increase earlier at approximately nine years. Point A is the only landmark that increases significantly at both 9 and 13 years of age.

Growth of the soft tissue nose has been described as progressing in an outward and down fashion (7,30). This pattern can be seen in the results presented in Table 3. Horizontal nasal length increases from 21 to 27 mm among males and 20 to 26 mm among females. Nasal tip angle decreases with age in females, from 40 to 29°, and in males, from 38 to 30°.

Only two measurements, prosthion and upper lip thickness, were significantly different between males and females. For all males, the mean thickness for prosthion (Pr) is 12.61 mm ± 1.67 and for all females it is 11.58 mm ± 1.42. These means are very close to the means for all males and all females for upper lip thickness (ULT), which is not surprising due to the close proximity of upper lip thickness to prosthion.

When females from Georgia and South Carolina were compared to females from Indiana (Table 5), only one measurement, nasal tip angle, was observed to be significantly different. The mean for the sample from Indiana is 20° and the mean for the sample from the southeast is 34 ($p < .05$).

Discussion and Summary

The purpose of this study was to examine variation in midfacial tissue thicknesses in African-American children and to add to the growing database of measurements useful for facial reconstruction. Of the independent variables, age seems to be the primary factor contributing to significant variation in facial tissue thickness. Few significant differences were observed between males and females or between females from different geographic regions. Interestingly, all of the tissue thicknesses that undergo significant increases are located on the masticatory complex. This fits well with fact that craniofacial skeletal growth after age 3 is characterized by a decrease in growth of the cranial vault with a concurrent marked enlargement of the face and jaws (30).

Results of this study are neither identical to previously published data regarding children nor are they markedly different. For example, when considering differences due to sex among children of European descent, Dumont (21) observed differences between males and females but only after 12 years of age, while Garlie and Saunders (20) and Hodson (22) describe only one or two landmarks that were significantly different. Only Manhein et al. (19) report significant differences between males and females in their study of African-American children. Significant differences due to age have been reported by Dumont, Garlie and Saunders, and Manhein et al., but not Hodson. However, only Dumont and Garlie and Saunders report specific ages. Dumont observed a significant increase at age 12 and Garlie and Saunders found an increase in thickness around age 9 and then again around age 14. This is interesting because significant growth periods were observed at age 9 and 13 among children in this study.

When means from this study are compared to means for children of European descent published by Dumont, the means from this study are smaller at four out of six landmarks. When compared to means from the children of European descent examined by Garlie and Saunders, no consistent pattern is evident; some landmarks are smaller and some are larger. Measurements from this study are consistently smaller than those reported by Manhein et al. and consistently larger than those reported by Hodson. Differences between thicknesses from this study and those of Manhein et al. could be due to the fact that they collected data on living individuals using ultrasound. However, differences to Hodson may be the result of differences in predominant ancestry.

Finally, significant differences in mean tissue thickness between African-American children of different ages have been demonstrated in this study, however, in many instances the difference between means is less than a millimeter. This may be enough to produce a statistically significant difference but such a small amount may not impair someone's ability to identify the unknown individual or affect a reproduction. For example, would someone be unable to recognize an African-American child if the facial reconstruction was generated using measurements intended for children of European descent? Therefore, further research is necessary to determine if the small but significant differences between means for children of different sex, age, and ancestry reported in this study and by others (19–22) are enough to hamper or establish an identification.

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