INTRODUCTION

Forensic facial reconstruction (FFR) is an important technique in the forensic anthropologist's toolkit and one that continues to see improvements in accuracy and ease of use as technology advances. As an analyst of human remains, the forensic anthropologist is often brought in to identify a deceased person. FFR serves the often pivotal role of approximating what a person's face looked like when they were alive from either skeletal or highly decomposed remains, in order to aid in accomplishing this goal. . It is particularly useful in cases where other forms of identification are not possible or feasible. The fundamental goal of FFR is to create a good enough likeness of a deceased person that the individual can be recognized in order to facilitate identification (Lee et al. 2011). As Cattaneo (2007) contends, it "should be used only to stimulate the memory of the public in order to reach a suspicion of identity." Often, facial reconstruction serves as a "last resort," and is especially important when other methods, such as DNA or dental records, fail or are unable to be used (Lee et al. 2011: 364). As it stands, a significant amount of conjecture is necessary in producing a reconstruction, leading to FFR's existence in a liminal space between science and art and inciting debates as to which category it should fall under. This is tied into debates of its overall accuracy and how much of the accuracy that does exist is dependent upon the skill and experience of the person doing the reconstruction (Lee et al. 2011). Identification is determined to be either certain, probable, possible, or excluded (Quatrehomme et al. 2007), with better reconstructions leading to more concrete results. Facial restoration, which depends on some of the soft tissue being present, has been deemed a preferable option due the fact that generally provides a model that is more easily recognized by those who knew the deceased person, in addition to being faster. In the absence of significant soft tissue, craniofacial reconstruction (CFR) may be used, which relies exclusively on the skull (Quatrehomme et al. 2007). Facial reconstruction itself does not constitute a positive identification, but can lead investigators in the right direction to the point where other means of positive identification can then be utilized. The biggest changes in FFR in the past few decades have centered on the introduction of 3D computer generated models. While these models can often be generated more quickly and may be considered more accurate considering their use of high tech measurement techniques and formulas, a great deal of artistry is still necessary in order to produce the most useful reconstructions. **As methods shift towards a computerized approach, it is necessary to bear in mind the level of objectivity and subjectivity present in each model and to recognize the part that skill plays in producing beneficial models.**

BACKGROUND

With regard to CFR, there are two basic approaches, consisting of two-dimensional (2D) and three-dimensional (3D) reconstructions. Each approach utilizes either a manual or computer-generated method (Lee et al. 2011). Computer generated models are particularly important to focus on in light of the technological advances that have been made in recent years and the increasingly heavy reliance on these methods. One of the main advantages touted by those favoring a computer-based method over the manual method is the objectivity of this method as opposed to the perceived subjectivity of manual methods (Lee et al. 2011).

Regardless of the method used, approaches can be broken down into three basic schools of thought: anatomical, anthropometrical, and combination (Lee et al. 2011). As Lee et al. (2011) explains, the anatomical view is heavily influenced by the prevalence of musculature in defining the shape of the reconstructed face, while the anthropometrical view focuses on the average tissue depth of the face as the key factor. The combination view, as one might suspect, is a way of merging the anatomical and anthropometrical, with average tissue depth serving to confirm details obtained by looking at the muscle and bone structure. The method chosen determines the measurements and formulas that one uses and the level of objective and subjective influences.

Another distinction to note is the one between approximations and reconstructions; terms that all too often seem to be used interchangeably. Approximations rely on the averaging of data sets obtained from multiple individuals and using them to conform to the individual being analyzed. Reconstructions on the other hand are based solely on the individual in question and attempt to determine the exact value for that individual. Although approximations use averages, they do not all end up looking the same and seem to be especially prevalent with computer generated models due to the comparative ease of averaging using computer technology. Approximations and reconstructions are tied to the anthropometrical and anatomical methods respectively (Lee et al. 2011). However, in spite of all of the datasets and individual characteristics that can be determined from the deceased, there is still extrapolation that must take place. There are many aspects of facial tissue that cannot be determined from a skull alone. These include, but are not limited to, skin color, skin texture, amount of fat, eye and hair color, and the size and shape of the lips and ears (Lee et al. 2011). It is especially important to note any characteristics that are unique to the individual in question that can be determined through examination of the remains to produce a reconstruction that is as representative of the person as possible and therefore more likely to be recognized. This seems to be best achieved through a combination of computer-generated results and careful assessment and analysis by a skilled analyst, which can be further improved upon with contribution from an artist that can add "believability" to the model (Lee et al. 2011: 369).

Automated computer-generated 3D facial reconstructions have increased in popularity due to the "subjective, time consuming, and overly…artistic" (Lee et al. 2011: 369) nature of their manual counterparts. Computer rendered models can either be semi or fully automated and are generally approached in two ways, by using a "sparse approach" or a "dense approach" (Lee et al. 2011: 369). The sparse approach uses only specific landmarks to build the face template, while the dense approach builds a template based off of a CT scan of all of the features of the skull and the face. Both approaches then use the process of "warping," whereby a closely matching skull from a reference database is molded to fit the shape of the unknown skull one is analyzing. This calculated deviation from the reference skull is then used to calculate how much the face shape of the skull in question should deviate from the known face shape of the reference skull. While quicker and more objective, the downside of using these reference templates in computer-generated models is that it can lead to a more generalized model lacking in individual character that is partial toward the template face that is used. Not very many reports have been provided on the accuracy and reliability of automated computer-generated FFRs. Notably, though, no computer-generated system has proved more reliable than similar manual approaches (Lee et al. 2011). New approaches are currently underway, such as the method that Guyomarc'h et al. (2014) suggest, Anthropological Facial Approximation in Three Dimensions. Through the use of CT scans and a consideration of factors such as "age, sex, corpulence, and craniometrics" (Guyomarc'h et al. 2014: 1) facial approximations were produced using 100 soft tissue landmarks. Samples of 500 faces were used to compare geometric morphometrics and statistical models. Although the method produces a face without texture that has to be artistically enhanced before being released, this study suggests that it is highly accurate, with an average accuracy in this examination of 4mm for the whole face.

Haptic feedback to produce a "virtual sculpture" is another method that uses a computer-generated approach This modeling system imitates manual methods by importing the unknown skull and using the surface of that particular skull to determine a profile and to extrapolate facial features. The haptic feedback is advantageous because it produces layers of muscle and skin that are distinct and can be viewed separately, an improvement over the manual method (Lee et al. 2011). Part of the appeal of this approach is "reproducibility, time conservation, and little or no damage to the original specimen (Lee et al. 2011: 372). However, as with manual methods, analysts require instruction and practice to master the system, along with artistic competence.

DISCUSSION

Studies into FFR vary as to how accurate it is, though it would appear that experience and the amount of data supplied by the skull plays a significant role (Lee et al. 2011). **Absolute accuracy, however, is not the end goal, but merely serves as an aid to recognition.** Resemblance ratings are often used in lieu of recognition tests, though these can be misleading (Quatrehomme et al. 2007). Stephan and Arthur (2006) showed through the evaluation of two CFRs for the same skull that although resemblance ratings can be similar, the ability to actually recognize the face can be vastly different. In light of the fact that it is positive identification based off of recognition that is sought in forensic cases, resemblance ratings would appear to be a poor assessor. Additionally, accuracy assessments often have people attempting to recognize unfamiliar faces. This is significantly more difficult to do than recognizing a familiar one, possibly skewing the results even in the case of recognition tests. A study of 25 CFRs conducted by Quatrehomme et al. (2007) to explore this concern over accuracy found that results improved when a trained specialist produced the CFR. They suggest that a detailed analysis of the skull and face and an X-ray analysis should be conducted before beginning a CFR. The study also concluded that having the angle of the reconstruction mimic the picture was important in facilitating recognition. Cattaneo (2007), however, seems skeptical of claims about the accuracy of CFR, which she asserts is "preferably referred to as facial approximation." She encourages scientific efforts to improve the accuracy of various aspects, though also notes that what prompts recognition is little understood and that collaboration with the cognitive sciences should be sought to further explore this relationship. Determining what initiates recognition would be helpful in refining techniques used to produce models that would help in achieving this goal.

The amount of accuracy present is in large part influenced by the soft tissue thickness on the model. Currently, all methods estimate the face shape based off of average tissue depth (Lee et al. 2011). Therefore, deriving an accurate database of soft tissue depth is critical. One method employed is the needle puncture practice used on cadavers. While easy and cheap, this method has been criticized as underestimating depth due to the way the muscle and skin changes after death (Lee et al. 2011). There is debate as to whether this criticism is valid however, and Stephan et al. (2013) are apt to point out that living tissue is subject to distortion based upon the posture that the person adopts. CT scanning and MRI have also been used, but are expensive and can also be misleading due to the way the tissue is pulled by gravity while laying down. Ultrasonic scanning captures the soft tissue depth in a sitting position, addressing some of the issues mentioned above, but has the additional problems of being difficult to measure and reproduce due to the imperceptibility of the bone underlying the tissue (Lee et al. 2011). Currently, research is focused on the development of cone-beam CT (CBCT) scanning and holographic topometry, which could lead to the compilation of more accurate results (Lee et al. 2011). Hwang et al. (2012) studied the reproducibility of CBCT through the analysis of four observers measuring the soft tissue thickness at 31 landmarks on 20 subjects. They found that thickness was measured with high reproducibility, though the study also suggested that certain landmarks should be redefined.

Concerns present in all of the methods available for soft tissue analysis are that landmarks on the skull do not necessarily coincide with landmarks on the flesh and that defined standards for landmarks and definitions do not exist (Lee et al. 2011). Stephan et al. (2013) also note imprecision in the measurement protocols. Additionally, there is a poverty of soft tissue data available for most ethnic groups. There has been a limited scope of analysis focused on White Europeans and Black Africans in countries where FFR is prevalent (Lee et al. 2011). This, however, may not present a significant concern, as some studies have shown that creating subcategories within adult datasets is unnecessary as the discrepancy between groups is minor. Using the data from the appropriate ethnic groups may provide more accuracy, but recognizable results are still produced in its absence. That being said, sex may still be a useful distinction to make, as other researchers have shown that certain tissues are significantly different between males and females. It is also recommended to take age into consideration insofar as separating children, young adults, and adults. Stephan et al. (2013) are particularly concerned with the use of the arithmetic mean for the computation of soft tissue depth. This is due to the fact that the mean will invariably be skewed by individuals with very thick tissue. Body mass index (BMI) is something that will significantly affect tissue depth to the point where using the wrong BMI may produce a reconstruction that is not easily recognized. One way to rectify that is to produce multiple reconstructions based off of a range of BMI values (Lee et al. 2011). Stephan et al. (2013), however, advocate for the release of one initial reconstruction and then, only upon failure of the first image to initiate recognition, release a second photo with a larger tissue thickness. This, they contend, will save time, effort, and money in the case that the first image is recognized and the second need never be produced, or will serve to double media exposure upon release of the second image.

Another crucial aspect of creating an accurate reconstruction is in the attribution of the characteristics of facial features, namely the eyes, nose, mouth, and ears. Efforts have been made to produce standards that can be used for feature prediction. Research has shown that there exists a "significant correlation between eyeball protrusion and orbital depth" for instance (Lee et al. 2011: 379). The nose has proved more difficult to reliably assess, with the best method proving to be the two-tangent method first proposed in 1955 (Lee et al. 2011). The width and thickness of the mouth have been demonstrated to be positively correlated to the distance between the irises or an intercanine width and teeth height respectively (Lee et al. 2011). **Despite the many ways to predict the specific characteristics of facial features, a great deal of the accuracy is still attributed to the discretion of a skilled analyst.**

Researchers contend that reasonably accurate soft tissue features can be determined from a skull. Tilotta et al. (2010) have taken a slightly different approach in looking at features through a localized, as opposed to a global, lens. They focused exclusively on the nose and chin of their subjects and used a continuous representation, which was able to take in all of the minor details overlooked by a landmarks approach. Although their population was limited to females within the same age range, their results were very promising, surpassing the results obtained through global reconstructions with the average error equaling less than 1 mm. More research into this method is certainly warranted and an analysis of the effects of different factors, such as age and gender, would help solidify the validity of this method.

Another means of applying CFR is in the practice of superimposition. In this case one has an antemortem photo of the person and is trying to determine whether the face in the photo matches an unidentified skull. Unlike other means of FFR, superimposition is seen as an acceptable method for actually confirming identity. To use this method, landmarks are matched up and then qualitatively assessed to determine the ranking from a strong match, rated 1, to excluded, a rating of 4. One downside is that the method is highly dependent on matching the orientation of the skull and the face in the photo (Lee et al. 2011). Sakuma et al. (2010) showed that renderings obtained from a mobile 3D-CT scanner accurately reflected the morphology of the skull they were scanning and provide an excellent image that can then be superimposed for the purposes of identification. They were using scanners that were about 20 years old and that scanned in slices of about 2mm thick, about four times thicker than scanners available today. Regardless, the fact that they were able to produce reliable images using this technology and the fact that it is mobile signifies that it may be something that would prove useful and practical for field application. Garrido et al. (2012) propose combining an automated computer-generated CFR with a large database of photos that are automatically superimposed and analyzed in order to quicken and automate the identification process. This would also serve to make superimposition applicable in cases where one does not already have a good idea of who the deceased person is. The results appear promising, though the databases used were small. Some false positives were obtained in their study, an occurrence that may necessitate a skilled analyst to verify results.

CONCLUSION

Overall, FFR must be recognized as a delicate mixture of art and science, where general rules do apply but the ultimate depiction is dependent upon the discernment of the analyst and an application of a certain amount of artistry. The objective calculations and measurements should be supplemented by subjective interpretation by someone who has a certain amount of forensic experience and artistic skill. Certainly in the case of CFR in particular, many of the details and factors cannot be known for sure and are based on conjecture. One way in which to address this issue might be to provide several possible variations to chose from in the hopes that one of them will spark recognition (Quatrehomme et al. 2007). Although limited by questions of accuracy and riddled with complications, FFR remains an essential tool in identifying unknown persons in the absence of other means. Computers have advanced the practice tremendously, providing a more streamlined, accessible, and cost effective method to produce FFRs. One way to improve computer-generated models would be to produce ample datasets for use as references. Soft tissue depth in particular is an area where more data and the application of new methods would prove beneficial. More research into the determination of facial features based off of skull measurements is warranted as well. Exciting new innovations utilizing computers are currently underway, though more analysis using larger sample sizes and more diverse population pool is needed before many of these proposed techniques could be implemented on a wider scale. Certainly, as databases and computer programs improve, it is anticipated that costs and other investments will decrease and the ability to implement FFR, perhaps even in the field, will increase proportionally. As computer generated models become quicker and easier to use, the need to interpret and refine the reconstruction with a critical eye must not be overlooked.

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