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Monica Domaracki,[1] *B.Sc. and Carl N. Stephan,*[1] *Ph.D.*

Facial Soft Tissue Thicknesses in Australian Adult Cadavers*

ABSTRACT: Craniofacial identification methods heavily rely on the knowledge of average soft tissue depths. This study measured soft tissue thicknesses of an Australian cadaver sample ($N = 33$) using published needle puncture techniques at 13 anatomical locations. Data were compared and contrasted with other studies that used essentially identical samples and methods. Full descriptive statistics were calculated for measurements made in this study and means, medians, and modes were reported. Differences between mean values for males and females were found to be minimal (2.2 mm or less) and considerable overlap was found between the groups. There were no statistically significant differences between the soft tissue depths of the sexes ($P > 0.05$). These findings indicate that differences between male and female soft tissue depths are of little practical significance for craniofacial identification and, therefore, data (means, standard deviations, and sample sizes) reported for Australians were pooled across the sexes and the studies. Although these new pooled means have increased statistical power, data distributions at some landmarks were skewed and thus emphasis is placed on median and modes reported for this study rather than upon the collapsed data means.

KEYWORDS: forensic science, forensic anthropology, craniofacial identification, facial approximation, facial reconstruction, facial reproduction, superimposition

Knowledge of the soft tissue thicknesses of the face is important for craniofacial identification methods such as facial approximation (1–5) and superimposition (6). Facial approximation has also been referred to as "facial reconstruction" and "facial reproduction"; however, many practitioners now agree that "approximation" is the most appropriate term (5,7–11), and thus it will be used here. Soft tissue depths are used in facial approximation to help estimate how much soft tissue bulk falls over the skull at particular anatomical landmarks during face construction. Soft tissue depths are used in superimposition methods to assess the soft tissue contours of a face relative to a skull to determine whether the face matches the skull.

Soft tissue thicknesses have been collected using a number of different methods. The oldest and most commonly published method is the needle puncture technique, where needles/pins are inserted into the face of a cadaver at various anatomical and anthropological landmarks and then measured (see e.g., (12–17)). Other techniques for measuring soft tissue depths have heavily relied upon technological developments. Radiographic techniques are one such method and have usually been used to investigate soft tissue depths in the median plane (see e.g., (7,15,18–21)). Ultrasound is another method that has been used (see e.g., (6, 22–24)), as has computed tomography (CT; see e.g., (25)) and magnetic resonance imaging (MRI; see e.g., (26)). CT and MRI are arguably the best techniques for soft tissue depth measurement, but studies using these methods have been infrequent due to the high cost of machinery and, in the case of CT, high radiation outputs during operation.

While all methods used to measure soft tissue depths have limitations and weaknesses, needle puncture techniques have received the most criticism in the literature. For example, Suk (27) and others (e.g., (28)) claim that reliable identification of measurement sites is not possible when using this method, and the measurement of decedents has also been questioned (25,29). However, despite their weaknesses needle puncture methods have a number of advantages, e.g., subjects do not move, the equipment is inexpensive, measurements can be directly taken using simple instruments, and investigators can measure any site on the head they desire. Thus, needle puncture methods have endured despite the development of other more technologically advanced techniques, as evidenced by recent publications using needle puncture methods (see e.g., (16,30)). Furthermore, needle puncture techniques have formed the basis for standard soft tissue depth values used for facial approximation procedures (see e.g., tables by Rhine and colleagues (17,31,32) cited in (3,5)).

No matter which method is used to measure soft tissue depths, some differences between means are found by sex, age, and race (29). Thus, conventional craniofacial identification protocols require the identification of these factors from the skull before soft tissue depths are selected so the appropriate soft tissue depth data can be applied (5,28). Since differences exist between particular groups of individuals (e.g., by sex and race), a need has been stressed for additional data to be collected so that the accuracy of the methods can be increased (17,23,33–36). This study aims to contribute to knowledge of human facial soft tissue depths by investigating a new sample of Australians of European extraction. The study also aims to collate, compare, and pool (where possible) other published and unpublished data sets measured on identical samples using similar methods.

Materials and Methods

Thirty-three adult cadavers (19 males and 14 females), donated to The University of Adelaide Medical School, were measured in this study. All cadavers had been embalmed for more than 6 months previously (15 cadavers embalmed > 12 months) ensuring that curing processes had been completed for each (typically

[1] Department of Anatomical Sciences, The University of Adelaide, Adelaide 5005 Australia.

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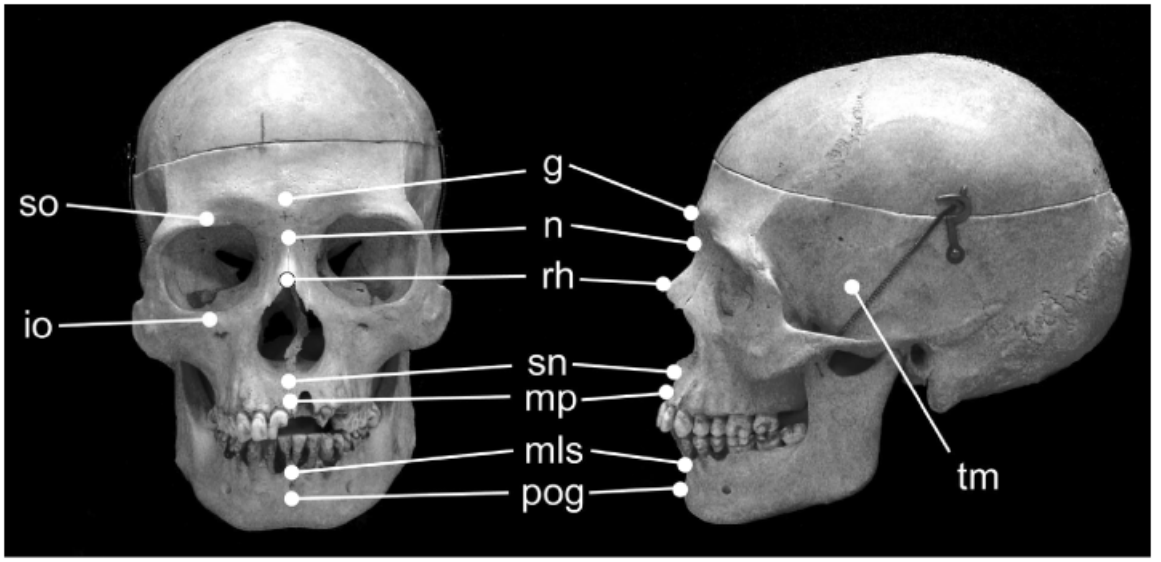

FIG. 1—*The 13 measurement sites used in this study. Median landmarks: g, glabella; n, nasion; rh, rhinion; sn, subnasale; mp, mid-philtrum; mls, mentolabial sulcus; pog, pogonion. Bilateral landmarks (illustrated for one side only): so, mid-supraorbital; io, mid-infraorbital; tm, temporal muscle point.*

requires 3 months). The age range of the sample was from 46 to 92 years while the average age of the males was 80 years ($s = 9$ years), and was 75 years ($s = 13$ years) for females. No cadavers showed any signs of deformity or disease affecting the soft tissues of the face.

Soft tissue depths were measured at a total of 13 points on the head, many being standard anthropological landmarks. Seven measurement sites were in the median plane while three were bilateral (Fig. 1). Soft tissue depths were measured essentially following the methods of Kollmann and Büchly (14) and His (13). A sooted needle was inserted into the soft tissue landmark, removed and the clean portion of the needle was measured on an osteometric board (scale readable to 0.5 mm; Fig. 2). At sites where tissue density had increased and needle insertion was difficult, e.g., over the temporalis muscle, a small amount of oil was placed on the tip of the needle to facilitate insertion following the methods of His (13).

The sooted pin method was used above needle puncture methods using rubber locators on needles (see e.g., (13,16)) since in the sooting method there is no need to manipulate the measurement apparatus once it is inserted and thus no chance of artificially altering the recording. As noted by other authors the skin sometimes formed a shallow depression upon the initial insertion of the needle (6); however, it was found that the skin would usually bounce back, close to its original position, upon gentle vertical movements of the needle. Measurement error was determined by remeasuring 10 randomly selected cadavers and calculating the coefficient of variation of the error.

General descriptive statistics were calculated for each measurement site, and the differences between mean values for males and females were compared using two-sample, two-tailed, unequal variance *t*-tests. Statistical significance was initially set at $P < 0.05$, but altered according to Bonferroni's adjustment for 10 tests. Thus, statistical significance was taken at $P < 0.005$. All data were analyzed using the Microsoft Excel® 2000 (Redmond, WA) and JMP® 4.0 (Cary, NC) statistical packages. The means and standard deviations were also compared with other studies by Sutton (37), Forrest (38), O'Grady et al. (cited in (30)), Anderson and Henneberg (personal communication), and Simpson and Henneberg (16), all of which measured Australians of European extraction using needle puncture methods.

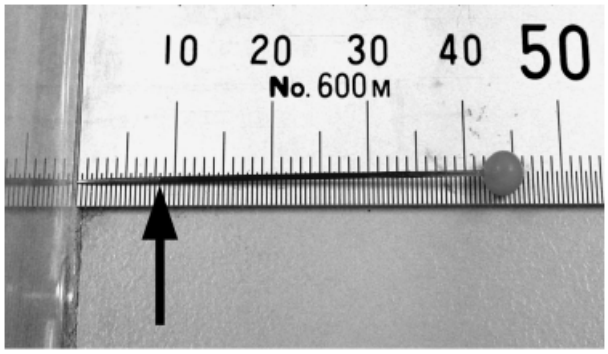

FIG. 2—*Soft tissue depth measurement using a sooted pin. Note the sharp demarcation of soot marking the soft tissue surface, in this case at 8.5 mm (arrow).*

Results

Coefficients of the variation of the error (CVE) were minimal at most measurement sites (Table 1). Technical error of measurement was found to be less than 1 mm (Table 1). The largest error was observed at the mentolabial sulcus (24% ≈2.4 mm). The measurement errors for this study were generally much smaller than those reported by other authors using needle-piercing meth-

TABLE 1—*Coefficients of variation of the error (CVE).*

Landmarks	CVE (%)	TEM (mm)
Glabella	10.7	0.7
Nasion	13.5	0.9
Rhinion	12.0	0.4
Subnasale	8.8	1.2
Mid-philtrum	24.1	2.4
Mentolabial sulcus	3.4	0.4
Pogonion	4.2	0.5
Mid-supraorbital	7.7	0.7
Mid-infraorbital	6.7	0.7
Temporalis muscle	5.5	0.9

TABLE 2—*Summary of soft tissue thickness measurements (mm) made in this study.*

	Males							Females							
Landmark	*n*	Mean	*s*	Median	Mode	Min.	Max.	*n*	Mean	*s*	Median	Mode	Min.	Max.	*P* value
Glabella	19	6.9	2.1	6.0	5.0	3.0	11.0	14	5.8	2.1	6.0	6.0	3.0	9.0	0.170
Nasion	19	6.7	2.0	6.5	6.5	3.5	12.0	14	6.2	1.8	6.5	5.0	3.5	9.0	0.460
Rhinion	19	3.3	1.3	3.0	2.5	1.5	6.5	14	3.0	1.2	3.0	1.5	1.5	5.0	0.540
Subnasale	19	13.4	3.4	12.5	11.5	7.5	20.0	14	13.7	4.2	13.8	16.0	7.5	22.0	0.800
Mid-philtrum	19	10.7	2.2	11.0	12.5	5.0	14.5	14	8.9	3.0	8.8	9.0	5.0	17.0	0.080
Mentolabial sulcus	14	11.8	2.7	11.8	10.5	6.5	11.5	9	9.6	2.5	9.0	7.0	6.5	13.0	0.060
Pogonion	19	12.2	3.2	11.5	11.5	6.0	19.5	14	12.3	4.9	12.3	12.5	6.0	23.5	0.990
Mid-supraorbital	18	9.2	2.5	8.8	7.5	6.0	18.5	14	8.1	3.1	7.8	6.0	3.0	15.0	0.140
Temporalis muscle	19	18.1	4.4	17.0	19.5	11.5	27.5	14	15.9	4.4	15.3	14.0	9.0	27.5	0.050

ods (e.g., (16)), in part because soot marks were left at measurement sites after the first measurement was taken enabling the first author (MD) to reinsert needles at precisely the same soft tissue surface points during re-measurement.

Data are summarized in Table 2. As no significant differences were found between the right and left sides of the face bilateral measurements were averaged and only single values were reported. Sample sizes for some landmarks differ in Table 2 because some cadavers had had some parts of the head removed for other medical research/teaching and thus could not be measured.

Overall, males were found to have greater soft tissue depths than females at seven measurement sites (glabella, nasion, rhinion, mid-philtrum, mentolabial sulcus, mid-supraorbital, and temporalis muscle landmarks) (Table 2). Females had greater soft tissue depths than males at three measurement sites (subnasale, pogonion, and mid-infraorbital landmarks) (Table 2). None of the differences between males and females were statistically significant ($P > 0.05$ after Bonferroni adjustment, Table 2). Standard deviations demonstrate that measurement values for each soft tissue landmark overlapped considerably between the sexes (Table 2). The largest difference observed between males and

TABLE 3—*Means, standard deviations, and sample sizes for facial soft tissue depths measured using needle puncture methods on Australian male cadavers of European extraction.*

	Sutton (37)			Forrest (38)			O'Grady et al. (cited in (30))			Anderson and Henneberg (unpublished)			Simpson and Henneberg (16)			Domaracki and Stephan (this paper)		
Landmarks	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*
Median points																		
Metopian							**4.6**	1.4	24.0	**4.9**	1.5	28.0	**5.5**	1.9	13.0			
Supraglabella				**4.3**	1.0	14.0												
Glabella				**5.6**	1.0	14.0	**6.6**	2.0	24.0	**6.6**	1.7	28.0	**6.7**	1.8	13.0	**6.9**	2.1	19.0
Nasion				**6.5**	1.3	14.0	**6.8**	1.2	24.0	**6.3**	1.7	28.0	**6.7**	1.4	13.0	**6.7**	2.0	19.0
Mid-nasal							**3.3**	1.3	24.0									
Rhinion				**3.5**	1.3	14.0	**3.9**	1.6	24.0	**3.5**	1.4	28.0	**3.0**	1.0	13.0	**3.3**	1.3	19.0
Subnasale				**14.9**	2.7	14.0							**13.5**	3.0	13.0	**13.4**	3.4	19.0
Mid-philtrum							**12.9**	4.1	24.0	**11.4**	3.4	28.0	**10.2**	3.3	13.0	**10.7**	2.2	19.0
Prosthion				**12.6**	3.4	14.0												
Labrale superius							**11.0**	3.0	24.0	**8.7**	3.2	28.0	**8.6**	2.6	13.0			
Labrale inferius										**10.3**	3.1	28.0	**9.6**	2.2	13.0			
Mentolabial sulcus				**11.0**	2.2	14.0	**11.9**	2.9	24.0	**10.6**	2.6	28.0	**11.1**	2.5	13.0	**11.8**	2.7	14.0
Pogonion				**10.5**	1.6	14.0	**9.1**	2.3	24.0	**10.4**	2.6	28.0	**8.0**	2.7	13.0	**12.2**	3.2	19.0
Menton				**7.3**	1.1	14.0	**9.4**	3.3	24.0	**8.0**	4.3	28.0	**7.4**	2.7	11.0			
Bilateral points																		
Superciliare													**8.2**	2.4	13.0			
Mid-supraorbital				**7.5**	1.9	14.0	**8.0**	1.6	24.0							**9.2**	2.5	18.0
Mid-infraorbital							**11.6**	4.4	24.0							**10.6**	4.6	18.0
Lateral orbit							**13.0**	5.0	24.0									
Temporalis muscle point																**18.1**	4.4	19.0
Alare curvature point										**10.9**	3.3	28.0	**11.4**	3.4	13.0			
Maxilla point													**17.4**	3.7	13.0			
Anterior zygoma										**12.2**	5.0	28.0						
Gonion				**12.7**	6.0	14.0	**15.5**	7.1	24.0	**18.5**	7.5	28.0	**18.5**	10.6	12.0			
Zygion	**13.3**	—	69.0				**10.3**	3.7	24.0	**11.7**	5.1	28.0	**10.9**	4.9	13.0			
Supraglenoid							**13.3**	4.4	24.0									
Supracanine										**9.7**	3.7	28.0	**8.8**	2.7	13.0			
Occlusal ramus point				**19.1**	3.2	14.0												
Mid-ramus							**24.3**	6.2	24.0	**22.0**	7.0	28.0	**21.0**	4.7	12.0			
Mid-mandibular border										**12.6**	6.3	28.0	**12.5**	7.1	9.0			
Anterior masseter border							**13.5**	4.8	24.0									
Mandibular mid-body				**8.4**	2.5	14.0				**15.0**	5.6	28.0	**12.2**	4.9	13.0			

TABLE 4—*Means, standard deviations, and sample sizes for facial soft tissue depths measured using needle puncture methods on Australian female cadavers of European extraction.*

	Sutton (37)			Forrest (38)			O'Grady et al. (cited in (30))			Simpson and Henneberg (16)			Domaracki and Stephan (this paper)		
Landmarks	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	*n*
Median points															
Metopian							**3.3**	1.2	28.0	**4.0**	1.4	17.0			
Supraglabella				**3.4**	0.7	9.0									
Glabella				**5.4**	1.2	9.0	**5.7**	1.5	28.0	**5.8**	1.4	18.0	**5.8**	2.1	14.0
Nasion				**5.4**	0.9	9.0	**5.5**	2.0	28.0	**5.3**	1.2	17.0	**6.2**	2.0	14.0
Mid-nasal							**2.8**	0.8	28.0						
Rhinion				**2.6**	0.4	9.0	**3.4**	1.8	28.0	**2.6**	1.0	17.0	**3.0**	1.3	14.0
Subnasale				**11.9**	2.3	9.0				**10.9**	3.3	18.0	**13.7**	3.4	14.0
Mid-philtrum							**11.3**	3.0	28.0	**8.3**	2.5	18.0	**8.9**	2.2	14.0
Prosthion				**9.2**	1.2	9.0									
Labrale superius							**8.0**	2.6	28.0	**6.8**	1.9	18.0			
Labrale inferius										**7.6**	2.1	18.0			
Mentolabial sulcus				**10.8**	2.7	9.0	**12.4**	2.6	28.0	**9.8**	2.4	17.0	**9.6**	2.7	9.0
Pogonion				**11.2**	1.9	9.0	**7.9**	3.0	28.0	**8.9**	2.7	18.0	**12.3**	3.2	14.0
Menton				**7.9**	2.5	9.0	**6.9**	2.1	28.0	**6.9**	2.2	14.0			
Bilateral points															
Superciliare										**6.8**	1.9	18.0			
Mid-supraorbital				**7.7**	1.4	9.0	**6.8**	1.6	28.0				**8.1**	3.1	14.0
Mid-infraorbital							**8.5**	3.3	28.0				**11.0**	4.5	14.0
Lateral orbit							**10.6**	3.5	28.0						
Temporalis muscle point													**15.9**	4.4	14.0
Alare curvature point										**11.4**	2.6	18.0			
Maxilla point										**15.6**	4.3	18.0			
Gonion				**12.6**	4.4	9.0	**12.8**	5.2	28.0	**13.6**	5.2	16.0			
Zygion	**14.8**	—	35.0				**8.9**	2.8	28.0	**9.1**	2.8	15.0			
Supraglenoid							**10.3**	4.2	28.0						
Supracanine										**7.6**	2.3	18.0			
Occlusal ramus point				**19.3**	5.9	9.0									
Mid-ramus							**20.4**	5.5	28.0	**17.6**	3.7	18.0			
Mid-mandibular border										**9.9**	3.7	15.0			
Anterior masseter border							**11.6**	4.6	28.0						
Mandibular mid-body				**8.3**	1.8	9.0				**12.1**	5.1	17.0			

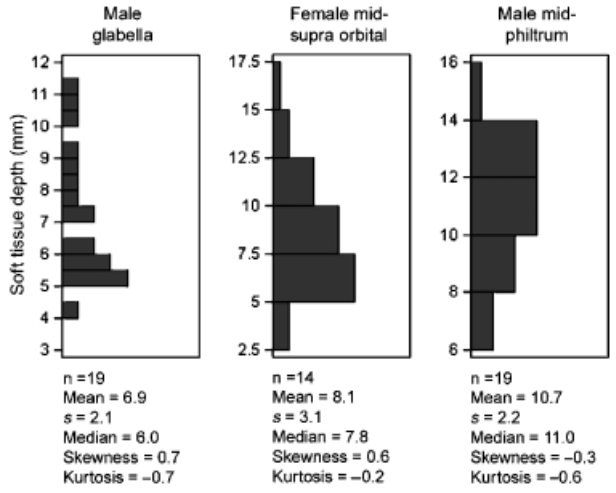

FIG. 3—*Examples of distribution frequencies for landmarks demonstrating skewness.*

TABLE 5—*Pooled soft tissue depths for Australian cadavers (of European extraction) measured using needle puncture methods.*

Landmarks	Mean (Weighted)	*s* (Weighted)	*n*	No. of Samples Combined
Median points				
Glabella	6.2	1.8	167	9
Nasion	6.2	1.7	166	9
Mid-nasal	3	1.1	52	2
Rhinion	3.3	1.4	166	9
Mid-philtum	10.8	3.4	144	7
Labrale superius	8.7	3.1	111	5
Labrale inferius	9.3	2.9	59	3
Mentolabial sulcus	11.2	2.8	156	9
Pogonion	9.9	3.1	167	9
Menton	7.8	3.1	128	7
Bilateral points				
Mid-supraorbital	7.8	2.2	107	6
Mid-infraorbital	10.2	4.3	84	4
Alare curvature point	11.2	3.1	59	3
Gonion	15.1	7.2	131	7
Zygion	10.2	4.1	108	5
Supracanine	8.8	3.3	59	3
Mid-ramus	21.3	6.2	110	5
Mandibular mid-body	12.1	5.3	81	5

females was 2.2 mm at the mentolabial sulcus and temporalis muscle landmark; however, this difference did not exceed the magnitude of one standard deviation in either case. Although soft tissue depth means varied between this study and others measured on similar samples using similar methods, large differences were not evident (Tables 3 and 4).

When distribution frequencies were plotted, skewness was evident for some landmarks. For example, the female mid-supraorbital (0.6) and temporal muscle point (0.8) landmarks displayed a considerable positive skew, as did the male mid-supraorbital (1.8) and glabella (0.7) landmarks. The male mid-philtrum landmark also showed a weak negative skew (− 0.3). (Note that all values

presented here are relative to zero.) Figure 3 gives examples of distribution frequencies for some of these measurement sites.

Discussion

The data collected here helped to contribute to the knowledge of soft tissue depth variation in humans. In particular, this study demonstrates that average differences between males and females are small and that data widely overlap. This lends support to claims of other authors (39,40) that sex differences are of little practical meaning for craniofacial identification techniques. These findings, while not specifically mentioned by other authors, are evident from many other average soft tissue depth studies that have found differences between the sex means to be small (e.g., (6,14,16,22,23,26)). Data for Australians of European extraction, measured in cadavers using needle puncture methods, were therefore pooled across studies and the sexes to increase sample sizes and provide more reliable data. Table 5 presents these data for landmarks commonly used in craniofacial identification.

The finding that some soft tissue depth values are skewed in this study is consistent with the results of other studies (e.g., (16,37,40)). Skewness is significant because means may not represent the central tendency of the data well (41). Skewed data can be better described by the use of medians and modes, which also give the same values as means for those data that display normal distributions (41). Although differences between means and medians for this study are rather small (≈ 1 mm), they have been found to be of twice the size in larger data sets (Stephan and Simpson, in preparation). Larger differences are also evident between the means and the modes (see e.g., Fig. 3). Thus, skewness is a significant factor to consider, as means may be inaccurate by up to two millimeters or more. Other landmarks for which considerable skewness has been reported to exist, in addition to those reported in this study, include the zygion (16,37), gonion (16), labrale superius (16) and mid-mandibular border (16). The choice of which statistic to use (i.e., median or mode) depends upon what an investigator wishes to achieve. The median will give a relatively close estimation for many individuals but often with some error. The mode will give the most exact and correct estimation for the largest proportion of the sample possible (i.e., the most frequent category/value) but with an error for everyone else. Thus, for incorrect cases, the mode is likely to give some larger errors in contrast to the median. Consequently, if practitioners wish to produce "facial approximations" (faces that will reliably include many errors), they should use medians to generate their visages. If they wish to attempt "facial reconstructions" (exact representation), they should clearly use modes. However, the effectiveness of either approach is unknown, for recognition tests of large samples of facial approximations constructed using medians or modes have not been conducted. Furthermore, it is unknown what effect facial dissimilarity (in the context it is presented here with respect to facial approximation) has on recognition, and thus whether tradeoffs (i.e., large errors in *some cases* for modes, and *many small* errors for medians) remain acceptable in terms of achieving method objectives.

Table 2 presents, for the first time in the literature, medians, modes, and means allowing investigators to compare values and select those consistent with their aims. However, we suspect that this freedom of choice will become restricted in the future as research investigations continue to identify optimal approaches. Already, it is clear that the use of medians and modes is favorable to that of means, even though the latter are commonly used (40).

While it is frequently observed that soft tissue depths display a positive skew, the mid-philtrum landmark was also found to display a significant negative (left) skew for males in this study. This observation runs counter to normal expectations because the soft tissue thicknesses can vary much more freely toward larger values but cannot move as freely in the opposite direction (i.e., the skull acts as a limiting factor, ensuring that thinner individuals have more similar values in contrast to heavier individuals). Thus, it may be possible that the one instance of notable negative skew observed in this study results from random selection of a small sample and may not be consistent with population trends. Further investigations should examine this issue to determine whether measurements at the mid-philtrum landmark are in fact skewed and in what direction.

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Additional information and reprint requests:
Monica Domaracki, B.Sc.
Department of Anatomical Sciences
The University of Adelaide
Adelaide 5005
Australia
E-mail: monica.domaracki@student.adelaide.edu.au