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In Vivo Facial Tissue Depth Measurements for Children and Adults*

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ABSTRACT: This study reports results of a facial tissue depth measurements project conducted over a two-year period on a modern sample of children and adults of both sexes and varying ages and races. The purpose of this research was to increase available tissue depth data for children and update facial tissue depth measurements for American adults. Most volunteers for this project were patients or visitors to the pediatric clinic at the Louisiana State University Medical Center, School of Dentistry, in New Orleans. Using state-of-the-art ultrasound technology, we scanned 551 children and 256 adults at 19 points across the face. Thirteen of the scanned points were traditional landmarks while six others were areas not measured by previous researchers or were points for which very little data exist for both children and adults. For this presentation, we analyzed data for 515 children and 197 adults. Results of Pearson's correlations, analysis of variance, and paired *t*-tests indicate that age, sex, and race are significant factors when considering tissue depth means for different measurement locations across the human face. These new standards are compared to the work of other researchers. Our results provide valuable assistance in both two-dimensional and three-dimensional facial reproductions and superimpositions.

KEYWORDS: forensic science, facial tissue depth standards, ultrasound, adults and children

To obtain in vivo facial tissue depth data on living adults and to enhance available tissue depth data for children, in 1995 the Louisiana State University (LSU) FACES Laboratory (Forensic Anthropology and Computer Enhancement Services) in Baton Rouge, and the LSU Medical Center School of Dentistry in New Orleans began a joint, longitudinal project. This paper presents results of a cross-sectional portion of this study. Supported in part by a grant from the Louisiana Educational Quality Support Fund (LEQSF, or 8 g), we used diagnostic ultrasound to scan children and adults from a variety of ethnic backgrounds. The standards created from this study have widespread applications.

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In forensic contexts, positive identification of human skeletal remains can come from a variety of different sources. Dental and other radiographs and DNA comparisons are among the more popular techniques which can provide the information needed to confirm an individual's identification. However, when an identification has not been established, other techniques such as facial reconstruction can aid in assisting with a putative identification.

Though clay death masks have been found in human burials that are thousands of years old, the history of the technique of applying clay across the skull to obtain a likeness of someone most recently dates to the 19th century. In the late 1800s, German anatomists such as Kollmann, Büchly, and His (1,2) collected facial tissue depth measurements on adult males and females of European ancestry. Early on, these measurements, taken from cadavers, were used to create facial reproductions of historically-important persons such as Bach, Raphael, and Dante (2–6).

Techniques that arose from reconstructions of physiognomy and photographic superimpositions of famous persons spread into forensic science in an effort to assist with identification of the dead. In the 20th century, researchers such as Suzuki (7) and Lebedinskaya (8) collected facial tissue depth measurements on a broad scale for various populations outside of the United States.

In the United States, the standards developed by some of the early European researchers were updated in the 20th century for American whites by Rhine et al. (9), while Rhine and Campbell (10) compiled additional measurements on American blacks.

In the past, soft tissue thickness data were often collected from cadavers using a calibrated needle which was gently pushed into the soft tissue (10). Occasionally, this method was shown to affect the measured depth of the soft tissue matrix (11). However, part of the reason for the use of this particular method was access to cadavers and lack of a safe, non-invasive alternative for obtaining such measurements on living people.

Using these facial tissue depth standards created by both 19th and 20th century researchers, forensic anthropologists, artists, and scientific sculptors have experienced success in identifications. Gatliff and Snow (12), Gerasimov (5), Helmer et al. (13), Krogman and İşcan (3), Neave (14), Rathbun (15), Rhine (16), Suzuki (17), and others have reported varying success rates in three-dimensional reconstructions. Some have recorded rates of identification as high as 75% for all cases attempted.

Several researchers have published tissue thickness standards for adults, but fewer such data on facial tissue depth thicknesses in children have been available. In the United States, Dumont (18) used radiographic analysis to collect mid-facial tissue thicknesses on approximately 200 white children ages 9–15. Williamson and Rathbun (19) used orthodontic radiographs to collect similar mid-facial tissue depths on approximately 200 black children. Williamson's unpublished MA thesis provides additional data on this study of African-American children in Columbia, South Carolina, and Augusta, Georgia (20). Garlie and Saunders' (21) recent study on mid-facial tissue depths of Canadian children is also available. Complementing these three mid-facial studies are unpublished data Krogman compiled from the Bolton studies of radiographs of white children taken at Western Reserve beginning in the 1920s (Gatliff, personal communication 1998).

Another study in the United States by Hodson et al. (22) used diagnostic ultrasound to measure tissue thicknesses in 50 Caucasoid children ages 4–15 along the median, right sagittal, and right lateral planes. Ultrasound technology has various applications, especially as a non-invasive diagnostic tool that is used widely in gynecological as well as other medical subfields. Its common usage on humans began more than 30 years ago (23,24). Hodson et al. (22) and Lebedinskaya et al. (8) chose ultrasound as their method for tissue depth data collection because it is both safe and accurate. In the ten or more years since Hodson et al.'s study, ultrasound technology has experienced unprecedented growth in terms of refinement of the equipment, portability, and increased use in the medical field as a safe, effective diagnostic tool.

The study reported here used ultrasound technology to measure facial tissue thicknesses in order to increase databases for children and adults and to provide tissue depth data for areas of the face where no data existed in the past. We also compare our results to those of earlier researchers.

Methods

After demonstrations of several different types of ultrasound systems (ranging in price from $10,000 to $125,000), for our project, we chose an Aloka SSD-500 OB/GYN system (black and white monitor) with an Aloka UST-5521-7.5 Mhz transducer. To that we added a Sony Video Graphic Thermal printer (UPP-890MD) which uses Sony thermal paper (UPP-110HD). At an approximate total cost of $15,000 for the complete system, this lightweight, portable equipment (less than 25 pounds) was easily transported to and from the data collection site.

The system's monitor displays the identification number for each case, date, time, ultrasound image for a particular point, and centimeter measurement increments at the top of the viewing field. Calipers within the machine, which are controlled from a track ball, measure the distance between designated points (surface of skin to bone) directly from the image displayed on the monitor. These calipers measure in centimeters and round to the nearest tenth, or millimeter.

A certified ultrasound technician worked extensively with us and trained Listi in the principles of sonography, operation of the equipment, and interpretation of the sonographic images. Additionally, he traveled to New Orleans to monitor Listi's application of techniques, noting inconsistencies for testing interobserver errors.

Using this ultrasound system, we collected in vivo tissue depth data at 19 points across the human face, our volunteers ranging in age from three to 97 years. Currently, our database for facial tissue thickness is composed of 551 children and 256 adults.

Volunteers for this project were solicited from among a pool of dental school patients and visitors who arrived daily for preventive dentistry in the pediatric clinic of the LSU School of Dentistry in New Orleans. A consent form and brief biographical data sheet were prepared for each subject by his/her parent. Information collected included name, birthday, height, weight, greatest lip height, subject's race, mother and father's race(s), and additional information on ethnic background.

The subject was seated and photographed in the frontal and lateral views. The transducer, coated with a liberal amount of ultrasonic coupling gel, was then lightly applied to each measurement site on the face for 3 to 5 s. The image was captured, then printed on thermal paper, and later stored in individual case files. Each printed image displays two measurement points. Therefore, each case file contains ten printouts representing the 19 measurements. These photo-quality printouts are permanently preserved in archival pouches for future reference and comparisons (Fig. 1).

Of the 19 points we measured, 13 are traditional landmarks while six others (points 4, 11, 12, 15, 16, and 19) are areas not measured in the past or are points for which very little data exist. For example, lateral eye (point 16) is an area often cited as problematic and difficult to contour in two-dimensional and three-dimensional facial reconstructions because no modern data exist for this site. Also, while current standards exist for points 13 and 14 (the cheek region), these standards have proven to be ineffective in reconstructions (Fig. 2).

One of our major goals for the data collection portion of this project was to establish a procedural guide that took into consideration the difficulty in locating a bony landmark covered by soft tissue. We wanted to ensure that the protocol for locating that landmark was one that others would find repeatable. Table 1 briefly outlines the procedure for determining the location of the bony substructures. Figure 3 shows the position of the landmarks on a volunteer's face (Fig. 3). The exact location of the landmarks was established in part by using the facial features of the individual volunteers. Such a procedure allowed for consistency in pinpointing the bony landmark's location despite differences in sex, age, or weight.

The 19 points on the face were measured on the right side of the face. Though slight facial asymmetry is commonly known, we chose to use just one side in order to complete the scanning on children in a timely manner. Data collection was facilitated by the fact that the volunteer needed to remain perfectly still for each measurement only during the brief few seconds the transducer was touching the face. Once the transducer was removed, the volunteer could relax for a few moments. We found this protocol to be especially effective with children.

In many cases, several siblings were measured, and multiple generations of family members participated. Oftentimes, at least, one parent and the children were scanned. In a few cases, three generations of the same family were scanned. These data will be used in future analyses to evaluate sibling and generational relationships in tissue thickness among family members.

A total of 807 volunteers were entered into SPSS/PC + (v.5.0) and analyzed using SPSS/PC+ and SPSSWIN (v.8.0). For this report, we have used a subset which includes 515 children and 197 adults of "normal" weight. Subjects were placed into a normal weight category if the visual assessment concluded that they were not severely under or overweight. The purposes of data analysis for this presentation were twofold: 1) to report standard summary statistics, including means, standard deviations, and ranges of tissue thicknesses for groups of varying ages, sexes, and races; and 2) to determine if any relationship existed between tissue thickness and age. Because of the large sample size, Pearson's correlations were calculated to determine the association between age and tissue thickness for different racial groups. Analysis of variance was used to determine if there were significant differences in the measurements among defined age groups, males and females, and race

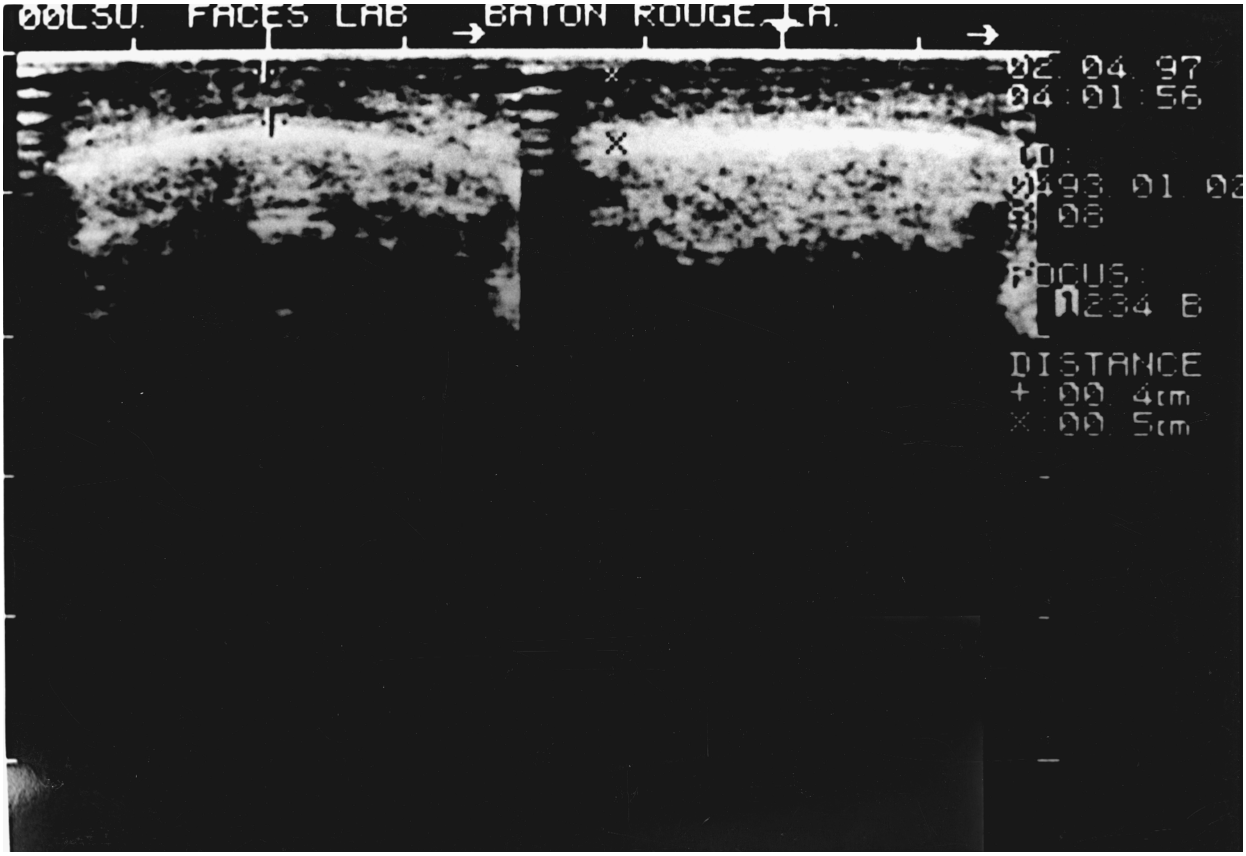

FIG. 1—*Thermal printout of ultrasound data displaying measurement points 1 and 2.*

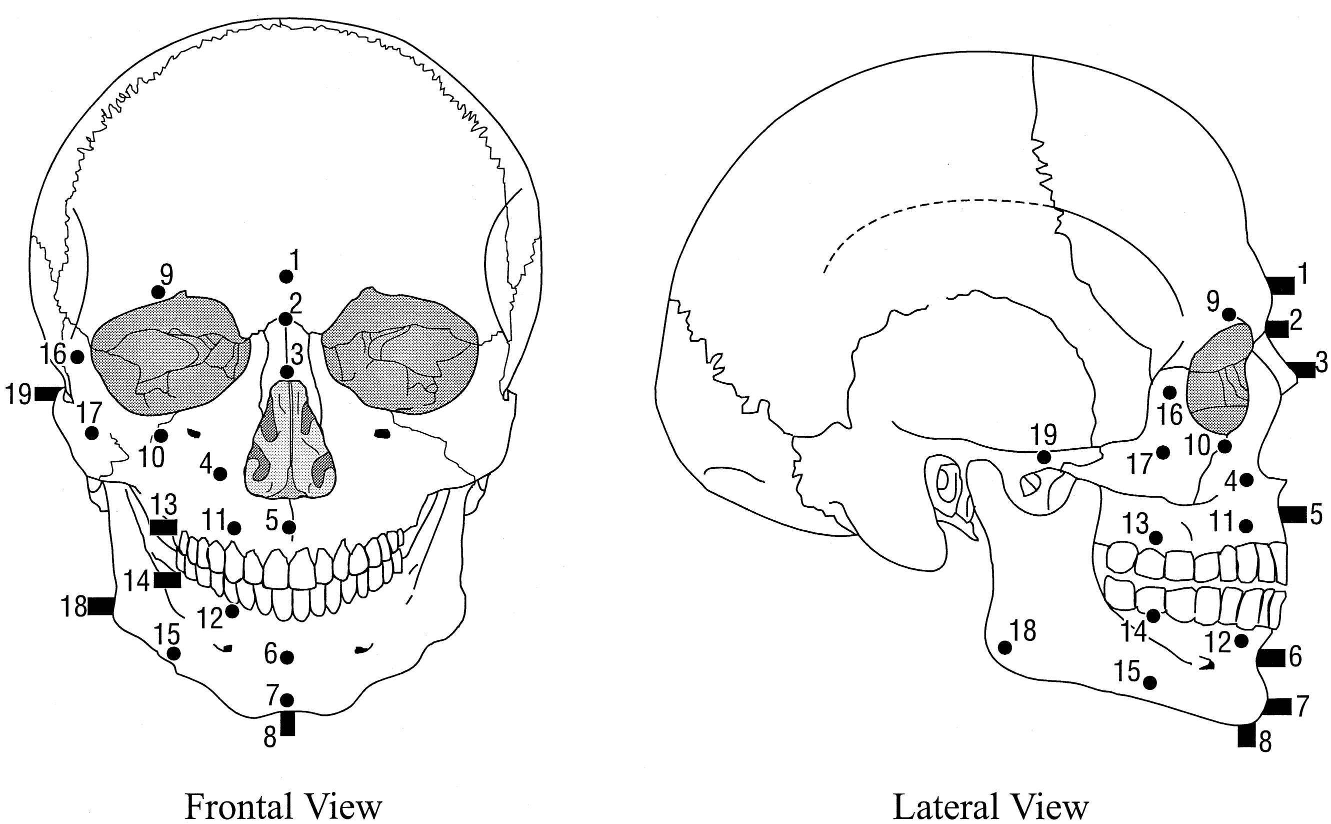

FIG. 2—*Data points on skull.*

TABLE 1—*Point numbers and descriptions*.

1 Glabella	approximately 1 cm above and directly between the subject's eyebrows
2 Nasion	directly between eyes
3 End of nasals	palpating to determine where bone ends and cartilage begins
4 Lateral nostril	approximately 0.5 cm to the right of the nostril
5 Mid-philtrum	centered between nose and mouth
6 Chin-lip fold	centered in fold of chin, below lips
7 Mental eminence	centered on forward-most projecting point of chin
8 Beneath chin	centered on inferior surface of mandible
9 Superior eye orbit	centered on eye, at level of eyebrow
10 Inferior eye orbit	centered on eye, where inferior bony margin lies
11 Supra canine	upper lip, lined up superiorly/inferiorly with lateral edge of nostril
12 Sub canine	lower lip, lined up superiorly/inferiorly with lateral edge of nostril
13 Supra M2	cheek region, lateral: lined up with bottom of nose; vertical: center of transducer lined up beneath lateral border of eye, measurement taken 0.5 cm to the left of center mark
14 Lower cheek	cheek region, lateral: lined up with mouth; vertical; same as 13
15 Mid mandible	inferior border of mandible, vertically lined up same as 13
16 Lateral eye orbit	lined up laterally with corner of the eye, on the bone
17 Zygomatic	lined up with the lateral border of the eye, on the zygomatic process
18 Gonion	found by palpating
19 Root of zygoma	anterior to and 0.5 cm superior to tragus
Greatest lip height	Measured from superior most point of the upper lip to the inferior-most part of the lower lip.

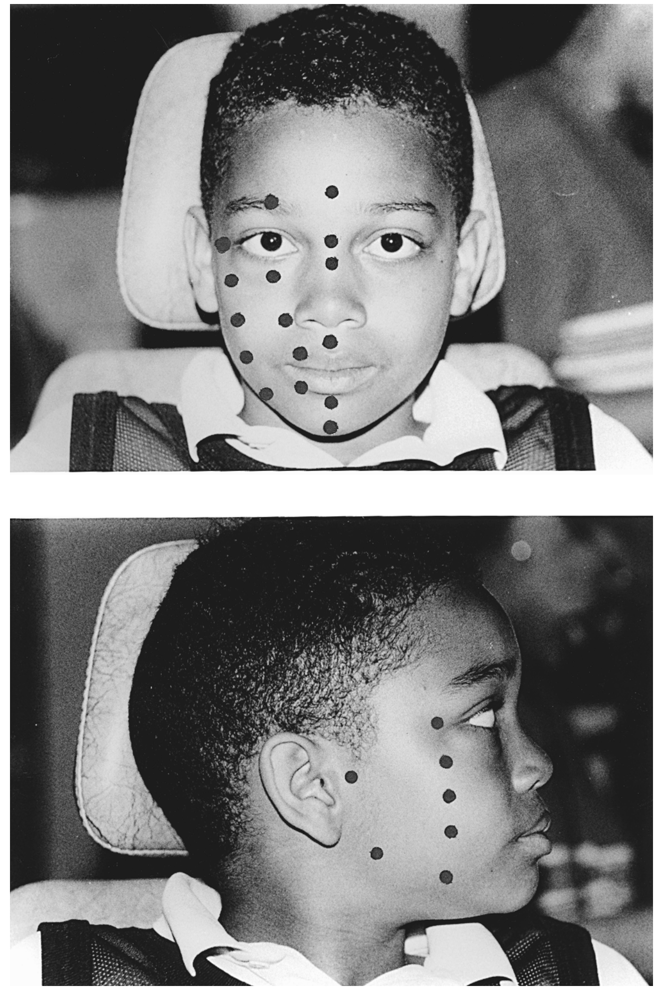

FIG. 3—*Frontal and lateral views of 10 year-old male volunteer showing measurement sites.*

categories. Additionally, a paired *t*-test was run on a small subset of volunteers (three adults and two teenagers) to test for variation in measurements when volunteers were lying down versus sitting. For all statistical analyses, a significance level of <0.05 and/or <0.01 was used.

Results

We first report results for children. These results are grouped in arbitrary age categories. Tables 2, 3, and 4 provide the means, standard deviations, and ranges for black ($N = 111$m and 136f), white ($N = 108$m and 129f), and Hispanic children ($N = 15$m and 16f). Those measurement sites showing the greatest standard deviation are 13, 14, 15, and 18 and are consistent among the three groups. This suggests a great deal of variation in tissue thickness in the cheek region for all three groups of children and may partially explain the difficulty reconstructionists have in producing a three-dimensional likeness.

Table 5 reflects results of Pearson's correlations for black, white, and Hispanic children with sexes combined, ages 3–18 collapsed. A significant relationship exists between age and tissue thickness at 16 of the 19 points for white, 17 of 19 for black, and eight of 19 points for Hispanic children. On the other hand, black, white, and Hispanic children do not show a significant relationship between age and tissue thickness at points 3 and 17. Additionally, when age categories are separated into shorter time spans, several points continue to show a significant correlation between tissue thickness and age.

Table 6 reports the results of the analysis of variance that demonstrates which specific sites reflect significance when each group is compared to another group. In this analysis, ages 3–18 were collapsed, while sex and race were separated. For example, at point 2, white males vary significantly from all other groups; at the same point, black females vary significantly from only white and black males, but not from white or Hispanic females, suggesting that sex influences tissue thickness at this measurement site.

Finally, for children, we compared our data to those collected by Hodson et al. (22), Dumont (18), Garlie and Saunders (21), and Williamson (20). The databases of Hodson et al., Dumont, and Garlie and Saunders are comprised of white children. Hodson et al., who also used ultrasound technology, shares 11 common sites with us. We collapsed our children ages 4–15 to correspond to Hodson et al.'s ranges. In most cases, tissue depth means for males and females vary minimally between Hodson et al. and LSU, except at points 13, 14, and 18.

Additionally, Dumont and Garlie and Saunders used lateral X-rays to measure tissue thickness in white children. Dumont shared six data points in common with us; Garlie and Saunders shared seven. Our means for each measurement site are consistently smaller than those of both Dumont and Garlie and Saunders. Williamson also used radiographs in his study of African-American children. Though his age ranges differ slightly from ours, our results for the seven shared measurement sites are consistently smaller than his.

TABLE 2—*Tissue depth means (mm) for black children of normal weight ages 3–18 years.*

Point Numbers & Descriptions	3–8 Years						9–13 Years						14–18 Years					
	Female ($N = 52$)			Male ($N = 37$)			Female ($N = 59$)			Male ($N = 62$)			Female ($N = 25$)			Male ($N = 12$)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	4.0	0.91	2–6	4.1	0.74	3–6	4.3	0.83	3–6	4.5	0.97	3–7	4.7	1.14	3–7	5.3	0.78	4–7
2 Nasion	4.9	0.96	3–8	5.4	0.96	3–7	5.4	1.00	3–7	5.4	0.98	3–8	5.3	1.11	4–8	6.1	0.51	5–7
3 End of nasals	1.7	0.61	1–3	1.8	0.48	1–3	1.7	0.56	1–3	1.9	0.46	1–3	1.7	0.54	1–3	2.1	0.51	1–3
4 Lateral nostril	7.0	1.48	5–11	7.3	1.68	5–11	7.6*	1.58	5–12	7.4	1.91	4–13	8.1	2.14	5–12	7.9	1.98	5–10
5 Mid-philtrum	8.9	1.57	6–14	9.0	1.18	6–11	9.6	1.56	7–13	10.0	1.69	7–18	9.9	2.20	7–16	12.1	1.73	10–15
6 Chin lip fold	8.2	2.05	3–15	8.6	1.44	6–12	10.3	1.77	7–15	9.8	1.84	6–13	10.1	1.79	7–13	12.6	1.93	10–16
7 Mental eminence	8.3	2.16	4–14	8.3	1.59	6–11	10.0	2.60	5–16	9.9	3.03	5–18	10.0	2.65	4–15	9.5	2.78	5–13
8 Beneath chin	4.8	1.61	2–10	4.5	1.12	2–6	5.8	2.15	2–12	5.5	2.09	2–11	5.6	1.93	2–10	6.3	1.86	4–10
9 Supraorbital	4.5	1.02	3–7	4.5	0.65	3–6	5.3	1.03	3–8	5.2	1.12	3–9	5.7	1.46	4–10	5.8	0.94	4–7
10 Suborbital	5.6	1.14	3–9	5.6	1.07	3–8	6.1	1.12	4–10	5.8	1.19	3–9	6.4	1.50	4–11	6.0	0.74	5–7
11 Supracanine	8.8	1.59	5–14	8.9	1.86	6–15	10.0	1.79	7–16	10.7	2.74	7–27	10.6	1.50	8–13	12.3	2.05	9–17
12 Subcanine	9.0	2.20	5–15	8.5	1.24	6–11	10.2	2.16	6–17	11.0	3.02	7–24	11.0	2.25	7–16	12.8	2.67	8–17
13 Posterior maxilla‡	23.0	3.39	15–32	22.1	2.47	17–27	24.5	3.72	18–34	23.6	4.35	12–33	27.6	3.52	22–37	26.0	2.89	21–30
14 Sup mid mandible‡	18.0	3.26	10–26	17.4	2.68	10–25	20.0	3.58	10–26	20.1	4.18	11–28	23.2	3.99	18–33	21.9	4.91	12–29
15 Inf mid mandible‡	9.8	3.16	5–20	8.7	2.03	5–14	10.8	2.99	6–18	10.3	3.86	4–20	12.0	3.16	7–20	11.2	3.93	7–20
16 Lateral eye orbit	3.9	0.89	2–6	4.1	0.85	2–6	4.4	1.24	2–10	4.4	0.89	3–7	4.6	1.08	3–8	4.4	0.67	3–5
17 Anterior zygoma§	8.3	2.23	4–15	7.8	1.55	5–12	8.9	2.22	6–14	8.3	2.66	4–15	9.2	1.68	6–13	7.3	2.05	5–12
18 Gonion	13.5	2.87	8–21	12.8	2.02	10–17	14.6	3.41	3–23	14.7	3.06	9–22	16.2	3.36	10–23	17.9	3.63	11–24
19 Root of zygoma	4.7	1.21	3–8	4.2	0.98	3–6	4.8*	1.55	3–8	5.0†	1.73	2–12	6.2	2.30	3–13	6.0	2.37	3–11

* Indicates $N = 58$.
† Indicates $N = 61$.
‡ Parallel to zygoma marker (bases of 13, 14, and 17 line up vertically in the Frankfort plane).
§ Marker placed just below bony ridge of eye orbit (see Fig. 1).

TABLE 3—*Tissue depth means (mm) for white children of normal weight ages 3–18 years.*

Point Numbers & Descriptions	3–8 Years						9–13 Years						14–18 Years					
	Female (N = 43)			Male (N = 36)			Female (N = 51)			Male (N = 45)			Femal (N = 35)			Male (N = 27)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	3.9	0.98	2–7	4.0	0.84	3–6	4.4	1.08	2–7	4.6*	1.04	3–7	4.6	0.98	3–6	5.0	0.73	4–7
2 Nasion	5.0	0.94	3–7	5.7	0.96	3–8	5.5	1.03	3–8	5.7*	1.09	3–8	5.4	0.88	4–8	6.3	1.07	4–8
3 End of nasals	1.7	0.52	1–3	1.8	0.67	1–4	1.5	0.54	1–3	1.6	0.53	1–3	1.8	0.51	1–3	2.0	0.44	1–3
4 Lateral nostril	7.0	1.86	4–12	7.2	1.75	4–11	7.7	2.00	4–15	7.4	1.71	5–12	7.7	1.78	5–12	7.8	1.96	5–12
5 Mid-philtrum	8.3	1.35	6–12	9.0	1.59	6–12	9.4	1.54	6–13	9.7	1.50	7–14	9.4	1.46	7–12	11.2	1.98	7–15
6 Chin lip fold	7.6	1.51	5–12	8.1	1.79	6–12	9.0	1.45	6–13	9.6	1.75	7–14	9.7	1.25	8–13	10.4	1.28	7–13
7 Mental eminence	7.4	1.81	4–11	8.3	2.14	4–12	8.8	1.98	5–14	8.7	2.93	4–17	8.7	1.75	5–14	9.3	1.9	7–14
8 Beneath chin	4.2	1.19	2–8	4.6	1.13	3–7	5.5	1.64	2–11	5.5	1.44	4–10	5.5	1.36	4–9	6.0	1.57	4–11
9 Supraorbital	4.4	1.15	3–7	4.6	0.84	3–6	5.1	0.92	3–8	5.2	0.82	3–7	5.7	1.47	4–12	5.7	0.83	4–7
10 Suborbital	5.6	1.12	3–8	5.5	0.94	4–8	5.6	1.08	4–8	5.9	1.14	4–9	6.0	1.25	3–9	5.3	1.23	4–9
11 Supracanine	8.4	1.29	6–11	9.4	1.98	6–14	9.8	1.68	7–14	10.0	1.77	7–15	10.3	3.22	7–26	11.7	2.33	8–19
12 Subcanine	7.9	1.44	5–11	8.4	1.4	6–13	9.2	1.61	6–13	9.6	1.70	6–13	9.8	2.40	6–21	10.6	2.32	7–17
13 Posterior maxilla†	22.7	3.48	14–30	23.3	3.73	14–31	24.3	2.88	19–32	24.7	4.30	18–34	26.8	4.96	5–34	27.4	3.38	22–35
14 Sup mid mandible†	18.9	3.59	8–24	20.7	3.64	13–31	20.8	3.63	13–29	21.6	3.71	15–30	23.2	4.58	5–30	23.2	3.48	15–31
15 Inf mid mandible†	10.5	3.33	4–18	10.4	2.8	6–15	11.7	3.24	4–18	12.1	3.99	6–22	13.4	2.76	9–19	12.3	4.49	6–24
16 Lateral eye orbit	4.0	0.89	3–6	4.1	0.91	2–6	4.6	1.09	3–9	4.4	0.87	3–7	4.5	0.85	3–6	4.3	0.86	3–7
17 Anterior zygoma‡	8.4	2.44	5–15	8.4	2.29	5–15	9.5	2.24	5–14	9.1	2.46	5–15	9.5	1.85	6–16	8.0	1.76	6–13
18 Gonion	13.9	3.27	7–22	13.7	2.89	8–20	14.4	2.90	8–19	15.4	3.63	9–24	17.0	2.67	12–22	18.1	3.04	14–24
19 Root of zygoma	4.6	1.51	3–10	4.8	1.02	3–7	5.2	1.58	3–10	5.4	1.79	2–10	6.8	1.88	4–12	6.0	2.07	4–12

* Indicates $N = 44$.
† Parallel to zygoma marker (bases of 13, 14, and 17 line up vertically in the Frankfort plane).
‡ Marker placed just below bony ridge of eye orbit (see Fig. 1).

TABLE 4—*Tissue depth means (mm) for Hispanic children of normal weight ages 3–18 years.*

Point Numbers & Descriptions	3–8 Years						9–13 Years						14–18 Years					
	Female (N = 6)			Male (N = 3)			Female (N = 9)			Male (N = 8)			Female (N = 1)			Male (= 4)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	4.2	0.75	3–5	4.7	0.58	4–5	3.8	0.83	3–5	4.1	0.83	3–5	7.0	–	–	4.5	1.00	4–6
2 Nasion	5.0	1.10	3–6	6.3	1.15	5–7	5.3	0.87	4–6	4.9	1.25	3–7	5.0	–	–	4.8	0.50	4–5
3 End of nasals	1.7	0.52	1–2	1.7	0.58	1–2	1.6	0.53	1–2	1.6	0.52	1–2	1.0	–	–	1.5	0.58	1–2
4 Lateral nostril	6.3	1.03	5–8	6.3	1.53	5–8	5.7	1.12	5–8	7.9	2.23	5–12	9.0	–	–	5.0	0.82	4–6
5 Mid-philtrum	8.0	1.55	7–10	7.3	0.58	7–8	9.2	1.20	8–11	9.3	1.75	5–10	8.0	–	–	11.5	1.29	10–13
6 Chin lip fold	8.7	2.07	6–11	7.0	2.00	5–9	9.2	1.48	7–12	10.0	1.85	6–12	11.0	–	–	11.3	2.06	9–14
7 Mental eminence	8.0	2.00	5–10	6.0	1.00	5–7	8.4	1.59	6–11	8.4	2.77	5–13	15.0	–	–	10.3	0.96	9–11
8 Beneath chin	4.2	1.72	2–6	4.7	1.53	3–6	5.1	1.36	3–7	5.1	0.99	4–6	9.0	–	–	5.8	0.96	5–7
9 Supraorbital	4.2	0.75	3–5	4.3	0.58	4–5	4.9	0.93	3–6	4.9	0.99	4–6	7.0	–	–	5.5	1.29	4–7
10 Suborbital	5.5	1.87	3–8	5.0	2.00	3–7	5.0	1.12	3–6	6.4	1.41	4–9	10.0	–	–	5.8	0.96	5–7
11 Supracanine	9.3	2.66	7–14	8.0	1.00	7–9	10.3	1.66	9–13	10.0	2.33	6–13	11.0	–	–	12.0	0.82	11–13
12 Subcanine	8.2	2.32	6–11	6.7	0.58	6–7	8.3	1.32	6–10	10.8	2.12	8–14	10.0	–	–	10.0	3.16	6–13
13 Posterior maxilla*	24.8	3.37	20–28	19.7	3.51	16–23	24.6	4.13	16–29	24.4	2.33	21–28	32.0	–	–	25.3	4.27	19–28
14 Sup mid mandible*	20.8	6.15	10–28	14.7	4.73	11–20	20.0	5.12	9–26	21.4	2.83	18–27	24.0	–	–	21.0	1.41	20–23
15 Inf mid mandible*	11.5	3.94	5–16	7.3	4.04	5–12	11.3	2.78	6–15	10.8	3.11	5–14	18.0	–	–	10.3	4.57	5–15
16 Lateral eye orbit	4.3	0.82	3–5	3.0	0.00	3–3	3.8	0.44	3–4	4.6	0.52	4–5	5.0	–	–	4.3	0.96	3–5
17 Anterior zygoma†	8.5	2.66	5–13	6.3	2.08	4–8	7.4	1.13	6–9	8.4	1.69	6–11	14.0	–	–	7.8	1.89	5–9
18 Gonion	14.0	3.41	8–18	13.7	5.03	9–19	14.6	3.05	10–19	15.4	4.63	7–21	24.0	–	–	15.3	4.86	9–20
19 Root of zygoma	4.3	0.82	3–5	4.3	2.31	3–7	4.6	1.33	3–6	6.3	1.28	5–8	8.0	–	–	4.8	1.50	3–6

* Parallel to zygoma marker (bases of 13, 14, and 17 line up vertically in the Frankfort plane).
† Marker placed just below bony ridge of eye orbit (see Fig. 1).

TABLE 5—*Pearson's correlations (r) between tissue thickness and age for children (ages 3–18).*

Point Numbers & Descriptions	White (N = 237)	Black (N = 247)	Hispanic (N = 31)
1 Glabella	0.350†*	0.330†	0.131
2 Nasion	0.191†*	0.180†	0.057
3 End of nasals	0.119	0.057	−0.154
4 Lateral nostril	0.177†	0.171†§	−0.011
5 Mid-philtrum	0.351†	0.350†	0.404‡
6 Chin lip fold	0.511†	0.497†	0.614†
7 Mental eminence	0.191†	0.264†	0.498†
8 Beneath chin	0.350†	0.243†	0.372‡
9 Supraorbital	0.441†	0.416†	0.551†
10 Suborbital	0.065	0.208†	0.261
11 Supracanine	0.336†	0.423†	0.557†
12 Subcanine	0.395†	0.412†	0.469†
13 Posterior maxilla	0.427†	0.380†	0.275
14 Sup mid mandible	0.369†	0.444†	0.284
15 Inf mid mandible	0.304†	0.237†	0.203
16 Lateral eye orbit	0.128‡	0.228†	0.248
17 Anterior zygoma	0.078	0.082	0.161
18 Gonion	0.446†	0.399†	0.360‡
19 Root of zygoma	0.415†	0.320†	0.286

* N = 236.
† $p < .01$.
‡ $p < .05$.
§ N = 246.

TABLE 6—*Summary of ANOVA (Duncan) showing significant variation among Black, White, and Hispanic children (3–18 years).*

Groups	Measurement Sites 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
White females (A)	–	B	D	E	B,D	B,C,D	C,D	–	–	–	B,D	C,D	D	D	C,D	–	D	–	D
White males (B)	C	A,C,D,E,F	–	E	A,C,E	A	–	–	–	C	A	D	D	C,D	C,D	–	–	C,D	D
Black females (C)	B	B,D	D	E	B,D	A	A	–	–	B	–	A,E	D	B	A,B	–	D	B	–
Black males (D)	–	B,C	A,C	E	A,C,E	A	A	–	–	–	A	A,B,E	A,B,C	A,B	A,B	–	A,C	B	A,B
Hispanic females (E)	–	B	–	A,B,C,D	B,D	–	–	–	–	–	–	C,D	–	–	–	–	–	–	–
Hispanic males (F)	–	B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

NOTE: Letters indicate the groups between which the differences in tissue thickness are significant. ($p < .05$).

Next, we report our results for adults. Tables 7 and 8 provide the means, standard deviations, and ranges for black and white adults. Again, as with the children, the greatest standard deviations and ranges are seen at points 13, 14, 15, and 18.

Table 9 reports the results of Pearson's correlations for white and black adults, ages 19–55 and sexes collapsed. A significant relationship exists between age and tissue thickness at eight of 19 points for white adults and five of 19 points for black adults. For example, measurement site 4 (lateral nostril) indicates that age influences this measurement for white adults at the 0.01 level of significance. On the other hand, age has no significant influence on this measurement for black adults. When broken down into shorter age spans, however, with few exceptions, results do not reflect the influence of age.

Table 10 summarizes the results of an ANOVA and indicates significant relationships among races and between sexes at each of the 19 data points (ages 19–55 collapsed). For example, for adults, no significant variation exists among the different groups at sites 4, 10, 13, and 14. Yet, white males vary significantly from white females at 11 of the 19 points.

We then wished to compare our data for adults to those published data collected by other researchers to answer the question of congruency over time. Table 11 outlines those comparisons and indicates some interesting results. In reviewing His and Kollmann-Büchly's data from 100 years ago, we note less than 2 mm of variation exists among the means for all researchers in most of the shared points. Generally, our measurements reflect an increase in tissue depths. This increase in facial tissue thickness would be consistent with the increase in size of modern populations from those of the nineteenth century.

Table 12 compares our data to Rhine and his colleagues. Though not tested statistically, means vary greatest at only three sites for white females—13, 14, and 18—and six sites for black females—3, 5, 13, 14, 17 and 18. Our white males vary greatest from Rhine's

TABLE 7—*Tissue depth means (mm) for Black adults of normal weight.*

Point Numbers & Descriptions	19–34 Years						35–45 Years						45–55 Years		
	Female (N = 18)			Male (N = 19)			Female (N = 21)			Male (N = 3)			Female (N = 5)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	4.6	0.70	4–6	5.2	1.12	3–7	4.5	0.93	3–7	5.3	1.53	4–7	4.8	0.84	4–6
2 Nasion	6.0	0.91	4–8	6.6	0.84	5–8	5.2	1.25	4–8	5.7	2.08	4–8	6.0	1.00	5–7
3 End of nasals	1.7	0.46	1–2	2.2	0.42	2–3	1.5	0.51	1–2	1.7	0.58	1–2	2.0	0.71	1–3
4 Lateral nostril	8.4	1.98	6–12	9.2	2.82	6–15	8.4	2.01	5–13	10.3	2.52	8–13	8.4	1.52	6–10
5 Mid-philtrum	9.2	1.82	6–13	13.0	2.20	10–18	8.8	1.92	6–13	11.0	1.73	9–12	8.2	2.49	6–12
6 Chin lip fold	11.8	2.20	7–15	12.7	2.05	10–17	11.7	2.42	8–18	12.7	1.15	12–14	10.0	2.55	6–13
7 Mental eminence	10.8	2.68	5–15	12.1	2.90	7–18	11.2	2.25	7–15	12.3	4.51	8–17	10.8	3.11	8–16
8 Beneath chin	6.7	2.02	3–10	8.8	1.89	6–13	6.4	2.65	3–12	7.0	2.00	5–9	7.2	1.92	4–9
9 Supraorbital	6.1	0.83	5–7	6.4	1.30	4–9	6.0	1.22	3–9	6.3	0.58	6–7	5.8	0.84	5–7
10 Suborbital	6.2	1.17	5–9	5.8	1.26	3–8	6.9	1.96	4–13	7.0	1.00	6–8	5.8	1.30	5–8
11 Supracanine	10.0	2.28	6–15	12.8	1.86	10–16	9.6	2.75	6–15	10.3	1.53	9–12	9.0	2.45	7–13
12 Subcanine	10.9	2.44	6–15	14.4	2.89	9–21	11.5	1.60	9–15	10.7	0.58	10–11	12.4	3.91	7–17
13 Posterior maxilla*	26.6	4.36	18–34	28.2	3.46	23–38	26.8	4.47	19–38	27.3	4.51	23–32	26.8	4.09	22–31
14 Sup mid mandible*	21.7	3.99	13–29	24.5	4.05	17–33	22.5	3.93	15–31	23.7	4.04	20–28	21.2	5.89	11–26
15 Inf mid mandible*	12.6	2.85	8–19	14.1	4.21	8–23	13.1	4.17	6–22	13.3	2.31	12–16	13.4	4.04	9–19
16 Lateral eye orbit	5.0	0.84	4–7	4.8	0.76	4–7	4.9	1.18	3–7	3.7	0.58	3–4	4.8	0.84	4–6
17 Anterior zygoma†	10.2	2.28	6–15	8.4	2.22	5–13	9.8	2.38	5–15	6.3	0.58	6–7	9.8	3.27	6–15
18 Gonion	17.0	4.23	9–27	21.1	3.24	17–29	16.2	3.64	11–24	20.7	2.89	19–24	14.8	2.86	11–18
19 Root of zygoma	6.4	2.25	3–11	7.4	1.77	5–12	5.6	2.22	3–10	5.7	1.15	5–7	6.0	2.24	5–10

NOTE: There are no males over 45 years of age, and no females over 55.
* Parallel to zygoma marker (bases of 13, 14, and 17 line up vertically in the Frankfort plane).
† Marker placed just below bony ridge of eye orbit see Fig. 1).

TABLE 8—*Tissue depth means (mm) for White adults of normal weight.*

	19–34 Years						35–45 Years						46–55 Years						>56 Years					
	Female (N = 52)			Male (N = 28)			Female (N = 15)			Male (N = 10)			Female (N = 6)			Male (N = 5)			Female (N = 9)			Male (N = 5)		
Points	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1	4.8	0.95	3–7	5.0	0.67	4–6	4.7	1.03	4–7	5.5	1.27	4–7	4.8	1.17	4–7	6.0	1.41	4–8	5.2	0.97	4–7	5.6	1.52	4–8
2	5.5	1.16	3–8	6.0	1.12	4–9	5.3	1.39	3–8	6.4	1.43	4–8	6.2	0.75	5–7	7.2	1.64	5–9	6.0	1.22	4–8	6.6	1.52	5–8
3	1.8	0.63	1–4	1.9	0.45	1–3	1.6	0.51	1–2	2.4	0.97	1–4	1.8	0.41	1–2	1.8	0.45	1–2	1.8	0.67	1–3	2.0‡	0.00	2–2
4	8.6	1.99	4–13	7.5	1.9	5–12	8.0	1.73	6–12	9.8	1.81	7–12	10.8	1.94	9–14	10.4	2.51	8–14	9.8	2.22	6–13	10.8	3.03	7–13
5	9.1	1.69	6–13	11.9	2.24	7–17	7.4	1.30	5–10	10.6	1.43	9–13	8.0	1.41	6–10	8.0†	3.00	5–11	8.0	2.65	5–12	9.4	1.52	7–11
6	10.3	1.55	6–13	11.1*	1.85	7–15	9.6	1.50	7–12	13.1	1.52	10–15	9.8	2.32	6–12	11.6	1.67	10–14	11.4	1.42	9–13	12.2	1.79	10–14
7	9.2	2.08	4–14	10.0	2.77	6–17	9.2	2.14	6–14	12.0	3.20	6–17	10.7	2.80	8–15	11.0	1.73	10–14	12.3	1.58	10–15	11.8	2.05	10–15
8	6.0	1.45	3–9	7.2*	1.73	5–13	5.4	1.84	2–9	8.0	1.05	7–10	6.7	2.94	4–12	7.2	1.79	5–9	8.0	1.87	6–11	5.6	0.89	5–7
9	5.7	1.04	4–10	5.3	1.25	3–7	5.5	1.19	3–8	5.9	0.88	4–7	6.5	0.84	6–8	7.7	1.67	5–9	6.3	1.00	5–8	5.6	1.14	4–7
10	6.1	1.05	4–8	5.8	1.58	4–11	5.7	1.33	4–9	6.2	1.87	4–11	7.3	4.08	3–15	6.8	0.84	6–8	7.0	2.50	5–12	5.0	2.0	2–7
11	9.3	1.74	5–14	11.9*	2.65	7–17	7.8	1.37	5–10	10.1	2.13	7–13	7.7	1.86	6–10	10.0†	2.00	8–12	8.0	2.00	6–11	9.2	1.10	8–10
12	9.4	1.56	5–12	11.5	2.17	7–16	8.7	2.23	4–12	10.2	1.32	9–13	9.0	2.97	6–12	10.0	2.35	8–14	9.7	3.39	5–14	11.8	2.39	9–15
13	26.3	4.94	11–44	28.5	4.69	21–39	25.1	6.74	13–40	24.6	6.45	12–32	27.2	6.11	20–35	28.2	7.53	17–35	29.4	4.82	20–36	23.6	8.11	13–33
14	23.4	4.53	9–31	25.1	4.15	18–35	20.1	5.15	10–29	21.1	6.69	12–34	21.7	5.32	18–32	21.4	3.85	17–26	27.2	5.59	19–35	20.6	6.11	13–26
15	13.7	3.25	7–22	14.8	4.48	8–25	12.6	4.21	6–22	15.6	4.81	9–23	13.0	4.29	6–17	15.4	4.39	9–20	17.4	3.28	13–21	11.4	3.65	7–17
16	4.7	0.88	3–8	4.2	0.79	3–6	4.3	0.90	3–6	4.3	0.82	3–5	4.5	1.87	2–7	5.4	0.55	5–6	4.9	1.76	2–7	5.2	0.45	5–6
17	9.3	1.70	6–12	7.8	2.38	4–12	8.7	2.74	4–16	8.2	2.20	4–12	10.2	1.60	9–13	8.2	2.05	5–10	11.0	2.45	7–15	6.4	1.34	5–8
18	17.4	3.70	7–27	20.0	4.27	10–31	15.3	4.50	9–25	19.6	5.87	13–30	14.7	4.68	7–20	19.0	4.69	15–25	16.9	3.59	11–21	14.0	4.95	8–20
19	7.4	2.07	4–13	7.8	2.29	4–14	4.9	1.44	3–9	6.6	3.86	3–13	6.0	1.55	4–8	5.4	1.52	3–7	7.4	2.3	3–11	5.2	1.10	4–6

* Indicates N = 27 (number excludes men with beards and mustaches).
† Indicates N = 3 (number excludes men with beards and mustaches).
‡ Indicates N = 4 (number excludes men with beards and mustaches).

TABLE 9—*Pearson's correlations (r) between tissue thickness and age for adults (ages 19–55).*

Point Numbers & Descriptions	White (N=130)	Black (N=66)
1 Glabella	0.197‖	−0.019
2 Nasion	0.157	−0.238
3 End of nasals	−0.036*	−0.273‖
4 Lateral nostril	0.363§	−0.020
5 Mid-philtrum	−0.355§†	−0.460§
6 Chin lip fold	0.109*	−0.170
7 Mental eminence	0.330§	−0.022
8 Beneath chin	0.090*	−0.236
9 Supraorbital	0.282§	−0.142
10 Suborbital	0.095	0.186
11 Supracanine	−0.334§‡	−0.460§
12 Subcanine	−0.125	−0.136
13 Posterior maxilla	−0.046	0.017
14 Sup mid mandible	−0.123	−0.037
15 Inf mid mandible	0.020	0.086
16 Lateral eye orbit	0.141	−0.017
17 Anterior zygoma	0.082	0.203
18 Gonion	−0.243§	−0.343§
19 Root of zygoma	−0.269§	−0.343§

* N = 129.
† N = 128.
‡ N = 127.
§ $p < .01$.
‖ $p < .05$.

measurements at points 9, 13, 14, and 18. Points 13, 14, and 18 increase for us; 9 decreases. For black males, we compare our data to Rhine and Campbell and note that points 13, 14, and 18 increase in thickness in our sample, while points 9 and 17 decrease in thickness in our sample.

Because many modern tissue depth standards were taken from cadavers, we conducted a paired *t*-test on a small subset of volunteers to determine whether there was a significant difference between measurements when a person was sitting versus reclining. Paired *t*-test results reflect that variation in tissue thickness between positions is significant only at point number ten.

Discussion

For many years, anthropologists and others have worked to identify people when only bones remained. In the past, tissue thickness standards for the human face were developed for adult populations worldwide with the goal of two-dimensional or three-dimensional facial reconstructions which could aid in a putative identification. A paucity of these kinds of data exists for children.

Throughout the early part of this century research such as the Bolton studies (25) focused on growth and development of the human face as it applied to the region surrounding the maxillofacial area. Through the use of lateral radiographs, this research assisted in developing "normal" expectations for growth in the dentofacial complex and was particularly helpful for dentists and orthodontists. Farkas and Munro's more recent studies of anthropometrics of the face and head have added to our knowledge of growth and development (26,27).

Various other researchers have suggested that both genetic and secular influences play major roles in an individual's development and timing of changes in the underlying bony substrate of the skull as well as the soft tissue matrix covering it. They also suggest that a thorough understanding of these influences is important in devel-

TABLE 10—*Summary of ANOVA (Duncan) showing significant variation among black and white adults (19–55 years).*

Groups	Measurement Sites																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
White females (A)	B	B,D	D	–	B,D	B,C,D	B,C,D	B,C,D	D	–	B,D	B,C,D	–	–	B	–	B,D	B,D	–
White males (B)	A,C	A,C	C	–	A,C,D	A,D	A,D	A,D	–	–	A,C,D	A,D	–	–	A,C	C	A,C	A,C	C
Black females (C)	B,D	B,D	B,D	–	B,D	A,D	A	A,D	–	–	B,D	A,D	–	–	B	B	B,D	B,D	B
Black males (D)	C	A,C	A,C	–	B,C,D	B,C,D	A,B	B,C,D	A	–	B,C,D	B,C,D	–	–	–	–	A,C	A,C	–

Letters indicate the groups between which the differences in tissue thickness are significant. ($p < .05$).

TABLE 11—*Comparison of tissue depth measurements for white males (19–55 years) between LSU, His (1895)†, and Kollmann-Büchly (1898)†.*

Point Numbers & Descriptions LSU	His	K–B		LSU ($N=43$)	His ($N=24$)	K–B ($N=21$)
1	2	st_2	Glabella	5.23	5.10	4.29
2	3	nw	Nasion	6.23	5.55	4.31
3		ns	End of nasals	1.98		2.12
5	6	Ig	Mid philtrum	11.27*	9.51	9.46
6	7	If	Chin lip fold	11.64*	10.26	9.84
7	8	kw	Mental eminence	10.56	11.43	9.02
8	9	k_3	Beneath chin	7.38*	6.18	5.98
9	10	abr	Superior eye orbit	5.72	5.89	5.41
10	11	ua	Inferior eye orbit	5.98	5.08	3.51
17		wb	Zygomaric	7.93		6.62
19		jb_2	Root of zygoma	7.21		7.42

* $N=38$.
† (as modified by Krogman and İşcan, 1986).

oping any research methodology to collect data on growth and development (28).

While taking these concerns into consideration, a data base of tissue depth averages for children of various races can greatly assist in medico-legal contexts where an identification for a child (or an adult) is the primary goal.

In collecting facial tissue depth data on children, we, of course, take into consideration that sex determination from only skeletal remains in pre-pubescent children is difficult, if not impossible. However, our data for male and female children clearly reflect some significant variation in tissue depth means between the two sexes (though that variation may or may not be great enough to influence an identification or lack thereof). Yet, if sex can be determined, the appropriate tissue depth means can be used and are more appropriate for three-dimensional facial reconstructions, photographic superimpositions, or two-dimensional line drawings. Also, an alternative method would be to complete two facial reconstructions, one using the male data and the other using female data.

For adults, our standards are comparable to those developed by Rhine and others, with a few exceptions. The greatest variation lies in the cheek region where our measurements were greater, sometimes overtly so. In creating three-dimensional clay facial reconstructions, Gatliff and others have noted that previously published standards for the cheek regions have rendered tissue depth markers "useless," or at least misleading, in those areas, often producing a rather gaunt face (Gatliff, personal communication 1998). In our own experience, using those tissue depth means published by Rhine and others for the cheek region results in a face that is very thin. We have often deleted or ignored these cheek markers, as have other artists and sculptors alike. Future research could assist in this area.

Finally, our new data for children and adults reflect that there are significant differences in tissue thickness between sexes and races. There is a significant relationship between tissue thickness and age. Also, the variation in tissue depth means reported by different researchers at points 13, 14, and 18 may reflect position of the volunteer when measurements were taken. Further study of sitting versus reclining positions using a larger sample size may help us understand this better. A possibility also exists that these differences may reflect regional population variation in tissue thicknesses.

TABLE 12—*Adult (19–55 Years) tissue depth means for normal weight comparison between FACES and Rhine's* measurements.*

Point Numbers		LSU	Black Adults						White Adults					
			Male			Female			Male			Female		
FACE	Rhine	Descriptions	FACES (*N*=28)	Rhine	Diff	FACES (*N*=44)	Rhine	Diff	FACES (*N*=43)	Rhine (*N*=37)	Diff	FACES (*N*=73)	Rhine (*N*=19)	Diff
1	2	Glabella	5.18	6.25	−1.07	4.57	6.00	−1.43	5.23	5.25	−0.02	4.79	4.75	0.04
2	3	Nasion	6.45	6.00	0.45	5.61	5.25	0.34	6.23	6.50	−0.27	5.52	5.50	0.02
3	4	End of nasals	2.14	3.75	−1.61	1.66	3.75	−2.09	1.98	3.00	−1.02	1.77	2.75	−0.98
5	5	Mid philtrum	12.68	12.25	0.43	8.86	11.25	−2.39	11.27†	10.00	1.27	8.64	8.50	0.14
6	8	Chin lip fold	12.73	11.75	−0.98	11.55	12.25	−0.07	11.64†	10.75	0.89	10.12	9.50	0.62
7	9	Mental eminence	12.09	11.50	0.59	11.00	12.50	−1.50	10.56	11.25	−0.69	9.30	10.00	−0.70
8	10	Beneath chin	8.59	8.25	0.34	6.61	8.00	−1.39	7.38†	7.25	0.13	5.90	5.75	0.15
9	12	Supraorbital	6.36	8.50	−2.14	6.02	8.00	−1.98	5.72	8.25	−2.53	5.74	7.00	−1.26
10	13	Suborbital	6.00	7.75	−1.75	6.48	8.25	−1.77	5.98	5.75	0.23	6.12	6.00	0.12
13	19	Posterior maxilla	28.09	22.00	6.09	26.70	20.25	6.45	27.56	19.50	8.06	26.14	19.25	6.89
14	21	Sup. mid mandible	24.36	16.50	7.86	22.00	17.00	5.00	23.77	16.00	7.77	22.59	15.50	7.09
17	15	Anterior zygomatic	8.14	13.25	−5.11	9.95	13.00	−3.05	7.93	10.00	2.07	9.23	10.75	1.52
18	18	Gonion	21.00	13.00	8.00	16.36	13.50	2.86	19.79	11.50	8.29	16.77	12.00	4.77

* Adapted from Rhine and Moore, 1982; revised 1984.
† *N*=38.

Although the use of ultrasound technology has demonstrated that sex, race, and age show a significant relationship to facial tissue depths at certain points, most tissue depth means are similar among different age groups, races, and sexes.

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