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The affect of tissue depth variation on craniofacial reconstructions

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Abstract

We examined the affect of tissue depth variation on the reconstruction of facial form, through the application of the American method, utilizing published tissue depth measurements for emaciated, normal, and obese faces. In this preliminary study, three reconstructions were created on reproductions of the same skull for each set of tissue depth measurements. The resulting morphological variation was measured quantitatively using the anthropometric craniofacial variability index (CVI). This method employs 16 standard craniofacial anthropometric measurements and the results reflect ‘‘pattern variation’’ or facial harmony. We report no appreciable variation in the quantitative measure of the pattern facial form obtained from the three different sets of tissue depths. Facial similarity was assessed qualitatively utilizing surveys of photographs of the three reconstructions. Surveys indicated that subjects frequently perceived the reconstructions as representing different individuals. This disagreement indicates that size of the face may blind observers to similarities in facial form. This research is significant because it illustrates the confounding effect that normal human variation contributes in the successful recognition of individuals from a representational three-dimensional facial reconstruction. Research results suggest that successful identification could be increased if multiple reconstructions were created which reflect a wide range of possible outcomes for facial form. The creation of multiple facial images, from a single skull, will be facilitated as computerized versions of facial reconstruction are further developed and refined.

Keywords: Facial reconstruction; Facial restoration; Facial reproduction; Craniofacial reconstruction; Craniofacial variability index; Forensic identification; American method; Facial recognition; Human variation

1. Introduction

Facial reconstruction is a useful forensic technique [1] which attempts to recreate an individual's face, from a skull or mold of a skull, for the purpose of attaining identification through recognition [2]. Within forensic anthropology facial reconstruction is employed when all other alternatives are unsuccessful, thus it is a last resort employed in the anticipation that someone, somewhere, will be able to identify the deceased and offer clues to law enforcement investigators which ultimately lead to an arrest. This arrest can bring about closure to friends and relatives of the deceased and assist police investigators in removing criminals from society. Facial reconstruction can also be helpful in investigations of genocide and mass death resulting from wars, accidents, terrorist attacks, etc. Historical facial reconstruction is typically undertaken to satisfy curiosity of the facial morphology for people of the past and to re-create the faces of prominent and legendary historical figures, thus giving the public a face to go with the person's name throughout historical education.

Anatomists were the first people to become interested in facial reconstruction as an ‘‘academic exercise’’ [3]. The German anatomist His took facial tissue depth measurements from a small number of cadavers and used those measurements to model a face onto a plaster cast of the skull of the composer Johann Sebastian Bach in 1895, demonstrating favorable results when compared to Bach's portraits [4]. In 1898, Dante's face was reconstructed by Kollman using a similar methodology [3]. His and Kollman both used sculptors to produce their three-dimensional reconstructions [3]. In 1899, Kollman went on to reconstruct the face of a stone-age woman from Auvenier, France, which is considered the ‘‘first real scientific reconstruction,’’ because Kollman used soft tissue thickness measurements from local women and used a technical plan to carry out the reconstruction [5], even later receiving praise from

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Gerasimov (who is credited with giving facial reconstruction much of its early recognition as a successful method of identification) when he stated that ‘‘Kollman’s work can rank as one of the most remarkable achievements in the history of science-based reconstructions of heads and faces from the skulls’’ [3]. In 1926, McGregor of Columbia University was the first person to carry out facial reconstruction in the United States and one of the first to employ a half-face reconstruction technique on prehistoric human skulls in which half of the face was sculpted onto the skull, while the other half of the skull was left bare, to give the viewer a better idea of the relationship between the finished face and the underlying bony structure of the skull [3]. Soon after, these methods began to be applied in forensic cases, although this method of identification would not become popular until after 1960 [6].

The Russian anthropologist Gerasimov is credited with pioneering the Russian or anatomical method of three-dimensional facial reconstruction in which the face is re-built muscle by muscle, without the use of tissue depth measurements [7]. Gerasimov believed that the details of the nose, eyes, mouth, and ears could be determined from examination of specific areas of the skull and he reported amazing success with his technique in over 150 forensic cases in which he was involved [3].

In 1946, the anthropologist Wilton Krogman, aided by sculptors, began studies into the accuracy of facial reconstruction techniques [3]. Using tissue depth data appropriate to the sex and racial origin of individual skulls, Krogman’s sculptors were able to reproduce faces that resembled photographs of the individuals in life [5], thus Krogman concluded that three-dimensional facial reconstruction could be a useful tool in forensic identification [3]. In 1946, Krogman published the FBI Law Enforcement Bulletin; an account, for the FBI, of how facial reconstruction ought to be carried out [5].

In the past, the accumulation of facial tissue depth measurements and averages was based upon research in which a sharp object was used to penetrate the face of a cadaver, at specific facial landmarks, and then measured to determine the tissue depth at that area [3]. Suk, an outspoken critic of three-dimensional facial reconstruction, criticized this skin puncturing technique because of the impossibility of correctly determining the different landmarks on the skull while the flesh is covering it and also because of possible human errors in taking those measurements [3]. Cadaveric studies have also been criticized because soft tissue distortion begins to occur at death and the horizontal positions of cadavers can create false tissue depth measurements due to the action of gravity [3]. Additionally, early tissue depth studies used destitute cadavers whose diet and health were not representative of the population at large [8]. Contemporary methods for accumulating tissue depth measurements employ ultrasonic echolocation, computed tomography (CT), and magnetic resonance imaging (MRI) [9].

Forensic artist Betty Pat Gatliff and forensic anthropologist Clyde C. Snow further developed and refined a method of facial reconstruction dubbed the American method of three-dimensional facial reconstruction, based on Krogman’s previous research [7]. The American method of facial reconstruction has yielded significant identification rates above chance when compared to other methods of facial approximation [10].

The American method of facial reconstruction mounts the skull, or a mold of the skull, into the Frankfort Horizontal Plane—an imaginary horizontal line passing through the inferior border of the orbit and the external auditory meatus on both sides of the skull, in an attempt to approximate the natural position of the head in life [10]. Vinyl erasers or wooden dowels are cut to specific lengths, representing average skin tissue depths, based upon previously collected reference data, which controls for variation by age, sex, and ethnic affiliation [11]. Next, tissue depth markers are attached to 32 appropriate anatomical points on the skull and modeling clay is used to rebuild the face onto the skull, relying on the tissue depth markers to determine skin thickness for each section of the face [7]. It is hoped that the final outcome is a face, similar enough to the actual face the skull bore when alive, to bring about recognition and provide leads in a forensic investigation.

Skeletal evidence is often used in forensic investigations [12] to determine information about an individual [13,14]. However, prediction of the body build of an individual from the skull alone tends to be less reliable [15]. Possible facial variation, resulting from different builds, has the potential to influence facial recognition [15]. Quatrehomme et al. make the assertion that ‘‘facial reconstruction is not easy, because there are many facial variations, particularly according to the nutritional status of the individual and the different rates and intensities of ageing. Furthermore, the details of the nose, eye, ear, lips, and chin cannot be constructed exactly from the skull characteristics’’ [16].

Recognition is extremely complicated [17] and various studies [18,19] are inconclusive in determining the exact mechanisms involved in facial recognition and how specific mechanisms interact with each other [20]. As Shepard notes, the ‘‘race of (a) subject, attractiveness of faces, and [. . .] sex of (a) subject have been shown in a number of studies to be important variables in face recognition’’ [21]. People generally find it easier to recognize faces from their own (culturally constructed) racial group [21]. Recognition is further complicated by the normal range of human variation exhibited in soft tissue facial features such as: eyeball relation to orbit; location, shape, and size of the ear; nose shape and size, and the width, height, thickness, and overall shape of the mouth [15]. Vanezis et al. state that ‘‘the type and colour of hair, the form of eyebrows and the possibility of facial hair in the male will also have a profound effect upon the appearance of any individual. Surface markings such as scars and skin blemishes, deep furrows, folds, wrinkles, ‘ethnic scarring’, tattoos, and the wearing of (ear)rings and spectacles are further details of a face that cannot be ascertained from a dry skull’’ [22]. These features undergo changes during senescence, further confounding facial recognition [23].

We chose to examine the range of normal human facial variation associated with body weight and its implications in facial recognition. We hypothesized that appreciable variation would occur between three facial reconstructions from the same skull using average tissue depth measurements for emaciated, normal, and obese faces; one set on each skull. We further hypothesized that the resulting morphological variation may affect recognition negatively.

2. Methods

The American method of three-dimensional facial reconstruction was utilized, as outlined by Taylor [7] and Gatliff [24] in Forensic Art and Illustration, to create three facial reconstructions. This method of facial reconstruction relies solely on tissue depth markers, rather than facial musculature, as is used in other methods of facial reconstruction, to create the final face upon the skull.

One author (Starbuck) was responsible for creating all three reconstructions. The emaciated facial reconstruction was created first, the normal facial reconstruction was created second, and the obese facial reconstruction was created last. These reconstructions utilized published tissue depth measurements for emaciated, normal, and obese faces [7]. The facial reconstructions were standardized by exactly following the same methodology for recreating each face onto the skulls.

The original male Caucasoid skull was used to create a mold from dental alginate. Using this mold, three plaster casts were created of the skull replicating it exactly. Each cast was mounted onto a stand in the Frankfort Horizontal Plane to approximate the natural position of the head in life [11]. Tissue depth markers were cut from vinyl erasers, for each set of measurements (emaciated, normal, and obese male Caucasoid), for the 10 midline and 11 bilateral locations on the skull that are utilized during the American method of three-dimensional facial reconstruction. The midline and bilateral locations follow as published by Taylor (Table 1) [11].

Respective tissue depth markers were then attached to that particular plaster copy of the skull, in the locations specified in Table 1, using standard super glue. Blue plastic prosthetic eye caps were used for the three facial reconstructions because this is a common eye colour associated with Caucasoids. Anteriorly, the prosthetic eyes were centered within the orbit from the north and south, and east and west. Laterally, the prosthetic eyes were placed with the outer point of the cornea tangent to the midline of the superior and inferior margins of the orbit. Non-drying polymer clay was used to secure the prosthetic eyes into the orbit once the final location was determined. Position was then rechecked and clay added or subtracted until the prosthetic eye rested in the final position determined previously.

Strips of non-drying polymer clay were used to fill in the gaps between tissue depth markers while never exceeding the depth outlined by the tissue depth markers. This was done for the majority of the face, while avoiding the immediate area surrounding the nose and mouth until after they had been fully developed.

The mouth was developed as outlined by Taylor [11]. The tissue depth marker for Lower Lip Margin was used to determine the depth of the mouth. Vertical thickness of the mouth was derived by measuring the height of the enamel of the upper and lower teeth on the original skull. The width of the mouth was determined by measuring the front six teeth.

Table 1
Landmarks for facial reconstruction [7]

Midline	Bilateral
Supraglabella	Frontal eminence
Glabella	Supraorbital
Nasion	Suborbital
End of nasals	Inferior malar
Mid-philtrum	Lateral orbit
Upper lip margin	Mid-Zygomatic
Lower lip margin	Supraglenoid
Chin–lip fold	Gonion
Mental eminence	Supra M^2
Beneath chin	Occlusal line
	Sub M_2

The eyelids were developed as outlined by Taylor [11]. Using small pieces of clay, shaped like trapezoids, the lower and upper eyelids were developed while keeping in mind that ‘‘the lids should hug the eyeball as you place them on the lateral side and come around just to the bottom of the iris. Then, as they wrap around toward the medial canthus or inner corner of the eye, they deviate away from the eyeball slightly, creating an S-curve. Thus, the medial canthus is naturally closer to the frontal plane than the lateral canthus or outer corner’’ [11]. After the lower lids were in place, the caruncle lacrimalis was developed from a small ball of clay to represent the pink tissue found at the inner corner of the eyes.

The nose was developed as outlined by Taylor [11]. Taylor reports (based on Krogman’s previous research) that ‘‘for Caucasoids, the nasal aperture is measured at its widest point, then 10 mm are added to get the total width (5 mm should be added to each side of the nasal aperture for a total of 10 mm)’’ for the nose [11]. The lateral projection of the nose is based upon measurement of the anterior nasal spine [11]. The length of the nasal spine is multiplied by three and added to the tissue depth marker for Mid-philtrum. Small blocks of clay were developed, based upon these measurements, to develop the anterior projection of the nose and the nostrils. Nostrils were placed 4 mm below the sill of the nasal aperture [11].

The ears were developed and attached to the facial reconstruction as outlined by Taylor [11]. Using coils of clay, all six ears (three right and three left) were developed and measured to be the same for each facial reconstruction. The ears were then attached to the facial reconstruction at a 15° angle, afterwards, the tragus was added to make the ears appear realistic.

Readers with questions regarding the methodology employed when using the American Method of facial reconstruction are invited to read chapters 11 and 13 in Forensic Art and Illustration by Taylor [11]. For an alternative to the American Method of facial reconstruction, known as the Manchester or Combination Method of facial reconstruction, readers are invited to read chapter 6 in *Forensic Facial Reconstruction* by C. Wilkinson [3].

Morphological variation was then measured both quantitatively and qualitatively. Quantitative analysis utilized digitized craniofacial anthropometry derived from three-dimensional computer scans of the reconstructed faces. Anthropometric measurements were taken as shown in Table 2.

Three-dimensional models of the completed reconstructions were obtained using the Minolta Vivid 910 fw available in the Advanced Visualization Laboratory of the Indiana University. We chose this method to avoid distortion that would be introduced if direct measurements were attempted on the soft clay of the models. The scanner uses laser technology to obtain coordinates in the *x*, *y*, and *z* dimensions. Three views, a left lateral, frontal and right lateral were obtained. These views were then stitched together using the Vivid software to create the final three-dimensional models. Measurements were obtained using a commercial digitizing software program (Rapidform©) and a customized ‘‘plug-in’’ for the measurement array we had chosen.

Measurements were chosen following a protocol outlined by Ward [25,26] for assessing and quantifying patterns of facial variability. All measurements were taken at least twice by the same observer to control for measurement error. If the difference between the first and second measurement exceed 2 mm a third measurement was obtained. The first of the two closest measurements was used in the analysis. In this fashion measurement error was kept at or below 2 mm for each variable. Measurements were standardized to published norms for Caucasian adults [27] and converted to *z*-scores for statistical analysis. Because we

Table 2
Anthropometric measurements and landmarks used in quantitative analysis [27]

Widths	Depths	Heights
Bizygomatic (*zy*–*zy*)	Right upper facial depth (t–gn)	Total facial height (n–gn)
Bitragal (t–t)	Right midface depth (t–sn)	Lower facial height (sn–gn
Bigonial (go–go)	Right lower face depth (t–gn)	Nasal bridge length (n–prn)
Outer canthal (ex–ex)		Nasal length (n–sn)
Inner canthal (en–en)		Philtrum length (sn–lbs)
		Right ear length (sa–sb)

were interested in comparing the overall pattern of measurements we calculated both the correlation coefficients between the three sets of facial measurements and the ‘‘craniofacial variability index’’ (CVI) for each reconstructed face. The correlation coefficient between the measurement sets can be shown in a graphic form described by Garn et al. (as a ‘‘pattern profile’’) where the higher the correlation the more similar the facial patterns [28]. The CVI is defined as the standard deviation of the averaged *z*-scores for the set of 14 measurements in a particular individual. It has been shown that the CVI is a robust measure of the overall harmony of the face [26]. Ward et al. calculated the distribution of CVI in a sample of 1312 normal individuals published by Farkas and in a smaller sample of controls collected by one of the authors [26]. The distribution of CVI in the reference population had a mean of 0.761, and standard deviation of 0.190. The CVI is analogous to the pattern variability index long developed by Garn [29] and long employed in cephalometric analysis. We would anticipate that because the facial features (eyes, mouth, ears, and nose) are held constant in each reconstruction while soft tissue depths are varied, that the CVI would increase in both the emaciated and the obese reconstructions, indicating a change in facial harmony that might be expected to affect recognition.

Qualitative analysis utilized survey data that assessed the subjective appearance of similarity among photographs of the three faces. Surveys were sent via e-mail to 656 college students. Forty students responded yielding an approximate 7% response rate. While this was not specifically a randomized sample, the students were drawn from a convenience sample of students registered on Oncourse, an online class directory utilized at Indiana University-Purdue University Indianapolis, to contact other students via e-mail.

3. Results

Fig. 1 shows the univariate anthropometric measurements collected, graphed from the largest to the smallest measurements. This graph shows that the emaciated face is smaller or equal in measurements to the other faces, while the normal face is typically larger or equal to the emaciated, but smaller or equal to the obese face. The most overlap as expected is in areas that are minimally affected by the different tissue depth variations such as those around the eyes, ears and nose. Fig. 2 demonstrates a facial pattern profile graphed from the *z*-scores for each

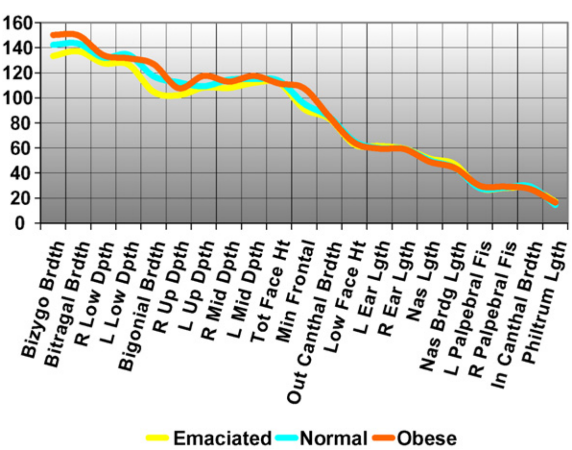

Fig. 1. Univariate anthropometric facial measurements (mm) are graphed together from largest to smallest. This graph indicates that measurements for the emaciated face (yellow line) are equal to or smaller than measurements for the normal face (blue line) and obese face (red line). Measurements for the normal face are typically larger or equal to the emaciated facial measurements and smaller than or equal to the obese facial measurements. The most overlap is seen in areas that are minimally affected by different tissue depths. Measurements which do not conform to this pattern are likely a result of measurement error, possible distortion from computer scans, or flaws in the manual clay reconstruction process.

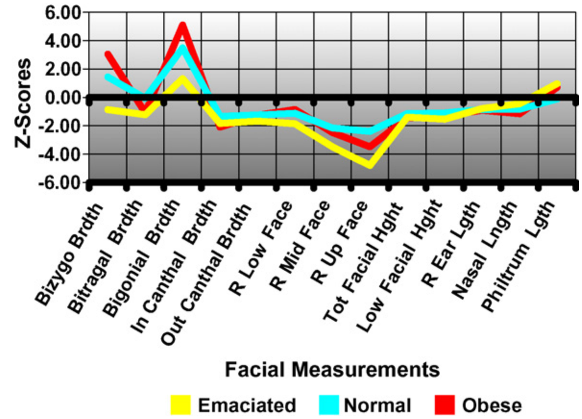

Fig. 2. This line graph illustrates the facial pattern profile graphed from Z-scores for midline and right lateral anthropometric facial measurements. The faces follow similar patterns while being small for many measurements when compared to a large reference population [27].

measurement standardized to previously published age and sex matched ‘‘norms’’ [27]. We calculated correlation of the pattern of variation among the three faces from collected facial measurements. Table 3 demonstrates that there is a strong positive correlation between each face, with the emaciated face having a 78% correlation with each other face, and the obese face sharing a 96% correlation with the normal face. Table 4 shows calculated CVI’s or ‘‘pattern variability’’ for each face. Calculated CVI’s illustrate more similarity between the emaciated and normal face. However, Chart 3 shows that all three CVI’s for the facial reconstructions are much higher than would be expected in a normal population [26,27].

Qualitative data measured survey results based upon the perception of similarity among photographs, taken anteriorly, of the three facial reconstructions. As noted previously, the surveys were sent via e-mail to 656 college students. A 45 students responded yielding an approximate 7% response rate. Approximately 51% of respondents answered that the emaciated and normal face were not the same individual, while 20% of respondents answered that these two photographs were of the same individual. Approximately 56% of respondents answered that the normal and obese face were not the same individual, while 22% of respondents answered

Table 3
Pattern profile correlation coefficients (correlation among resulting faces)

	Emaciated	Normal	Obese
Emaciated	1	0.783	0.779
Normal	0.783	1	0.964
Obese	0.779	0.964	1

Table 4
Craniofacial variability index for each face

Sample	Observed	Expected
Emaciated	1.568	0.482–1.106
Normal	1.55	0.482–1.106
Obese	2.234	0.482–1.106

that these two photographs were of the same individual. About 56% of respondents answered that the emaciated and obese face were not the same individual, while 22% of respondents answered that these two photographs were of the same individual. Overall, when two faces were compared, respondents answered that they were not the same individual an average of 54% of the time, while believing them to be same individual an average of 21% of the time. Therefore, the qualitative data is in opposition with the quantitative data. Photographs of these three faces seem to be perceived, by a significant number of observers, as completely different individuals.

4. Discussion

Quantitative data analysis reveals that the three faces differ primarily in size, as would be expected. The resulting faces tend to get larger when analyzing individual measurements, moving from emaciated to normal to obese. Yet from a quantitative perspective the faces are very similar (facial measurements, *z*-scores, and pattern profiles). Each face shows a strong positive correlation with the other faces as indicated by the high pattern profile correlation coefficients. The strongest correlation is seen between the normal and obese face. The pattern profile shows that the faces have similar morphological patterns of variation based upon the calculated *z*-scores.

However, Fig. 2 also illustrates that while the faces follow a similar pattern, they are surprisingly small for many measurements, particularly those that assess facial depth, when compared to a large reference population (thus they have large negative *z*-scores). This may be a product of the original model skull's unique morphology or possibly errors in approximating facial depths when using the American method of facial reconstruction. The source of this error may be in the placement of the ears, which provide a common reference point for assessing depth and which involve some subjectivity in determining location, shape and size, during the reconstruction process. The results from the CVI analysis are similarly complex. As predicted, the normal face has the value closest to the expected mean, but it and the other two faces show much higher CVI's than would be expected from the reconstruction of a normal Caucasian face.

We believe this could also be attributed to distortion or abnormality in the original skull from which the casts were obtained. Alternatively, these deviations may be an artifact of the reconstruction technique or the imaging process. In fact, the problem described above in properly positioning the ears using the American technique might well contribute to the high CVI values seen in these reconstructions.

To summarize, the quantitative data suggests that these three faces are very similar to each other and the faces follow consistent patterns of variation when compared to one another. The faces show interesting but unexplained differences in several measures from the reference ‘‘normal’’ data [26].

Our qualitative data results show that an average of 54.3% of respondents believe the individual faces are completely different individuals when one is compared to another. An average of only 21.3% of respondents believe the individuals are the same individual when one face is compared to another. Thus, our qualitative data conflict with our quantitative data. In one sense, it appears as though the quantitative data confirm that the faces have been reconstructed in a comparable fashion leading to high correlations in the overall facial patterns. However, data drawn from subjective assessment of the reconstructions suggests that the morphological variation present in the resulting three facial reconstructions may affect recognition negatively, thus decreasing the forensic usefulness of the reconstructions. Even when the facial features are the same, modifications in the thickness of facial soft tissues seems to lead many observers to view the faces as coming from different individuals.

We have demonstrated that the utilization of tissue depth measurements for emaciated, normal, and obese faces during facial reconstruction has a minimal affect on the overall pattern of facial form. However, subjective assessment of the emaciated, normal, and obese faces was significantly affected by the use of differing tissue depths. These results suggest that variations in weight may be an important contributor to the ability to achieve correct recognition of a reconstructed face. Even using fairly rigid guidelines, outlined by the American method of facial reconstruction [7], it appears that variation in the size of the face may be more important than facial configuration in identifying individuals. Facial features, such as placement of ears and eyes; size and shape of the nose and mouth, did not change between the three facial reconstructions, yet the majority of viewers perceived the faces as completely different individuals.

z-Scores measurements for bizygomatic breadth, bigonial breadth, bitragal breadth, and upper facial depth vary among the three facial reconstructions. Disparity in the breadth measurements is a result of increasing facial size associated with emaciated, normal, and obese tissue depth measurements. We agree with Stephan's assertion that there is a need for many subjectively determined facial approximation guidelines to be scrutinized and subjected to scientific experimentation in order to determine which methods are accurate and which require further investigation [30].

If, as we speculate, the high CVI values indicate a problem with the basic reconstruction process, including placement of the ears, it suggests that additional research needs to undertaken through studies of cadavers or advanced imaging of the living to better inform the process of positioning the ears and defining their shape.

Our results suggest a more fundamental problem with facial reconstructions, centered around the painstaking and time consuming nature of the process. Indeed, it could be argued that the present study would have benefited from a wider range of subjects treated to the same three-fold reconstruction (females, or individuals from a variety of ages and ethnic backgrounds could have been presented). Yet, the very nature of the reconstruction process makes such an undertaking unlikely. In addition it is difficult to make drastic alterations, such as employing differing tissue depths, to the reconstruction once finished. When it is not possible to do more than one facial reconstruction, the skull characteristics may help to determine the choice of which tissue depth category to use for the facial reconstruction, although accuracy studies note that ‘‘when the race of a skull is not certain, it is suggested that a composite face be made using carefully selected tissue depths’’ based upon skull morphology [31], and ‘‘inappropriate facial tissue data may compromise the accuracy of the facial reconstruction’’ [32].

Alternatively, various computer facial reconstruction programs have been developed [16,33,34] which may help to alleviate these deficiencies. As Helmer et al. note ‘‘such factors as hair length and form, the existence of facial hair, signs of illness, or clues to the lifestyle and social standing of the individual are of primary importance and should be included in the reconstruction’’ [35]. Computer modeling could allow for rapid transformation and manipulation of various facial features, including tissue depths and other various factors previously mentioned to create a range of possible reconstructions.

Computerized facial reconstruction can also employ more tissue depths than the traditional 32 depths used in the American method. We agree with Vanezis et al. when they state that employing computerized methodology and utilizing various tissue depths ‘‘will allow reconstructors to generate a range of possible faces, rather then a single reconstruction, in order to increase the chances of identification’’ [22]. A similar contention is held by Haglund and Reay when they argued that ‘‘because of the subjective nature of facial approximation techniques, more than one approximation version should be used’’ [36].

5. Conclusion

In conclusion, this research illustrates the confounding effect that normal human variation contributes to the creation of a representational three-dimemsional facial reconstruction. It is suggested that this is a situation in which ‘‘more is better’’. Multiple reconstructions reflecting the range of human variation associated with build and weight, may improve recognition and identification in forensic investigations. We believe that the creation of multiple reconstructions will be facilitated and improved in speed, cost, and accuracy, by three-dimensional facial reconstruction computer programs as these programs become more technological advanced, refined, and pervasive.

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