

TECHNICAL NOTE

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Mid-Facial Tissue Depths of White Children: An Aid in Facial Feature Reconstruction

REFERENCE: Dumont, E. R., "Mid-Facial Tissue Depths of White Children: An Aid in Facial Feature Reconstruction," *Journal of Forensic Sciences*, JFSCA, Vol. 31, No. 4, Oct. 1986, pp. 1463-1469.

ABSTRACT: Available facial tissue thickness standards for facial feature reconstruction are based on adult measurements. Mid-facial tissue thicknesses for male and female white adolescents are presented here. Measurements were taken from lateral radiographs produced in an orthodontic practice. Statistical analysis indicates that age, sex, and to some extent, dental occlusion pattern are factors that should be taken into account when attempting facial feature reconstructions.

KEYWORDS: physical anthropology, human identification, children, facial feature reconstruction, radiographs, age, sex, occlusion

Anthropological interest in facial feature reconstruction is rooted in a 19th century interest in history. European anthropologists and anatomists generated methods of facial feature reconstruction to create likenesses of historical figures based on the skulls of the individuals [1-3]. Today, its prime use is centered in personal identification. Individuals working in law enforcement use reconstructions, in addition to traditional skeletal analysis, to achieve more precise personal identification in forensic science cases [4-8].

There has been much debate over the validity of three-dimensional facial feature reconstructions. Wilder [9] states that given the appropriate tables of facial tissue thicknesses it would be difficult not to produce a successful reconstruction. Stewart [7] feels that the method deserves more notice than it has been previously afforded. However, variables such as the skill and experience of the artist and the degree of publicity generated over a particular case have been cited as important factors in the efficacy of reconstructions [10]. In addition, Suk [11] has demonstrated that the most common method of measuring facial tissue thickness is not entirely accurate.

Soft tissue measurements are typically taken by palpating a cadaver to locate underlying bony landmarks, then inserting a needle through the soft tissue until it reaches bone. The depth of the tissue may be determined with a calibrated needle [12] by the amount of candle soot displaced by the skin surface [1, 7], or by the amount of displacement of a rubber or metal sheath by the skin [1, 13]. Suk [11] conducted experiments that indicated superficial

Received for publication 25 May 1985; accepted for publication 13 Dec. 1985.

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palpation does not accurately locate underlying bony landmarks. In his experiments, landmarks were missed by an average of 3 mm. Needle insertion can also depress the soft tissue and thus give an incorrect measurement [13]. Data generated by the needle insertion method are still being used today.

There have been several modern attempts to justify the use of facial feature reconstruction in forensic anthropology [14-16]. Snow [16] most rigorously tested the utility of three-dimensional reconstructions in personal identification. He and his team tested peoples' ability to identify an individual by means of a reconstruction. The test was comprised of a photograph of a reconstruction and photographs of several individuals, including one of the reconstructed individual. While positive identifications of individuals from reconstructions occurred at a greater than chance level, the percentage of correct choices varied greatly from case to case. Three factors were cited as contributing to this variation. The first two involve the photographs used for identification: first, the discrepancy between the age of the individual when the photograph was taken and their age at death and, second, the widespread use of cosmetic studio photography which tends to minimize personal idiosyncracies. The third factor is the sampling error contained in the available tables of facial tissue thicknesses. While there is a variety of data for Europeans [1], American whites [17], American blacks [12], and Japanese [13] among others, Rathbun [18] points out the need for data on subadult samples.

In this study I have considered a subadult sample. In addition, I have used a radiographic tissue thickness measurement technique that I consider an improvement over the needle insertion method. Three hypotheses are addressed. First, there is variation in facial tissue thicknesses between adolescents of different ages. This stems from the assumption that tissue thicknesses will either increase or decrease as the individual grows. Second, males and females will differ in tissue thickness. This hypothesis stems from the observation that adult males and females have considerably different tissue thickness measurements [1, 7, 12, 13, 17, 19]. Third, there is variation in soft tissue thicknesses in individuals possessing different dental occlusion patterns. This hypothesis stems from Krogman's statement that, "the dead skull is . . . the matrix of the living head," [4, p. 244]. Hence, any variation of this matrix will be reflected in the tissue covering it. Inter- and intra- observer error in the radiographic measurement technique will also be evaluated.

Materials and Methods

The data source is a series of lateral radiographs produced in a Southeastern orthodontic practice. The radiographs were made with Kodak® X-OMAT L XL-5 film. A Cephalometric® head positioner was used to place the subject's head in a standardized plane. The element-to-film plate distance of the X-ray machine remains constant, thus eliminating magnification inconsistencies among the radiographs.

Radiographs provide three advantages that previously used data sources could not. First, radiographs offer views of living individuals rather than cadavers, which may suffer tissue distortion as a result of drying and embalming [19]. Second, radiographs avoid the possibility of distorting the soft tissue by needle insertion. Third, radiographs make it possible to gather large data bases that include groups unlikely to be represented in cadaver populations, in this case, a large sample of adolescents. While radiographs have been used to obtain facial tissue depths, they have not been employed since 1898 [13].

Nine measurements were taken from each radiograph. These were soft tissue depth at glabella, nasion, midnasal, rhinion, inferior nasal spine, prosthion, chinfold, menton, and gnathion as defined by Krogman and Sassouni [20] (Fig. 1). In the present study, the inferior nasal spine measurement was redefined: rather than measuring the spine from its tip, it was measured from its base at the nasal aperture. This method was used because the tip of the inferior nasal spine is extremely small and thus not a reliable radiographic landmark.

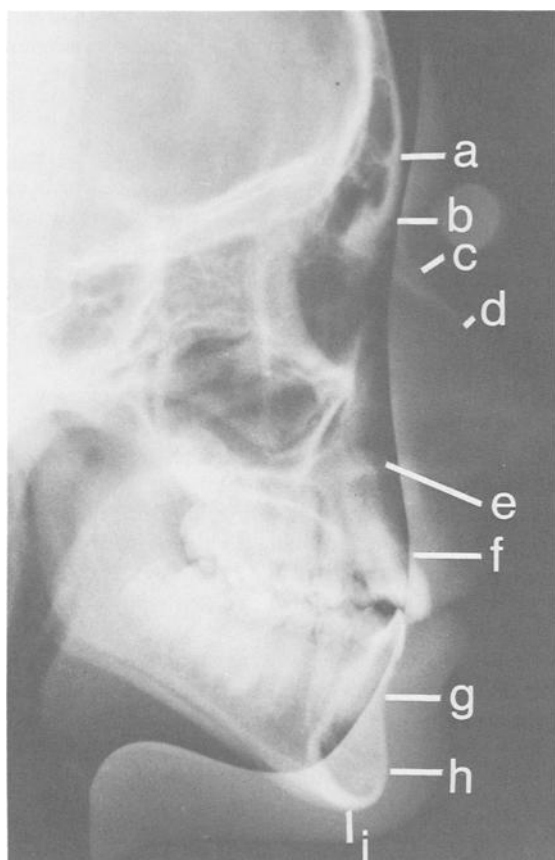


FIG. 1—Radiograph with measurement points indicated as: a = glabella, b = nasion, c = midnasal, d = rhinion, e = inferior nasal spine, f = prosthion, g = chin fold, h = menton, and i = gnathion.

Measurements were taken only when the bony landmark and the tissue surface were clearly visible. Of the potential data set, 3% was lost as a result of X-ray quality. The radiographs were placed on a light box and measurements taken with sliding vernier calipers to the ± 0.1 mm. Age, sex, and dental occlusion pattern for each individual was also recorded.

Dental occlusion is broken down into three main categories: Class I, Class II, and Class III [21]. Occlusion pattern is defined by the first mandibular and first maxillary molars when the teeth are held in habitual occlusion. Habitual occlusion is defined as the occlusion a subject consistently exhibits [21]. Class I is considered the most desirable occlusion by the orthodontic community. It is characterized by the paracone of the first maxillary molar occluding with the buccal groove of the first mandibular molar. Class II is characterized by the metacone of the maxillary first molar occluding with the buccal groove of mandibular first molar. This produces an overbite where the mandibular molar is posterior to the maxillary molar. Class III is characterized by the paracone of the first maxillary molar occluding with the distobuccal groove of the first mandibular molar. This produces an underbite where the mandibular molar is anterior to the maxillary molar.

The data set consists of 194 individuals (females = 101, males = 93) aged 9 through 15. There are a minimum of 9 and a maximum of 18 individuals in each age-sex group. The age

range of 9 through 15 was selected as there were few younger or older individuals available. All of the subjects were white and presumed to be of middle socioeconomic standing.

Results

The Statistical Package for the Social Sciences (SPSS) package of statistical programs [22] and a CDC 855 computer provided by the Wrubel computing center at Indiana University were used to analyze the data. Intraobserver error was tested on a sample of 18 adult individuals (females = 10, males = 8). Data were collected on two consecutive days. Student's *t* tests were not significant on any variables ($p < 0.05$). A second observer who is familiar with various measurement methods repeated the radiographic measurements after approximately 1/2 h of instruction. Again, student's *t* tests were not significant on any variables ($p < 0.05$). The range of error in both intra- and inter-observer samples was between 3 and 11% for any variable.

The first hypothesis, that tissue thickness varies with age, was tested by regressing age on the range of tissue thicknesses for each variable. Results indicated that three variables for males (inferior nasal spine, prosthion, and chinfold) and two for females (inferior nasal spine and chinfold) had regression slopes that were significantly different from 0 ($p < 0.05$). Because these variables exhibit significant changes with age, their samples were divided into two age categories, age groups 9 through 11 and 12 through 15. These categories were selected as they roughly divide the sample in half and represent prepubescent and pubescent individuals.

Males and females in the two age categories were compared using student's *t* tests for the variables inferior nasal spine, prosthion, and chinfold. In the age category 9 through 11, males and females were not significantly different ($p < 0.05$). Thus, male and female values for these variables were combined to provide a larger sample. For the age category 12 through 15, males and females are significantly different ($p < 0.05$) with males having thicker tissue.

Because age was not a significant factor in tissue thickness variation for the variables glabella, nasion, midnasal, rhinion, menton, or gnathion, student's *t* tests were used to compare males and females aged 9 through 15. The variables glabella, menton, and gnathion are not significantly different between males and females ($p < 0.05$). The mean male and female values for these variables were again combined to provide a larger sample. The variables nasion, midnasal, and rhinion are significantly different ($p < 0.05$) between males and females with males again having thicker tissue. Table 1 presents adolescent male and female

TABLE 1—Mid-facial tissue depths of adolescents and adults obtained from radiographs in millimetres.

Variables	Females			Males		
	9-11 Years	12-15 Years	Adult	9-11 Years	12-15 Years	Adult
Glabella	6.7	6.7	6.6	6.7	6.7	6.6
Nasion	6.8	6.8	6.3	7.3	7.3	7.3
Midnasal	4.0	4.0	3.5	4.6	4.6	4.4
Rhinion	2.7	2.7	2.8	3.2	3.2	3.3
Inferior nasal spine	18.9	20.3	21.6	19.8	22.2	26.2
Prosthion	13.4	12.6	10.3	13.7	14.9	14.4
Chin角度	11.7	12.1	11.7	12.1	12.8	15.3
Menton	8.6	8.6	12.2	8.6	8.6	9.4
Gnathion	7.4	7.4	8.3	7.4	7.4	10.1

mean variable values derived from these computations. To remove the effects of age and sex on tissue thickness, measurements were converted into *z* scores for further statistical comparisons.

Four variables were chosen for analysis based on occlusion pattern. The variables prosthion, chinfold, menton, and gnathion were chosen as their proximity to the mouth suggests they would be the primary areas effected by variation in occlusal pattern. Student's *t* tests were performed on each variable between each group to determine their similarities and differences. Gnathion between Class I and Class II individuals is the only variable that is statistically distinct ($p < 0.05$). It is likely that Class III individuals would be significantly different from Class I and Class II individuals if the sample size ($n = 7$) were larger (Class I, $n = 62$; Class II, $n = 44$). In comparison to Class I individuals, the gnathion measurement is relatively larger in Class II individuals and smaller in Class III individuals.

To observe further the effect of occlusion pattern on facial tissue thickness, a classification by means of a discriminant analysis was performed. The procedure used a stepwise process in which the computer selected the order of variable entry based on the Wilks' lambda value of each variable. Only the variable gnathion was entered. The function generated by the computer was used to classify correctly 52 of 62 cases in the Class I group, 6 of 44 cases in the Class II group, and none of 7 cases in the Class III group. Again, a larger sample of Class III cases may have improved the classification results for the group. Overall, 53% of the cases were correctly classified. Although this is over the random expectation of approximately 33%, it does not indicate that occlusion pattern is a significant factor in tissue thickness variation in this data set.

Table 1 also presents a comparison of adult and adolescent data collected from radiographs. For the variables inferior nasal spine, prosthion, and chinfold, not only do tissue thicknesses differ between juveniles and adolescents, but the values for adults are also distinct. Adults have thicker tissue at rhinion, menton, and gnathion and thinner tissue at glabella, nasion, and midnasal. While statistical comparisons have not been made between the adolescent and adult samples because of the small size of the adult sample (18 individuals), it is clear that these groups are not equal. Small sample size may also account for the atypical sexual dimorphism in the adult menton measurement.

Discussion

Age, sex, and dental occlusion pattern all affect tissue thickness to varying degrees. In this sample, the variables nasion, midnasal, rhinion, inferior nasal spine, prosthion, and chinfold vary with respect to sex. Males consistently exhibit larger measurements. This seems reasonable in light of the sexual dimorphism characteristic of adult samples where males are again consistently larger [1,12,13,17]. Age affects the variables inferior nasal spine, prosthion, and chinfold. While males and females aged nine through 11 do not differ significantly for these variables, measurements for males and females twelve through fifteen are significantly different. It is likely that with the onset of puberty males and females diverge in their growth pattern at these points. The inferior nasal spine grows as individuals age; thus, males seem to be exhibiting more rapid growth than females in the same age range. Tissue thicknesses at prosthion and chinfold may be increasing more rapidly in males than females because of the development of facial hair.

Dental occlusion pattern has relatively little effect on variation in tissue thickness. With increasing mandibular protrusion (underbite), tissue thickness at gnathion decreases slightly. Conversely, with increasing retraction of the mandible (overbite), tissue thickness at gnathion increases slightly. The relatively slight effect of occlusion on tissue thickness variation indicates that despite the clinical origin of this sample, occlusion has little effect on soft tissue measurements. While this sample is not an unbiased population sample, occlusion pattern does not seem to be the primary factor here.

TABLE 2—Mid-facial tissue depths of adult males and females in millimetres.

Variables	This Study		American Whites ^a		American Blacks ^b		Europeans ^c		Japanese ^d	
	F	M	F	M	F	M	F	M	F	M
Glabella	6.6	6.6	4.8	5.3	6.3	6.3	4.3	4.8	3.2	3.4
Nasion	6.3	7.3	5.5	6.5	5.8	6.0	4.5	5.0	3.4	3.7
Midnasal	3.5	4.4	...	...	...	...	...	...	3.4	3.6
Rhinion	2.8	3.3	2.8	3.0	3.8	3.8	2.0	2.0	1.6	2.0
Inferior nasal spine	21.6	26.2	...	...	...	...	10.0	11.5	9.4	11.6
Prosthion	10.3	14.4	8.5	10.0	11.3	11.3	8.3	9.5	...	...
Chinfold	11.7	15.3	9.5	10.8	12.0	12.0	10.0	10.0	8.5	8.6
Menton	12.2	9.4	10.0	11.3	12.3	12.3	10.0	10.3	5.3	6.8
Gnathion	8.3	10.1	9.0	7.3	7.8	8.0	6.3	6.0	2.8	3.2

^a [17].^b [12].^c [1].^d [13].

Table 2 presents adult mid-facial tissue thickness data collected from radiographs and cadavers. The measurements collected from radiographs are typically larger than those collected from cadavers. This discrepancy can be explained in several ways. The primary consideration is the difference in data collection methods. While several methods using needles inserted through the skin have been used extensively, these methods have some inherent problems. First, it has been demonstrated that palpating bony landmarks through soft tissue is not necessarily accurate [11]. Other than dissecting the face to determine the position of the landmark, there is no good way of checking measurement points for accuracy. Second, although recent research uses only those cadavers 12 h dead and those refrigerated overnight [17], there still may be tissue distortion as a result of drying. Todd [19] illustrated that cadavers lose 1.5 lbs (0.7 kg) each day and that this weight loss affects soft tissue measurements. Note that data collected for Europeans [1] and Japanese [13] were collected without concern for the time elapsed between death and data collection. Third, variations among the adult samples may be a result of racial and regional variations in facial tissue thicknesses.

Conclusions

Radiographs have proven to be a good method of obtaining facial tissue thickness measurements. With radiographs it is possible to gather large data sets of any age range in a relatively short amount of time. The ability to store radiographs also make them more convenient than cadavers. Large numbers of radiographs are available through doctors, hospitals, dentists, and orthodontists. While I have used lateral radiographs to obtain mid-facial tissue thickness measurements, radiographs can easily be taken from a three-quarters view to obtain lateral tissue thicknesses. The equipment needed to take these radiographs is available in any X-ray room possessing a head positioner.

The differences between adult and adolescent mid-facial tissue thickness values indicate that using adult values to reconstruct an adolescent's may not yield an accurate representation of the individual. Importantly, many individuals working with reconstructions [9,12,15,17,18] note that accurate tables of tissue thicknesses are essential to producing accurate reconstructions. This analysis clearly indicates that age, sex, and, to some extent, dental occlusion pattern should be taken into account when attempting reconstructions. Facial tissue thickness standards for white adolescents are a needed addition to current facial

feature reconstruction literature. With this data, more accurate reconstructions of male and female white adolescents will be possible.

Acknowledgments

I would like to thank Drs. Della Cook and Paul Jamison for their guidance, advice, and encouragement. Dr. James Dumont deserves thanks for his editing and participation in collecting data and producing visual aids. Dr. John Pryse, D.D.S. and his staff deserve the greatest of thanks for their support and patience during data collection. I would like to thank Dr. J. Stanley Rhine for providing otherwise unobtainable reference material. Very special thanks go to Edmond Furia for his advice, editing, help with data collection, visual aids, and continued support in every aspect of this research.

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