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Midline Facial Tissue Thicknesses of Subadults from a Longitudinal Radiographic Study*

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ABSTRACT: Fourteen midline facial tissue measurements were taken from 615 tracings of lateral radiographs of subadults aged 8 to 20 years. The data were collected to examine two questions: First, are there differences in facial soft tissue measurements between female and male subadults? Second, do facial tissue thicknesses change as children grow? Results indicate that males exhibit greater tissue thickness measurements than females but only significantly so after age 14. Results further indicate a trend of increased facial tissue thickness as individuals grow; however, correlations are weak and suggest that other unknown factors are involved. Data presented here can be of practical application for facial reproduction in forensic cases.

KEYWORDS: forensic science, forensic anthropology, facial reproduction, facial soft tissue thickness, subadults, human identification, radiographs

The personal identification of fragmentary or intact skeletonized human remains by way of facial reproduction is widely debated. A number of researchers claim that there are portions of the cranium that do not directly correspond to the overlying facial soft tissues and, thus, likenesses cannot be reproduced but have to be surmised through artistic renditions (1–3). Many other researchers argue that there is significant potential for producing leads for the identification of unknown individuals through one of several facial reproduction techniques (4–8).

Facial reproduction, utilizing three-dimensional clay reconstructions (9), pencil sketches (10) and computer-generated images and overlays (8), is accomplished by employing standardized facial soft tissue measurements that have been collected through a variety of means and published since the turn of the century (see, for example, 11–18). This technique of reproducing unknown facial features may offer forensic specialists a useful alternative for the identification of human remains when other conventional methods have failed (4–8).

Throughout the 20th century attempts have been made to collect and record accurate measurements of facial soft tissues at specific points on the head (11–18). Unfortunately, many of the recorded depths currently in use were collected at the turn of the century on small samples of European adult cadavers, generally male, and subject to poor statistical validity (for example, 11–13). In recent years, other researchers have attempted to add to these data, but continue to use cadaver samples to obtain their measurements (17,19). Such methods often result in distorted tissue thickness measurements due to fluid loss directly after death (20). Therefore, it is critical that facial tissue measurements be obtained from living individuals of various ages and population origins in order to document variability and obtain statistically reliable results (for examples, see 14–16). A variety of methods, including radiographs, cat-scans, magnetic resonance imaging (MRI), and ultrasound technology, for such data collection is available to researchers. This study uses X-rays from a longitudinal growth study of children[2] to collect tissue depth measurements along the midline of the face. Two specific questions are examined: (1) Are male subadult facial tissue thicknesses greater than female subadult tissue thicknesses? (2) Do facial tissue thicknesses increase as individuals grow from 8 to 20 years of age?

Materials and Methods

The sample was drawn from a longitudinal growth study of 1380 children completed over a 20-year period, from 1952 to 1972, in Burlington, Ontario, Canada. The portion of the sample obtained for this study includes 43 females and 47 males radiographed at yearly intervals from ages 8 to 20 years ($n = 615$) (see Table 1).[3] This portion of the larger data set was chosen because it encompassed the complete number of nontreated and minimally treated children[4] in the growth study. Lateral radiographic tracings were used to assess midline measurements from individual faces.

The nature of the growth study provides an excellent opportunity to examine variables that are associated with possible variation in tissue thicknesses. The Burlington study was able to control for such factors as population origins, nutrition and health data, and genetic relatedness, as well as the sex and age of the individuals (21,22). At the time the study began, the town of Burlington consisted of approximately 5000 people of northwestern European origins, mainly from Britain, who had a slightly higher income than the Canadian national average (21,22). Therefore, the sample is relatively homogenous in terms of geographic origins and economic status. Furthermore, this set of radiographs has a constant

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[2] The Burlington Growth Study.

[3] Sample numbers vary as a result of radiographs being absent for certain years and excluded due to poor quality.

[4] The term ''nontreated'' refers to the fact that there were no orthodontic or reparative treatments performed on these children. ''Minimally treated'' refers to individuals who had only minor reparative treatments completed (i.e., fillings).

TABLE 1—*Burlington Growth Study Sample* used for present study.*

Age	8	9	10	11	12	13	14	16	17	18	20	Grand Total
No. of males	19	42	22	23	43	23	38	38	17	20	38	323
No. of females	23	36	21	21	35	20	37	38	10	19	32	292
Total no.	42	78	43	44	78	43	75	76	27	39	70	615

* Sample numbers vary as a result of radiographs being absent or excluded due to poor quality.

enlargement factor of 9.84% that can be taken into account when comparing statistical results from this study to the results of other studies. The radiographic images were taken close to the individual's annual birth date whenever possible and chronological age was determined by rounding, to the nearest whole number, the age of the child. The radiographs were also carefully monitored to control for anode and subject distance over the entire period of the study. This results in a database of films that are relatively consistent and provide reliable data for this type of research.

To obtain suitable tracings from the radiographs, a sheet of frosted acetate paper (0.003 mm thick) was attached to the film and placed on a light table to illuminate the bony portions of the skull and the associated soft tissues. The margins of the skull and the soft tissues were then traced using a pencil that was continually sharpened. To reduce tracing errors, Enlow has suggested that pencils be kept sharpened to less than (0.20 mm) thick (23). Only radiographs showing clear images of the underlying bone and outer soft tissues were included in this study. Once the X-ray films were traced, 14 anatomically defined metric points on both the facial bone margin and soft tissue margin were placed directly on the tracings to control for measurement precision. These points are named as follows: 1) supraglabella; 2) glabella; 3) nasion; 4) midnasal; 5) rhinion; 6) nasal length; 7) mid-philtrum; 8) prosthion; 9) alveolar; 10) infradentale; 11) chin lip fold; 12) pogonion; 13) gnathion; 14) menton (Fig. 1). Measurements were taken to the nearest one-hundredth of a millimeter (0.01 mm) using a pair of calibrated 6 in. (15.2 cm) Fowler electronic digital calipers with fresh batteries. The measurements were then transcribed onto data collection forms and entered into a computer database for analysis. An intra-observer error test was conducted to compare measurements from two sets of the same films ($n = 20$), with measurements taken four weeks apart and analyzed using paired t-tests ($p < 0.05$) (24). Measurements collected from the 14 points along the midline of the face, when available, resulted in a database of approximately 10 000 measurements. Statistical analyses were carried out using the Statistical Package for the Social Sciences, version 6.0 and 6.1 (25).

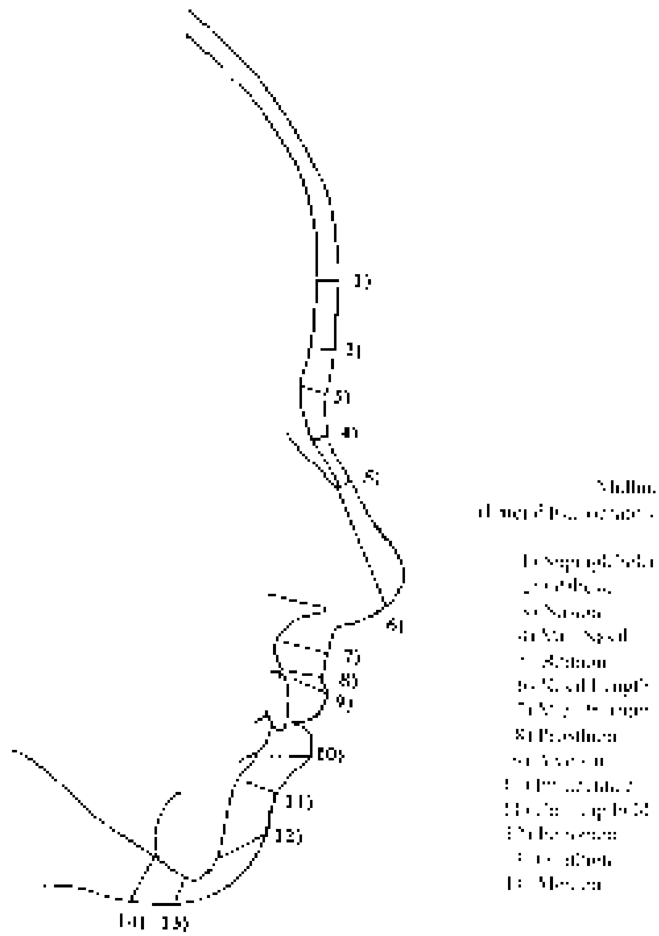

FIG. 1—*Midline metric points used to assess facial tissue thickness.*

Results

The comparison between male and female subadult facial tissue thicknesses was analyzed first. The means, standard deviations and number of individuals present for each sex are presented in Table 2. These data indicate that male subadults generally have greater mean tissue thicknesses than female subadults. Figures 2 and 3 present the mean values and 95% confidence intervals for the variable mid-philtrum and mid-nasal. A one-way ANOVA (Analysis of Variance) was performed to address whether the differences seen between male and female subadults for the recorded mean tissue depths are statistically significant. The f-values from the ANOVA results are given in Table 3. Results show that there are several age groups for each variable with statistically different measurements, where males have larger tissue thicknesses than females. These differences in tissue thickness appear to aggregate after the age of 14, although some are present around the age of 9.

The association between facial tissue depths and the growth of individuals was also explored by testing whether tissue thickness increases as individuals age. A linear regression analysis was performed regressing the range of tissue thicknesses on chronological age for each variable with males and females separated. The results of this analysis are presented in Table 4, showing the coefficients of determination, regression coefficients, and p-values for male and female subadults. Figures 4 and 5 are scattergrams of the variables mid-philtrum and nasal length showing the relationship between absolute age change and tissue thickness for each sex, with associated lines of best fit and r^2 values for each variable.

The results of this analysis indicate that for subadult males, only nasion exhibits a regression slope that is not significantly different from 0, where the coefficient of determination was small, indicating a poor relationship between growth and tissue thickness (see

TABLE 2—*Subadult summary statistics*

Variable	Age / Sex	8 Male	8 Female	9 Male	9 Female	10 Male	10 Female	11 Male	11 Female	12 Male	12 Female	13 Male	13 Female	14 Male	14 Female	16 Male	16 Female	17 Male	17 Female	18 Male	18 Female	20 Male	20 Female
Supraglabella	mean	5.02	4.64	4.92	4.69	4.94	4.97	5.07	5.08	5.09	5.14	5.11	5.44	5.45	5.57	5.26	5.41	5.67	5.70	5.87	5.41	5.70	5
	sd	0.6	0.68	0.56	0.72	0.55	0.58	0.59	0.64	0.76	0.7	0.65	0.75	0.75	0.79	0.79	0.69	0.97	0.95	1.15	0.72	0.84	0.67
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Glabella	mean	6.28	6.27	6.1	5.71	6.13	5.95	6.24	5.86	6.25	6.17	6.35	6.04	6.85	6.38	6.97	6.14	6.5	6.2	6.17	6.04	6.35	5.75
	sd	1.23	1.02	0.95	0.70	0.88	0.8	1.09	1.02	0.81	0.85	1.21	0.8	1.22	0.84	1.12	0.8	1.12	0.7	1.01	0.97	1.1	0.78
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Nasion	mean	9.17	8.13	9.34	8.65	9.41	8.76	9.54	8.91	9.5	6.77	9.31	8.52	9.33	8.57	9.71	8.54	8.85	7.80	9.33	8.51	9.45	8.23
	sd	1.44	1.5	1.36	1.4	1.50	1.8	1.12	1.57	1.57	1.5	1.25	1.59	1.63	1.28	1.45	1.41	1.45	0.97	1.67	1.58	1.37	1.8
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Mid-Nasal	mean	4.74	3.9	4.34	3.82	4.26	3.95	4.29	3.97	4.33	3.97	4.33	3.55	4.58	3.99	4.75	3.95	4.72	3.51	4.52	3.75	4.78	3.62
	sd	0.76	0.86	1.03	0.78	0.95	0.7	0.97	0.68	1.15	0.8	1.07	0.53	1.14	0.66	1.21	0.77	1.71	0.62	0.77	0.60	1.21	0.98
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Rhinion	mean	2.62	2.53	3.30	2.50	2.56	2.5	2.63	2.42	2.4	2.44	2.66	3.43	2.6	3.47	2.71	2.36	2.77	2.16	2.77	2.28	2.77	2.2
	sd	0.44	0.51	0.57	0.55	0.54	0.45	0.51	0.41	0.66	0.55	0.57	0.53	0.75	0.5	0.69	0.46	0.71	0.6	0.75	0.56	0.76	0.6
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Nasal Length	mean	28.54	27.24	28.26	27.75	29.28	30.4	30.46	30	31.48	30.15	32.05	32.22	33.81	31.98	32.06	33.54	37.33	34.55	48	44.48	38.14	34.22
	sd	1.53	1.69	1.73	2.27	1.65	3.07	1.75	2.25	1.76	2.56	1.88	1.03	1.88	3.41	3.28	3.53	2.07	3.33	1.56	3.44	2.76	3.56
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Mid-Philtrum	mean	13.41	12.12	13.42	12.55	13.22	12.69	12.46	11.5	14.02	15.79	15.2	14.12	16.22	14.58	17.81	14.36	17.56	15.35	16.65	15.07	18.12	14.6
	sd	1.55	1.53	1.52	1.43	1.29	1.52	1.65	1.34	1.75	2.14	1.89	1.46	1.66	1.3	1.03	1.96	1.02	1.91	1.72	1.12	1.8	1.36
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Prosthion	mean	12.05	11.36	12.77	11.25	12.31	11.03	12.43	11.66	12.42	11.3	12.96	11.81	13.19	12.1	14.37	11.34	13.46	12.95	14.04	12.45	14.74	11.77
	sd	1.9	2.05	1.44	1.57	1.47	1.96	1.67	1.75	1.78	2.06	1.91	1.78	1.79	1.95	1.67	2.17	1.52	1.76	1.67	1.91	1.68	1.85
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Alveolare	mean	15.17	14.21	15.4	14.63	15.62	13.31	15.34	14.21	15.6	14.12	15.91	14.88	16.26	15.18	17.57	14.63	17.21	15.5	15.25	15.68	17.61	14.58
	sd	2.25	1.17	1.71	1.85	1.58	2.26	2.04	2.1	2.1	2.63	1.59	2.04	1.9	2.12	1.78	2.73	1.71	2.26	2.2	1.6	1.95	2.33
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Infradentale	mean	14.81	11.17	15.94	15.57	15.77	13.63	15.86	14.48	15.45	13.22	16.37	14.5	17.21	15.39	17.94	15.63	17.92	16	17.82	15.43	15.97	15.19
	sd	1.47	2.4	2.29	2.14	1.65	2.25	1.75	2.65	2.02	3.02	2.64	2.46	2.43	1.77	3.56	2.37	1.24	0.72	2.45	1.96	1.9	2.27
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Chin Lip Fold	mean	9.55	9.61	10.42	9.96	9.92	9.77	10.97	9.8	10.61	9.98	11.07	10.42	11.94	10.55	12.57	10.89	12.54	10.71	12.41	11.23	12.61	11.02
	sd	1.35	1.3	1.45	1.85	1.34	1.5	2.3	1.41	1.54	1.37	1.58	1.5	1.74	1.2	1.73	1.63	1.1	0.84	1.72	1.5	1.19	1.3
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Pogonion	mean	11.24	10.58	11.66	10.93	12.12	10.9	12.56	11.38	11.85	11.75	12.63	11.57	12.39	12.05	12.72	12.22	13.55	11.74	13.56	11.89	14.11	11.91
	sd	1.65	1.82	2.15	2.02	2.26	1.66	2.39	1.67	2.1	1.94	2.21	1.52	2.72	3.64	2.56	2.13	2.5	1.74	2.45	1.97	2.09	1.95
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Gnathion	mean	8.16	7.58	7.99	7.35	7.77	7.92	8	8.43	8.58	8.29	8.8	9.01	8.97	8.56	9.02	8.12	9.46	7.88	9.47	8.42	10.06	8.11
	sd	2.12	1.84	1.95	2.15	1.6	2.5	1.95	2.49	2.28	2.14	2.01	2.44	2.02	2.28	1.73	2.15	1.93	1.95	2.44	2.56	2.3	2.49
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32
Menton	mean	10.74	11.57	10.48	10.49	11.05	10.93	11.22	9.81	10.95	9.57	12.12	10.51	10.75	10.27	10.13	10.2	12.72	9.47	11.72	9.99	12.77	9.36
	sd	[illegible]	3.01	2.04	2.05	2.05	2.16	2.36	2.08	3.01	2.37	2.14	2.98	2.19	2.69	2.57	2.41	3.42	2.21	2.73	2.08	3.21	2.07
	number	19	23	42	36	22	21	23	21	43	35	23	20	38	37	38	38	17	10	20	19	38	32

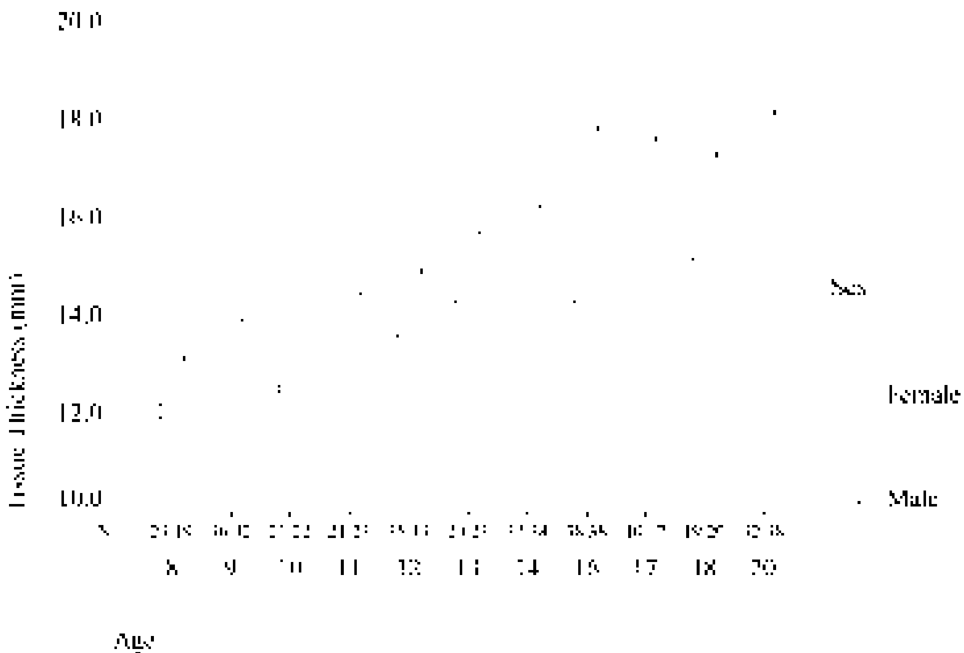

FIG. 2—*Mean tissue depths and 95% confidence intervals for mid-philtrum.*

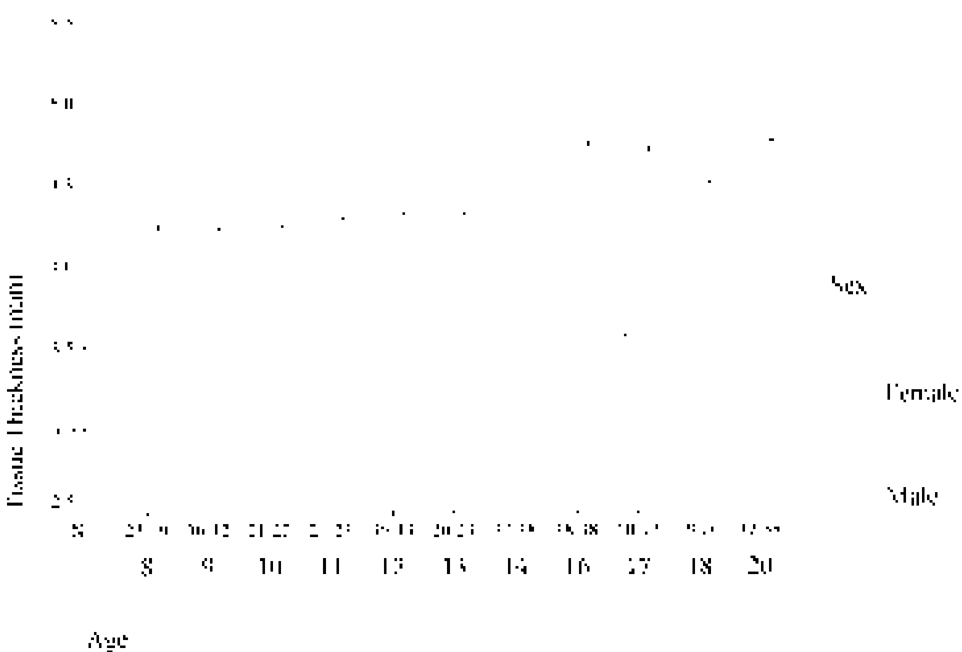

FIG. 3—*Mean tissue depths and 95% confidence intervals for mid-nasal.*

Table 4). The other 13 variables—supraglabella, glabella, mid-nasal, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, gnathion, and menton—have regression slopes significantly different from 0. However, all but two variables, nasal length and mid-philtrum, have low coefficients of determination, indicating that age changes explain only a limited proportion of the variability in these measures. Comparisons of the variables nasal length and mid-philtrum to age resulted in coefficients of determination that indicate a stronger correlation between growth and tissue thickness (see Table 4). For female subadults there are four variables—glabella, nasion, mid-nasal, and gnathion—that have regression slopes that are not significantly different from 0. Coefficients of determination are again low for these variables, demonstrating weak correlations (see Table 4). The other ten variables—supraglabella, rhinion, nasal length, mid-philtrum, prosthion, alveolar, infradentale, chin lip fold, pogonion, and menton—all exhibit regression slopes significantly different from 0. The coefficients of determination are also low for these variables and therefore explain a very small proportion of the variation. Nasal length and mid-philtrum again demonstrate a good correlation between growth and tissue thickness (see Table 4).

From these results it appears that male and female subadults

TABLE 3—*ANOVA f-ratios for male and female subadults, 8 to 20 years old.*

	Age										
	8	9	10	11	12	13	14	16	17	18	20
Variable											
supraglabella	3.4799	2.5292	0.0118	0.0052	0.0731	0.3868	0.5157	*4.2274	0.0560	2.1514	‡18.4830
glabella	0.0551	*4.3187	0.4543	0.2634	0.4481	*4.1937	3.6960	*4.4884	0.6032	1.0777	†6.9261
nasion	3.4927	*4.7461	1.7080	2.2848	*5.6337	†7.9164	*3.8417	†10.6010	3.4375	1.9081	†12.7122
mid-nasal	1.8001	*3.9970	1.6003	1.3794	3.2082	2.3628	†6.6553	†10.9750	†7.7481	†10.6238	†12.4957
rhinion	0.2677	2.3099	0.1438	0.4285	0.1037	1.8077	0.8017	†7.1696	*5.0186	*5.0244	†12.0933
nasal length	*5.9902	*5.3224	0.4073	0.2799	*5.5133	0.4632	1.2084	2.4641	*4.4650	‡18.5055	§29.7700
mid-philtrum	3.6811	§16.1000	‡13.2783	3.5520	†6.6038	†9.2179	‡15.7918	§59.9110	†8.5185	†12.0507	§67.6680
prosthion	1.6416	§23.0443	*6.9565	2.2471	†6.5264	*4.2716	*6.2028	§37.6905	3.0528	†8.2061	§50.5439
alveolare	1.9553	§20.7000	†9.9946	0.9990	†6.8113	2.3095	*5.0923	§29.6761	*5.8896	†7.7933	§34.0601
infradentale	0.2572	‡15.1102	†9.2953	*4.2777	*4.6261	*5.7116	‡13.8890	§22.2350	*5.7911	†12.8573	§33.5988
chin-lip fold	0.0213	1.5553	*4.2202	*4.0079	3.6164	3.4187	‡15.7221	§19.1118	§20.5711	†7.2672	§37.2401
pogonion	1.4906	2.3046	*3.9797	2.6872	2.2892	2.8579	†6.6171	†7.7799	†10.4248	*5.5721	§20.3304
gnathion	0.9339	1.3860	0.0566	0.4154	0.3199	0.0887	0.6608	1.7693	*4.0690	*4.0577	†12.5618
menton	0.3830	0.0295	0.0163	3.1770	*4.4708	2.9992	1.5100	0.0036	*5.1199	3.4132	‡16.1005

* ($p < 0.05$).
† ($p < 0.01$).
‡ ($p < 0.001$).
§ ($p < 0.0001$).

TABLE 4—*R-squared values and p-values for male and female subadults.*

	Males			Females		
	Rsq-Values	Reg Coefficients	P-Values	Rsq-Values	Reg Coefficients	P-Values
Variable						
supraglabella	0.16	0.09	0.00	0.06	0.05	0.00
glabella	0.02	0.04	0.02	0.00	−0.01	0.81
nasion	0.00	0.01	0.69	0.00	−0.02	0.36
mid-nasal	0.03	0.05	0.00	0.00	−0.01	0.56
rhinion	0.03	0.03	0.00	0.04	−0.03	0.00
nasal length	0.75	0.89	0.00	0.50	0.64	0.00
mid-philtrum	0.44	0.43	0.00	0.18	0.23	0.00
prosthion	0.19	0.23	0.00	0.03	0.08	0.01
alveolare	0.14	0.22	0.00	0.02	0.08	0.02
infradentale	0.19	0.29	0.00	0.06	0.16	0.00
chin lip fold	0.27	0.26	0.00	0.11	0.13	0.00
pogonion	0.13	0.24	0.00	0.05	0.12	0.00
gnathion	0.11	0.19	0.00	0.01	0.06	0.11
menton	0.03	0.15	0.00	0.02	−0.10	0.02

have similar changes in the growth of the nose and the thickness of the tissues of the upper lip. Results indicate that nasal length and mid-philtrum (upper lip) have a strong correlation with the growth of individuals, although female subadults have smaller measurements than male subadults. The other points along the midline of the face show a trend for increasing tissue thickness with growth but the results indicate poor statistical correlations.

Discussion and Summary

The results presented indicate that subadult facial tissue thicknesses vary with respect to sex and age for specific variables and age groups. It is clear from the Burlington Growth Study sample that male subadults tend to have greater mean facial tissue depths than their female counterparts (see Table 2). In fact, only 4% of the mean measurements show females as having greater tissue depths than males, and less than half of these thicknesses are more than 0.1 mm thick. Statistical results, in the form of ANOVAs, provide further evidence of sexual dimorphism between males and females, especially after the age of 14. The tissue thickness differences occurring after age 14 appear to be linked to the divergence of growth in males and females after puberty (26,27). Some significant differences are seen prior to age 14, but these may be attributed to individual variability (i.e., beginning the pubertal growth spurt early). However, a pattern of differences occurs at age 9 for several of the variables that may suggest the presence of a mid-growth spurt for males (for a discussion see 26,27). Although this may be the case, Tanner and Cameron (26) and Bogin (27) suggest that this mid-growth spurt occurs most often in males around the ages of 7 or 8 years. The later onset observed in this study may be a factor of sample size or population differences. Other unknown factors may be involved.

The second question examined whether patterned variations in facial tissue depths occur as children grow, using chronological age as a grouping variable. Results indicate that there is an increase in tissue thicknesses as individuals grow. However, the majority of the variables resulted in small coefficients of determination, indicating a weak correlation between growth of an individual and midline facial soft tissue depths for this sample. This weak correlation requires that other factors be identified and tested.

From the examination of subadult radiographs it becomes clear that variation in facial tissue depths occurs with respect to sex

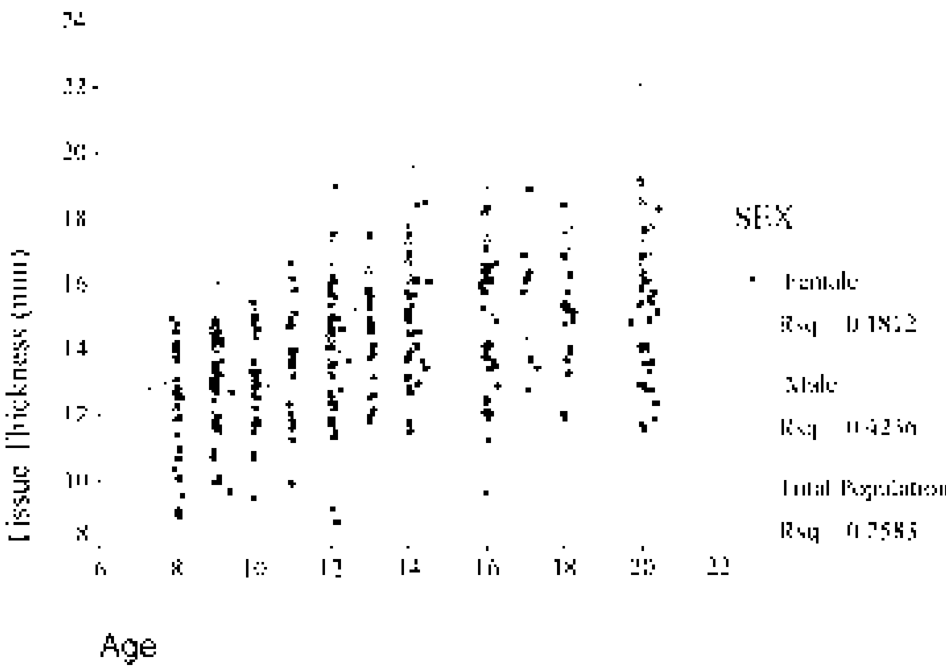

FIG. 4—*Scatterplot showing r^2 values and 95% confidence intervals for mid-philtrum.*

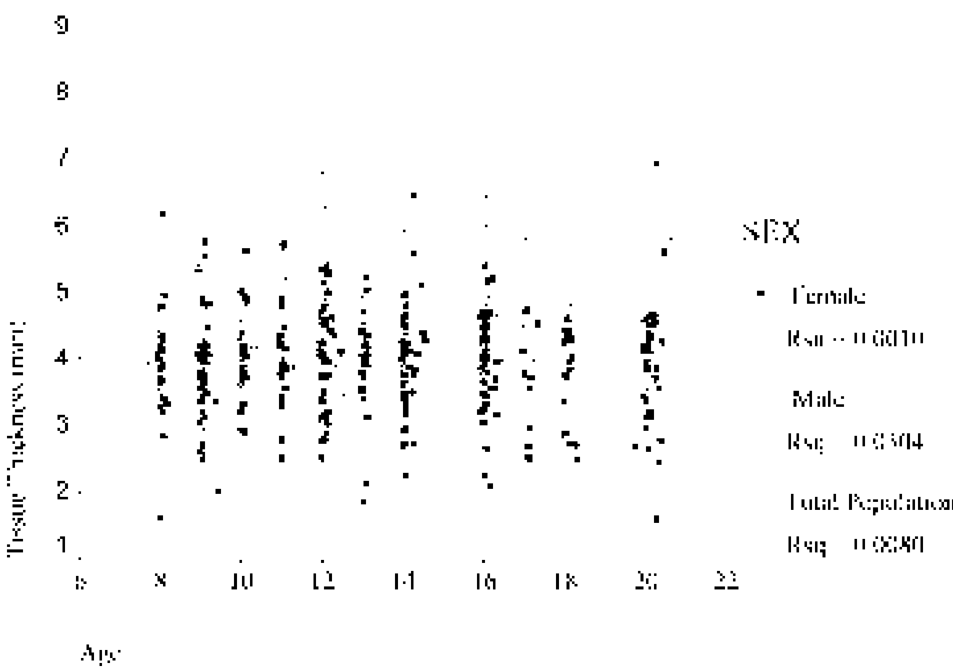

FIG. 5—*Scatterplot showing r^2 values and 95% confidence intervals for mid-nasal.*

and age for specific midline variables. Male subadults consistently display greater tissue thicknesses than female subadults, especially after the adolescent growth spurt. Furthermore, it is apparent from examining absolute age changes, from 8 to 20 years, that there is a weak relationship between tissue thickness and growth. Though there seems to be a trend to increased tissue depths as children grow into adolescents, there is no clear relationship between individual growth and tissue depth. The results from this study indicate that some consideration should be given to what measurements can and should be used for facial reproduction. For adolescents and young children there does not seem to be much reason to separate male and female measurements. This is important due to the difficulty of assessing the sex of a skeleton in early subadults. However, as the age of an individual increases there is a divergence in facial tissue thicknesses between males and females. This split seems to occur around the time of the adolescent growth spurt and therefore it may be necessary to apply separate standards for older children, a time when skeletal indicators of sex become more reliable.

However, it is important to remember that the actual differences in tissue thicknesses are quite small and although statistically different results were found they may not be applicable in a practical sense for facial reproduction. Nonetheless, the possibility is present that this method can provide some leads to identification of forensic cases when conventional ones have failed. This possibility is further enhanced when such measurements are added to others from the lateral portions of the face. The use of facial tissue thickness data aided by computer technology can provide a significant avenue for quicker reproductions while removing a great deal of the artistic attributes often criticized in traditional three-dimensional clay reproductions and pencil tracings.

Radiographic films were chosen for this study because they provide a quick and accurate way to collect tissue depth measurements from living individuals. Furthermore, radiographic data sets are often available through dental practices or hospitals and can thus provide large samples. The composition of the sample is also better distributed among the populations, providing the opportunity to include different age, sex, and population groups. This would be very difficult to accomplish with cadaver samples for they often represent marginal segments of the population. The storage of such radiographic material is also easier and provides the ability to return to the database and collect more data or run further analytical tests, something that cannot be completed on cadaver samples.

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