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Facial Soft Tissue Depths in Craniofacial Identification (Part II): An Analytical Review of the Published Sub-Adult Data*

ABSTRACT: Prior research indicates that while statistically significant differences exist between subcategories of the adult soft tissue depth data, magnitudes of difference are small and possess little practical meaning when measurement errors and variations between measurement methods are considered. These findings raise questions as to what variables may or may not hold meaning for the sub-adult data. Of primary interest is the effect of age, as these differences have the potential to surpass the magnitude of measurement error. Data from the five studies in the literature on sub-adults which describe values for single integer age groups were pooled and differences across the ages examined. From 1 to 18 years, most soft tissue depth measurements increased by less than 3 mm. These results suggest that dividing the data for children into more than two age groups is unlikely to hold many advantages. Data were therefore split into two groups with the division point corresponding to the mid-point of the observed trends and main data density (0–11 and 12–18 years; division point = 11.5 years). Published sub-adult data for seven further studies which reported broader age groups were pooled with the data above to produce the final tallied soft tissue depth tables. These tables hold the advantages of increased sample sizes (pogonion has greater than 1770 individuals for either age group) and increased levels of certainty (as random and opposing systematic errors specific to each independent study should average out when the data are combined).

KEYWORDS: forensic science, soft tissue thickness, facial approximation, facial reproduction, facial reconstruction, superimposition

Extensive categorization of the soft tissue depth data according to the results of statistical significance tests without contextual interpretation, and ongoing data collection without any overarching synthesis, has resulted in an unwieldy and complex set of data (1). Furthermore, a lack of standardization between studies makes these data even more complex (2,3). A need, therefore, exists to examine the data to determine if a synthesis is possible.

Analysis of the adult data with respect to measurement errors (e.g., measurement method uncertainty, measurement repeatability, and casework application errors) has revealed that many of the statistically significant differences commonly observed are small and thus have limited practical or clinical relevance (1). It, therefore, appears to be justifiable to disregard the small differences that exist in terms of study year, race, and sex and pool the data to increase sample sizes, simplify the data, and triangulate as closely as possible upon the true soft tissue depth values by averaging out errors specific to any given measurement method or study (1).

With respect to the sub-adult data there is little reason to suspect that there are any major differences with regards to the variables that have been assessed for adults. Rather some differences are expected to be less as sub-adults have not reached their terminal growth and development stages. However, growth during the sub-adult phase may itself impact on soft tissue depths and with a magnitude that is larger than levels of data uncertainty. This study, therefore, examines the effects of advancing age on soft tissue depth values of sub-adult individuals. As for the adult data, this study does not heavily rely on statistical significance tests (results of which are influenced by sample sizes and p levels), rather it is based on the contextual interpretations of the magnitudes of differences that may exist relative to factors that have a bearing on how practically useful any differences in the data may be.

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Materials and Methods

Studies reporting soft tissue depth measurements on sub-adults (<18 years) were identified from literature searches conducted using Medline (Silverplatter), Current Contents, and traditional methods (reference lists of other articles). These searches produced five studies reporting mean values (for sub-adults) at single integer age groups (4–8). A further nine studies were found which classified sub-adults according to broader age ranges (9–17).

The data from the five studies reporting values at single integer ages were pooled according to each chronological year and these data plotted by craniometric landmark to display age trends (Fig. 1). Pooling studies resulted in sample sizes ranging from 27 to 830 individuals for the various landmarks examined (see Fig. 1).

Results

The plots revealed that soft tissue depths for sub-adults increased and/or decreased with advancing age, however, many of these trends were slight (Fig. 1). From 1 to 18 years the greatest increase was ~7 mm at mid-philtrum. Most other soft tissue thickness measurements increased by less than 3 mm over this age range (Fig. 1). An exception was nasion, which appeared to decrease from the age of 1–10 years and then remained relatively constant (possibly increasing slightly in later years; Fig. 1). Mid-nasal and rhinion landmarks were the only two which showed no fluctuation with advancing age (Fig. 1).

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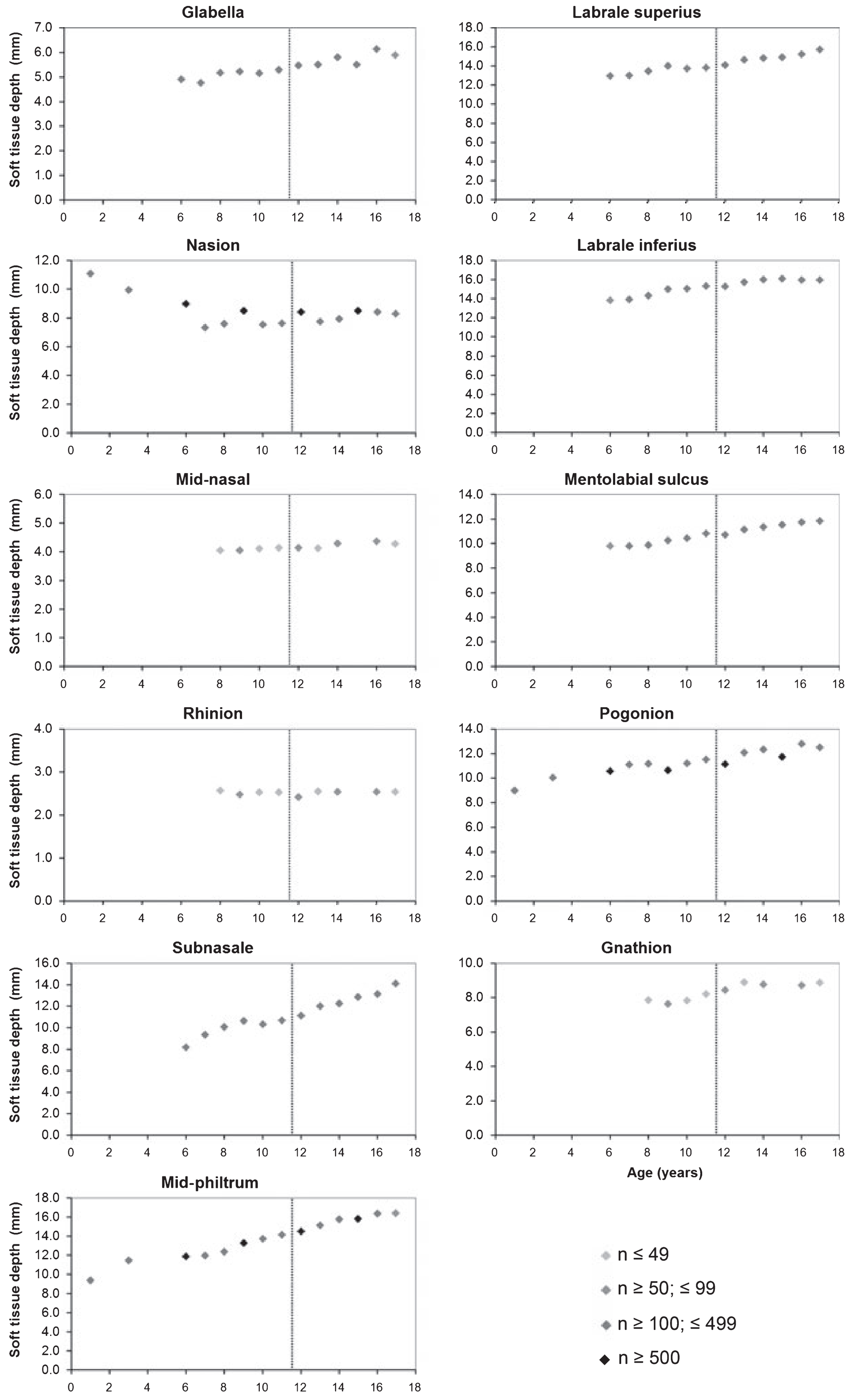

FIG. 1—*Trends in sub-adult soft tissue depth data by subject age. The broken line represents the division point for data pooling.*

These results suggest that dividing the data for children into more than two groups is unlikely to be useful, as for any given age group, neighboring groups are very similar and measurement errors are likely to collectively exceed 2 mm. As soft tissue depths varied systematically in a sequential and incremental fashion with age, data were grouped according to two chronological age categories. A division point just before the age of 12 years was used as this splits the densest cloud of data in half.

Data from sub-adult studies which did not report values for single integer ages were classified into one of these two groups depending on the greater weight of their samples, however, most contained only small numbers of individuals inconsistent with the allocated group. Since most studies included in the younger age bracket (0–11 years) primarily consisted of individuals aged older than 8 years, this younger age bracket is probably more representative of older sub-adults (i.e., those aged between 8 and 11 years). Definitions for the landmarks that are approximated by these studies are given in Table 1, while the two age-specific soft tissue depth tables derived by the collapsing of all 14 sub-adults studies published in the literature are given in Tables 2 and 3.

TABLE 1—*Soft and hard tissue landmarks approximated for sub-adults aged 12–17 years.*

Skeletal Landmarks	Definitions	Soft Tissue Landmarks	Definitions
Median points			
Glabella (g)	Most anterior midline point on the frontal bone	Glabella (g′)	Most anterior midline soft tissue point overlying the glabella (g)
Nasion (n)	Midline point on the naso-frontal suture	Nasion (n′)	Midline soft tissue point directly overlying hard tissue nasion (n) and superior to sellion
Mid-nasal (mn)	Point on internasal suture midway between nasion and rhinion	Mid-nasal (mn′)	Midline soft tissue point directly overlying the hard tissue mid-nasal point (mn)
Rhinion (rhi)	Midline point at the inferior free end of the internasal suture	Rhinion (rhi′)	Midline soft tissue point directly above the hard tissue rhinion (rhi)
Subnasale (sn)	Midline point just below the anterior nasal spine	Subnasale (sn′)	Midline point of the angle at the comulella base where the septum and upper lip join
Mid-philtrum (mp)	Midline point midway between the base of the nasal spine and prosthion (see below) on the anterior edge of the maxillae	Mid-philtrum (mp′)	Midline point midway between soft tissue subnasale and the vermilion border of the upper lip in the groove of the philtrum
Labrale superius (ls)	Midline landmark at the most anterior edge of the superior alveolar ridge of the maxillae (or prosthion)	Labrale superius (ls′)	Midline soft tissue point at the vermilion border of upper lip
Labrale inferius (li)	Midline point at the most anterior edge of the inferior alveolar ridge of the maxillae	Labrale inferius (li′)	Midline soft tissue point at the vermilion border of lower lip
Mentolabial sulcus (mls)	Deepest midline point in the groove superior to the mental eminence	Mentolabial sulcus (mls′)	Deepest soft tissue point on the midline of the groove just superior to the chin
Pogonion (pg)	Most anterior midline point on the mental eminence of the mandible	Pogonion (pg′)	Most anterior midline point on the eminence of the soft tissue chin
Gnathion (gn)	Midline point halfway between the most anterior (pg) and inferior (m) points on the bony chin	Gnathion (gn′)	Midline soft tissue point directly overlying the hard tissue gnathion (gn)
Menton (m)	Most inferior midline point at the mental symphysis of the mandible	Menton (m′)	Midline soft tissue point directly overlying the hard tissue menton (m)
Bilateral points			
Mid-supraorbital (mso)	Point on the supraorbital rim at the midsagittal plane of the orbit	Mid-supraorbital (mso′)	Soft tissue point anteriorly overlying the hard tissue mid-supraorbital point (mso)
Mid-infraorbital (mio)	Point on the infraorbital rim at the midsagittal plane of the orbit	Mid-infraorbital (mio′)	Soft tissue point anteriorly overlying the hard tissue mid-infraorbital point (mio)
Alare curvature point (acp)	Point ∼3 mm lateral to the border of the nasal aperture	Alare curvature point (acp′)	Soft tissue point indicating the most lateral insertion of the alare base into the face
Gonion (go)	Point on the lateral aspect of the border of the mandiblular angle where a tangent bisects the angle formed by the posterior ramus border and the inferior corpus border	Gonion (go′)	Soft tissue point directly overlying the hard tissue gonion (go)
Zygion (zy)	Most lateral extent of the lateral surface of the zygomatic arch	Zygion (zy′)	Soft tissue point directly overlying the hard tissue zygion (zy)
Supra canine (sC)	Point on superior alveolar ridge superior to the crown of the maxillary canine(s)	Supra canine (sC′)	Soft tissue point directly overlying the hard tissue supra canine point (sC)
Infra canine (iC)	Point on inferior alveolar ridge inferior to the crown of the mandibular canine(s)	Infra canine (iC′)	Soft tissue point directly overlying the hard tissue infra canine point (iC)
Supra M^2 (sM^2)	Point on superior alveolar ridge superior to the crown of the maxillary 2nd molar(s)	Supra M^2 ($sM^{2'}$)	Soft tissue point directly overlying the hard tissue supra M^2 point (sM^2)
Infra M_2 (iM_2)	Point on inferior alveolar ridge inferior to the crown of the mandibular 2nd molar(s)	Infra M_2 (iM_2')	Soft tissue point directly overlying the hard tissue infra M_2 point (iM_2)
Mid-ramus (mr)	Point at the center of the mandibular ramus	Mid-ramus (mr′)	Soft tissue point directly overlying the hard tissue mid-ramus point (mr)
Mid-mandibular border (mmb)	Point on the inferior border of the mandibular corpus midway between pogonion and gonion	Mid-mandible border (mmb′)	Soft tissue point directly overlying the hard tissue mid-mandibular border point (mmb)

Landmarks used for the 0–11 age group are a subset of these points (see Table 2). Landmarks are positioned assuming that the skull is in the Frankfurt horizontal.

TABLE 2—*Pooled soft tissue depth data for sub-adults aged 0–11 years (rounded to the nearest 0.5 mm).*

Soft Tissue Depth Measurement	Total Weighted Mean	*n*	Number of Samples	Weighted Mean for *s* Studies	*s*	*n*	Number of Samples	Estimated min. (mean −3 *z*-scores)	Estimated max. (mean +3 *z*-scores)
Median points									
g-g′	5.0	2116	50	5.0	1.0	2098	48	2.5	7.5
n-n′	8.0	4088	57	7.0	1.5	2102	47	2.0	11.5
mn-mn′	4.0	433	18	4.0	1.0	415	16	1.0	6.5
rhi-rhi′	2.5	1064	37	2.5	1.0	1046	35	0.0	4.5
sn-sn′	10.0	1447	29	9.5	2.0	1247	19	4.0	15.0
mp-mp′	11.5	3671	44	12.0	2.5	1703	36	5.0	19.0
ls-ls′	13.5	1675	42	13.5	2.0	1475	32	7.0	20.0
li-li′	14.5	1493	41	14.5	2.5	1293	31	7.5	22.0
mls-mls′	10.0	1884	53	10.0	2.0	1666	41	3.5	16.5
pg-pg′	10.5	4285	69	10.5	2.5	2099	49	3.0	18.5
gn-gn′	6.5	1062	38	6.5	2.0	1044	36	0.0	13.0
m-m′	9.0	160	6	9.0	3.0	160	6	0.5	18.0
Bilateral points									
mso-mso′	5.0	469	14	5.0	1.0	469	14	1.5	8.5
mio-mio′	6.0	521	17	6.0	1.5	521	17	2.0	10.0
acp-acp′	7.5	410	12	7.5	2.0	410	12	2.0	12.5
go-go′	13.0	575	18	13.0	3.5	575	18	2.5	24.0
zy-zy′	7.5	110	5	7.5	1.5	110	5	3.0	12.0
mr-mr′	18.0	108	4	18.0	4.0	108	4	6.5	29.5
mmb-mmb′	10.5	411	12	10.5	3.5	411	12	0.5	21.0

Landmark definitions are given in Table 1 and illustrated in Fig. 2. The "number of samples" represents the number of subcategorized groups previously used for averaging and, therefore, may include several samples from any one study. A subset of studies reporting standard deviations were used to generate the statistics for the "Weighted mean for *s* studies."

TABLE 3—*Pooled soft tissue depth data for sub-adults aged 12–17 years (rounded to the nearest 0.5 mm).*

Soft Tissue Depth Measurement	Total Weighted Mean	*n*	Number of Samples	Weighted Mean for *s* Studies	*s*	*n*	Number of Samples	Estimated min. (mean −3 *z*-scores)	Estimated max. (mean +3 *z*-scores)
Median points									
g-g′	5.5	1558	45	5.5	1.0	1539	42	2.5	8.5
n-n′	8.0	2754	47	7.5	1.5	1751	40	2.5	12.5
mn-mn′	4.0	472	19	4.0	1.0	454	17	4.0	7.0
rhi-rhi′	2.5	719	31	2.5	1.0	700	28	0.5	4.5
sn-sn′	12.0	1233	32	12.0	2.0	993	20	5.0	18.5
mp-mp′	15.0	2485	38	14.5	3.0	1500	33	6.5	23.0
ls-ls′	14.5	1798	50	14.5	2.5	1558	38	6.5	22.0
li-li′	15.5	1639	48	15.5	2.5	1399	36	8.0	23.0
mls-mls′	11.0	1687	52	11.0	2.0	1428	37	5.5	16.5
pg-pg′	11.5	3020	63	12.0	2.5	1777	44	5.0	19.5
gn-gn′	7.5	679	31	7.5	2.0	660	28	1.0	14.0
m-m′	9.0	103	5	9.0	2.5	103	5	2.0	16.5
Bilateral points									
mso-mso′	6.0	246	12	6.0	1.0	245	11	2.5	9.5
mio-mio′	7.0	521	14	7.0	1.5	250	13	2.0	11.5
acp-acp′	8.0	104	6	7.5	2.0	103	5	1.5	13.5
go-go′	17.0	109	8	17.0	3.5	108	7	6.5	27.5
zy-zy′	8.0	147	8	8.0	2.0	147	8	1.5	14.5
sC-sC′	11.0	104	6	11.0	2.5	103	5	3.0	19.0
iC-iC′	10.5	104	6	10.5	2.5	103	5	3.0	18.5
sM^2-$sM^{2'}$	27.0	104	6	27.0	4.0	103	5	14.5	39.5
iM_2-iM_2'	23.0	104	6	23.0	4.0	103	5	10.5	35.5
mr-mr′	19.5	142	6	19.5	4.5	142	6	5.5	33.5
mmb-mmb′	12.5	104	6	12.5	3.5	103	5	1.5	23.5

Landmark definitions are given in Table 1 and illustrated in Fig. 2. The "number of samples" represents the number of subcategorized groups previously used for averaging and, therefore, may include several samples from any one study. A subset of studies reporting standard deviations were used to generate the statistics for the "Weighted mean for *s* studies."

As for the adult data (see 1), landmarks that can only be ambiguously determined either on the soft tissue (e.g., supra-glabella) or on the skull (e.g., trichion) or for which minimal data are reported, have been excluded from the pooled data tables. Figure 2 illustrates the skeletal landmark sites approximated by the pooled data and definitions for both the hard and soft tissue positions (which were approximated by the majority of studies) are given in Table 1. As landmarks based on tooth position will vary depending on whether permanent or deciduous teeth are considered we only included these landmarks with respect to

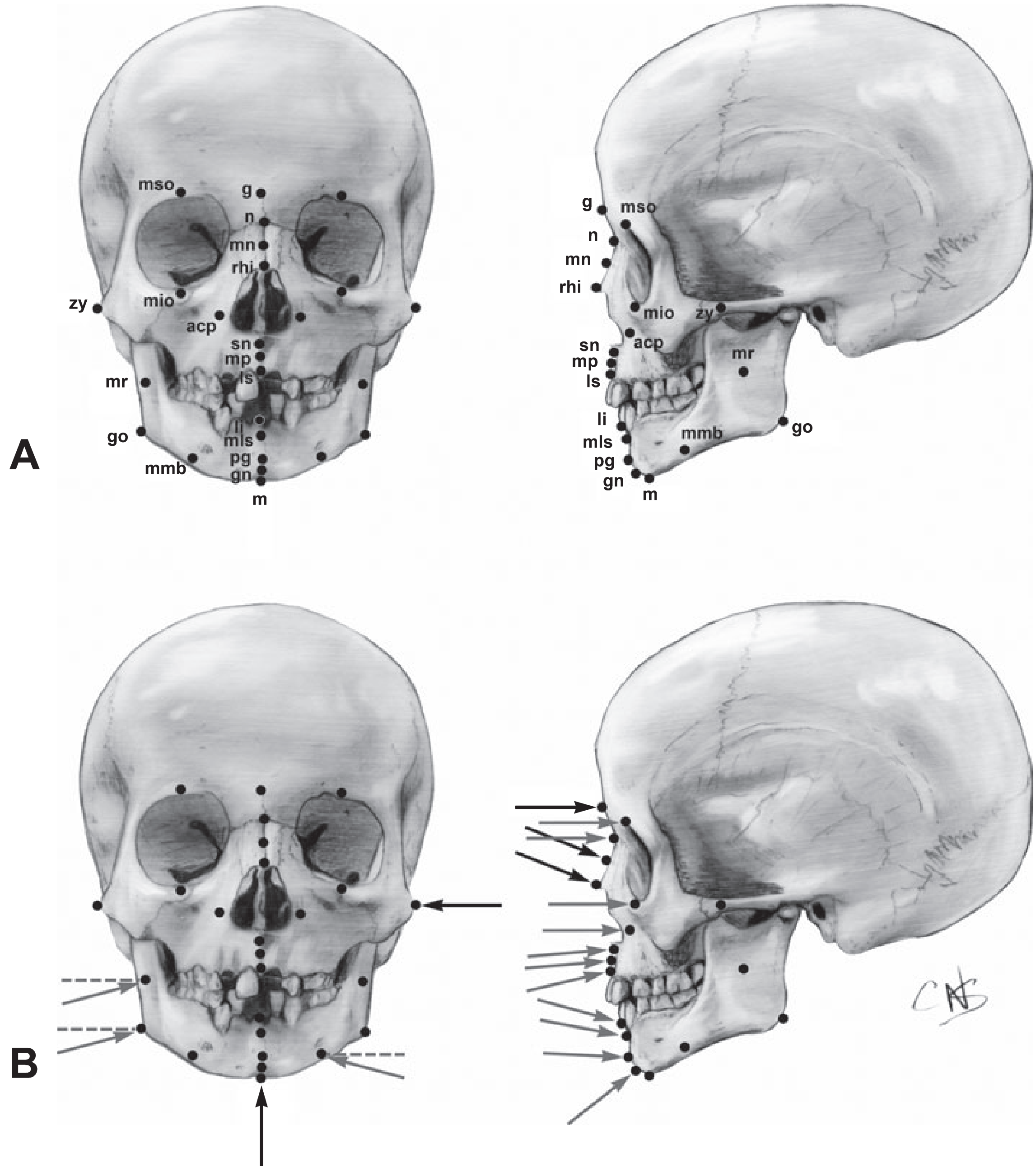

FIG. 2—*Soft tissue depth measurement sites approximated by the pooled data means for sub-adults. Top row (A) illustrates the hard tissue landmarks (see Table 1 for definitions). Bottom row (B) illustrates the typical directions in which the soft tissue depth measurements at these landmarks are taken. Black arrows indicate measurements at angles that bisect the curvature of the bone surface (typically, though incorrectly, known as "perpendicular" measurements). Gray arrows indicate measurement directions that do not bisect the curvature of the bone surface, but are intentionally orientated in other directions (often horizontally or toward other soft tissue features, see Table 1). Arrows with accompanying dashed lines indicate horizontal orientation of the soft tissue depth measurement with anterior inclination. For supra and infra canine and M2 landmarks see (1).*

permanent dentition. This resulted in 19 landmarks for sub-adults aged 0–11 years and 23 landmarks for sub-adults aged 12–17 years. Weighted means and standard deviations are also presented in Tables 2 and 3 for those studies which reported standard deviations (referred to as "weighted means for *s* studies"). All values have been rounded to the nearest 0.5 mm so as not to overemphasize precision (see 1 for additional discussion of this point). As it is not possible for soft tissue thicknesses to be negative, or equal to zero, the estimated sample ranges (Tables 2 and 3) demonstrate that some of the soft tissue variables for sub-adults do not display symmetrical distributions and, therefore, other central tendency indicators such as medians or modes may be more appropriate.

Discussion

The results of this study indicate that extensive subcategorization of the sub-adult soft tissue depth data according to age is of little use for craniofacial identification where errors introduced during data collection or soft tissue depth application are relatively large [>2 mm; repeatability error alone is known to be 1–2 mm (see 18–24)]. Given present measurement errors and data trends by age, it seems appropriate for only two data tables for sub-adults to be used, at least at this stage when measurement errors are so large. These data tables offer the advantage of a simplified data set, increased sample sizes, and better triangulation upon the real central tendencies of soft tissue depth values. However, they suffer from the limitation of being derived from arithmetic means when some data are not normally distributed.

Comparison of the pooled data for older sub-adults to that of the adults reveals that small differences (<1 mm) at 10 of the 23 landmarks exist (see Table 3 and also 1), but that the 12- to 17-year old data are generally larger. The greatest differences were observed at gonion (7 mm), mid-philtrum (4.5 mm), and infra M_2 (4 mm). These larger differences are consistent with the use of particular measurement methods to collect the sub-adult data at these points, which tend to generate higher values. For example, the sub-adult data at gonion and infra M_2 are principally derived from ultrasound studies which have previously been shown to give high values at these landmarks (see 1). Similarly, radiographic methods have been shown to produce very high values at mid-philtrum (see 1), and unsurprisingly, since this method was heavily used at this landmark in the sub-adult studies, data for this landmark are large. However, in an absence of a longitudinal study that employs one measurement method across all age ranges it maybe premature to assign total accountability for these differences to measurement methods alone. It may be possible that some of the changes in the volume of the soft tissue between sub-adults and adults results from growth/aging.

An interesting observation of this study was that soft tissue depth values at nasion decreased in the first 10 years after birth (see Fig. 1). As the first three points on the nasion trend line represent data from the same large sampled longitudinal study (4) this decrease should not be an artifact of chance results between different studies on different samples. Subtelny also observed this trend in his original data set, but dismissed the changes as minimal because from 3 to 18 years the change is less than 1 mm (4). However, from 3 to 15 years it can be seen that the difference in the values lies closer to 2 mm. At this time, we can offer no robust explanation for the decrease in the soft tissue depth at nasion during the early years of life except to mention that there is no *a priori* reason to expect that all measurements will grow in size with development/maturation. Change in form from the juvenile to the adult state is a complex process of organization and reorganization not simply a problem of upward scaling (see e.g., 25,26). For the most part, however, the majority of soft tissue depths measured on the face show increases from the juvenile to the adult state.

In the future, the soft tissue depth data should be again reviewed, but with consideration of all possible influencing variables (see 1). As for the adult data, a principal components analysis should be favored as the best basis for interpretation of the sub-adult data. Unfortunately at this time such an analysis is not possible due to poor raw data availability (see 1 for further discussion). To avoid this situation in the future an online raw-data store has been established to which investigators can voluntarily donate their raw data and/or access the database (see http://www.craniofacialidentification.com). Future collection of raw data will be most useful if it: (i) is not biased toward people of "normal" weight; (ii) reports a complete set of descriptive statistics rather than means alone; (iii) minimizes and measures its respective measurement errors; (iv) uses a minimum set of standardized measurement sites; (v) makes use of a number of measurement methods so data can be pooled across measurement methods to reduce method bias; and (vi) longitudinally tracks individuals across the sub-adult/adult divide. If uncertainty of measurement is dramatically reduced in the future smaller differences between groups may become meaningful and extensive categorization of the data may be useful, thus the conclusions reached in this study may need to be reassessed.

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