A Review on the Detection of Skull by Forensic Analysis

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Abstract

Skull identification is extremely important in today's society, especially in medico-legal circumstances. As a result, all technological advancements in this field can contribute to the growing need for precise and robust tools that allow for the establishment and verification of human identity. Identification of skulls when all other proof and evidence are destroyed or limited requires the usage of facial reconstruction for the forensic team. The facial graphics serve as an emphasis for public attention to specifics of the case to generate additional investigative guidance. The physical appearance of the face is at its best a significant cause for the purposeful identification and communication to the investigating authorities of knowledge. Human identification is one of the most remarkable approaches in the field of forensic medicine. The identification mission is performed in the field of forensic anthropology by the examination of the skeletal remains. Anthropologists have been paying attention to improve the techniques that allow accurate and clearer identification. Therefore, forensic identification has become an active field of study and skull detection has emerged as a vital source for identification. Skull identification is attracted and applied in many forensic areas. This review articleis a summation of the various facial reconstruction approaches and their role in forensic science to identify the individual.

Keywords: *Craniofacial superimposition (CFS), Forensic Identification, Skull Detection, Facial Approximation, Forensic Anthropological Analysis*

Introduction

Anthropologists advocated forensic application in the early days. In the early 1990s, computerized face alignment approaches were initiated. The term "Facial Approximation" was used as a synonym for "Facial Reconstruction."The morphological and anatomical correlations of the skull and face have been primarily studied in various fields of research such as maxillofacial and plastic surgeries, genetics, and prominently in the craniofacial reconstruction area. Therefore, several decades of consistent landmarks were identified inboth the skull (craniometric) and face (cephalometric). Numerous studies were conducted using data from different populations and techniques that measured the soft tissue depth between the relevant landmarks.

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Egyptians implemented several measures to preserve many details of their ancestors[1]. In the late 19th century, the similarity of the surface soft tissues of the face and the skull's underlying ossic structure started to be studied by anatomists and anthropologists, and forensic odontologists. Modern times have seen the emergence of facial reconstruction to assist archaeologists in demonstrating the appearance of the early person. Recently, forensic science play a significant role in producing an image from the skull. For hundreds and millions of years, skulls can exist and offer incomparable means of identification[2].Identification will be needed if a skull is unintentionally restored from a backyard, forest, etc. Conventional methods such as dental examination, radiography, DNA analysis, etc, can neither be employed nor have been unsuccessful. Forensicfacial reconstruction can be applied as a major tool to aid in skull identification and to identify the individual[3].

Skeleton-Based Forensic Human Identification

When other technologies fail, forensic facial reconstruction can be used to identify unknown human remains[4]. Numerous techniques areavailable for facial reconstruction, ranging from 2D graphics to 3D models. With the advancement of 3D technology, a fastand cost-effective computerized 3D forensic face reconstruction method has been developed, which reduces the level of errors previously encountered[5]. Forensic facial reconstruction is a combination of scientific methods and artistic skills. It can be used to reconstruct soft tissues on the skull to obtain images of individuals for identification and recognition[6]. Some commentators believe that forensic facial reconstruction is a method of facial approximation.

Various facial patterns can be created from the same skull. However, other researchers believe that each skull can only produce one face, so it is certain that a person uses the term "face reconstruction"[7]. Forensic facial reconstruction is used in both forensic science and archaeology. In forensic science, this method is used to identify individuals who are unsuccessful in conventional/common identification methods. In archaeology, it is used to identify the faces of people in the past, bone remains, embalmed bodies, etc.[8]. A person's face has several different types of exclusive features, so it is crucial in recognizing a person. Whena body is found, a facial photograph is taken. Sometimes the photo is digitally processed to make it suitable for witness identification or newspaper publishing that eventually leads to the identification of the body. The victim's family, friends/acquaintances are visually identified, but not found to identify the only body part of identification is the face. Sometimes, due to animal damage, physical attacks, or environmental factors, the face of the deceased cannot be identified because the face cannot be recognized. In cases where little or no other evidence is available, forensic facial reconstruction is another method in the identification process[9]. Reconstruction techniques can be divided into two types: two-dimensional (2D) and three-dimensional (3D) techniques[10]. They can be performed manually or analyse specific software (computerized).The 3D manual methods used in forensic facial reconstruction are anatomical (Russia), anthropometric (US) and Manchester combined (UK) methods developed by Gerasimov, Krogman, and Neave, respectively[11,12].

Forensic Anthropological Analysis

The active scientific identification of human remains recovered in the context of forensic medicine is the main goal of forensic anthropological analysis.Many aspects of anthropological activities, including search and recovery, identification of species, the estimation of gender, age of death, body size, time of death, detection of ancestry, and unique anatomical features, can be used to narrow the search for missing persons[13]. In the end, forensic anthropologists will contribute to active scientific identification directly or through a large amount of supplementary information provided. Direct contributions such as evaluating various anatomical features and compare them with pre-existing information are revealed through radiography and related images. The recognition types include provisional, environmental, presumptive, and positive types[14]. The first three types listed indicate that actual identities cannot be excluded, so these remains or other inspection evidence represent specific individuals. Research and case studies have shown that facial recognition is unreliable, especially when performing advanced decomposition[15,16].

Positive recognition represents a higher level of probability and involves a two-step process. First, it is necessary to discover the anatomical features shared between the examined evidence and the known prior information about the specific individual. Second, the analyst should determine that the compared features are sufficiently unique to be able to be identified. Besides, any discrepancies should be recorded and explained satisfactorily. Recognition errors are divided into two categories:[1] the difference is evidence of exclusion representing other factors;[2] the uniqueness is not fully considered when presenting shared features to support the recognition[17].

There is a particular need for contributing forensic anthropologists to identification, and especially in the analysis of extensive decomposition and skeleton human remains. Experimental research reported by Sauerwein et al.[18] pointed out that the process of decomposition can quickly destroy many indicators commonly used for identification, although the speed of destruction depends on many variables. In their study, fingerprints survived for 4 days after death at high temperature and survived for more than 50 days at low temperature.The time for iris recognition after death is 2 to 34 days, depending on the variable[18] .

Accurate recovering, documenting, and evaluating the biological characteristics of human remains are important factors leading to active identification[19]. To focus on the appropriate missing persons for identification, investigators must have meaningful information about the age of death, gender, ancestry, body size, and time since death[20].All evidence must be retracted together with detailed documents. It should be restored and analysed in a way that meets the requirements of legal procedures[21.]

The unique function required by identification can be provided through surgical procedures, especially those that remain in bone tissue[22]. For example, Hogge et al. detected postoperative defects associated with unilateral lambdoid combined resection, the body can be actively identified. The remains were identified as people who underwent neurosurgery for this rare congenital abnormality[23]. Many orthopaedic devices with human remains provide information to the manufacturer. According to current laws, certain devices contain digital information that can be traced back to specific operating rooms or even individual patients[24].

Forensic anthropologists discovered these inorganic materials in their case. For example, Bennett et al.,[25]reported the identification of burned wreckage recovered from automobiles through inspections of internal fixtures. Radiographic examination of the recovered residue revealed that many wires were identified as osteo stimulators. The serial number is not recorded, but it is a material related to the documented bone stimulator used to treat a patient's back injury to stimulate bone production during surgery.

Dental characteristics often provide the information needed for identification[26]. Forensic odontologists explain dental restorations and other characteristics related to the dental practice. However, anthropologists and dentists have common interests and expertise in tooth morphology, which can provide evidence for positive scientific identification. Useful features for identification include the number of teeth present, missing front teeth, the pattern of tooth displacement, and pattern of abnormal rotation[26].Typically, comparative antemortem data are available via radiographs and related imaging. Murphy et al.recorded that 60 percent of the scientific identification in the St. Louis region of the United States resulted from radiographic evaluation in a 15-monthfrom April 1978 to July 1979. Most of the specific data used in positive scientific identification were provided by anatomical variants, disease alteration, and post-operative features[27]. As noted by Fitzpatrick et al., to promote contrast, positioning, magnification, beam centring, angulation, and bone orientation techniques should be used properly[28].

Craniofacial Superimposition

A forensic technique for detectingthe skull known as craniofacial superposition (CFS)is used to investigate the anatomical and morphological connection between a skull and the face[29]. It includes overlaying the skull with a varying number of facial images. Most people now have images with identifiable faces and hence, this technique plays a significant role in skull detection.

Photographic superimposition (introduced in the mid-1930s), video superimposition(extensively applied since 1970s), and computer-aided superimposition (developed in the late1980s) are the three stages of craniofacial superimposition[30]. From the viewpoint of recognition approaches, Yoshino et al. divided computer aided CFS into two groups. The firstapproach is to digitize the skull and face pictures[31]. Image processing tools were employedto compare the two images morphologically. The second step is to perform a morphometrictest to assess the match between the skull and facial images. The above contributions weremade before the last decade's image-processing boom[32]. Damas et al. analyzed the currentapproaches contemplating a computing-based classification standard and are furtherconcerned with the use of computers at various stages of CFS processing. To properlycharacterize any CFS method, and the authors have specified various stages involved in thecraniofacial process[33]. "These stages include face enhancement and skull modelling, skull-face overlay, and decision making." The first stage entails creating a digital model of theskull and improving the image of the face. Instead of creating a 3D model of the skull, theoldest and most modern systems still obtain a photograph and a sequence of video shots of it.

Regarding face images, most modern systems employ a 2D digital image. This stagedemands image-processing techniques to improve the quality of the face image that wasgiven when an individual is missing. The skull-face overlay is the second level. It involvesfinding the best overlay of a 2D image of the skull/face or a 3D model of the skull/faceobtained during the first stage. The final and third stage of CFS are decision making. Basedon the skull-face overlay attained, the identification decision is made by examining theframework and soft-tissue thickness at different anthropometric landmarks, as well asanatomical details to determine the spatial relationships of the skull to face sections[34].

Forensic identification and technology involve two (or more) separate images/models/data and explore similar and compatible patterns. The data applied for comparison are the same 'object' in methods such as DNA, fingerprints, facial recognition, dental identity; for example, two DNA stringcomparison, fingerprint images, photographs of the face, and teeth x-rays. This is not the case for CFS, a human identification technique in which photographs of the face and skull are contrasted to determine the identity of a given subject. The entire CFS method can be divided into 3 subsequent steps: 1) The acquirement and processing, e.g., skull andante-Morten (AM) face images and somatometric marks on both sides; 2) skull-face overlay (SFO) to perform thepotential overlay for the skull and a single AM picture of the person that is missing. This is done in reiterative aspect with each photograph, attain different overlays; and3) decision-making aimed at deciding the degree of match support, based on SFOs obtained in the earlier step[35].The technique of CFS identification has tremendous potential for use today becausemany people have photos (AM), where their faces are visible. A bone that deteriorates with the impact of fire, humidity, high or low temperatures, and distant future; is the counterpart skull.

Craniofacial superimposethe characteristics of the recovered skull with the antemortem picture of the missing person who may be represented by the remains. This technique can be used when it has not been positively identified by molecular analysis, dental reconstruction comparison, or anthropological radiological evaluation[36]. Usually, this method can be used when a complete skull or crania can be used for comparison, but it is even tried using fragmentary evidence[37]. Once a clear image of the compare crania that can be used to compare the recovery is found, forensic anthropologists must spend some time adjusting the orientation of the skull, usually using Q-tips as placement markers so that the images can be placed correctly on each other. Comparison techniques have become more complex and complicated, which mainly allow rejection rather than active scientific identification. Images are taken from police records, surveillance, or directly from relatives of possible individuals. The quality of the image corresponds to the accuracy of the exclusion process[38].

Dorionpointed out that if used improperly, photographic superimposition can lead to recognition errors[39]. He noted that this technology should not be used as the only way of identification. The research reported by Austin et al.supported this expression of concern. They compared the front and side views of the three skulls with pictures of ninety-eight people. They reported a positive comparison with 9. 6% and 8 of the side view and 5% of the front view. However, the consistency percentage is reduced to zero and 6% when using both front and side views[39].

Skull/photo video superimposition

Kahana defined this approach for the first time. This technique is effective if photographs of one or more probable progeny are available. On adjustable support is attached the skull to be marked. While the antemortem photograph is placed at right angles with a high-resolution video camera, the skull is aligned with a 2nd video camera. The lens centre position should be on an equal level as the photograph's horizontal centre. Both the cameras process the two images in a vision mixer to achieve horizontal, vertical, super-imposed, and negative stimulus.In the case of the presence of teeth, the enlargement can be done until the teeth of the antemortem photograph intersect the teeth exactly in the super-imposed picture. If there are no teeth present, it is important to estimate the vertical height of the skull photograph[40].

Computerized 3D facial reconstruction

This approach uses computer programs to convert 3D skull images scanned with a laser into faces. Even though the findings are reproducible rather than sculpted reconstructions, certain subjectivity will continue to be added to the digitized skull matrix by a composite face image[41]. A list of head models with their age, race, nutrition status, and other personal characters either skulls, faces, or soft tissue depths is essential. Remains of the dead are checked and used to pick the suitable skull and soft tissue models by the medical team and the evidence given.The skull is mounted in an upholstered head holder. The length varies as the skull rotates on the platform and with each latitude, the radius is determined. A wireframe with 256 x 256 radii must be converted to produce the basis of facial reconstruction using measurements of tissue depth. The facial characteristics unforeseen by the skull contour (nose, eyes, mouth) ought to be applied to the wireframe face to create a wire colour and texture.

Facial Approximation Facial approximation means trying to generate the individual's facial similarity from the skull. Although this method cannot be used directly foridentification, the resulting images can be used to communicate with the public to collect information about missing persons who may be represented by recovered remains.Major advances in methodology include new soft tissue in-depth population data, new guidelines for evaluating facial features, and innovative computerized methods. Although several studies on the depth of soft tissues have been published, Stephen et al., notethat the data showthat there is no clear secular trend, and the value is increasing. They recommend that existing data be aggregated for use by adults. They also found similar results in sub-adult data and suggested that the data be divided into two age groups (0-11 years and 12-18 years old)[43].

Although facial approximation is reported to be useful in collecting information related to recognition, Stephen and his team still expressed concern about the relative similarity level. Henneberg et al., published an experimental method to judge the recognition value and question the value for recognition[44].With the enhancement of information about the relationship between hard and soft facial tissues and more sophisticated computer technology, facial approximation technology is constantly improving.Despite these advances, the facial approximation does not represent a positive scientific identification method. However, the generated image proves to be helpful and assist thepublic in disseminating the remains of someone with specific visual and demographic characteristics.

Unique Cranial Evidence

Although other methods have led to preliminary identification, the unique features present on the skeleton allow for more definitive classification. Skulls provide anthropological analysis with unique information required for active scientific identification. There are two main reasons: (1) Historically, many studies have focused on skulls, revealing huge differences in many anatomical features; (2) Front radiographs and related images are available for the headand contain multiple views[45]. As described by Smith et al., skull images can present many unique features useful for recognition. In their case report, they pointed out that the detection of the frontal sinus, sphenoid sinus, ethmoid sinus mastoid air sacs, sagittal sutures, and internal protrusions of the occipital bone by computed tomography (CT) can be used for positive scientific identification.Culbert and his teamprovided extensive information on the use of the nasal cavity and mastoid system to identify deceased elderly patients in India[46]. Sperry et al.offeredfurther examples of detection using the frontal sinus and intracranial nervous system[47]. Rogers et al.also adopted a cranial suture pattern, claiming that the path they followed for this activity fulfilled the legal requirements of the United States and Canada at that time[48].

Frontal Sinus Variation

While several features of the human skull show great differences and can be used for individual identification, many researchers have focused their attention on the frontal sinus. The sinus is located above the supraorbital bulge, higher than the nostrils, and shows significant changes, ranging from the smallest presence to the formation of large labia intussusception. Reflecting the environmental and developmental influence, even the same twins show morphological differences in the frontal sinus expression.Schuller specifiedthe significance of the frontal sinus for positive scientific identification. Later, for comparative purposes[49], Ashersonet al.established a method of using outlines of sinus expression[50]. Ubelakerand colleagues in 1984, explainedhow frontal sinus comparison, combined with sella turcica morphology and other cranial characteristics, was used in a murder trial for positive scientific identification. Radiographs of cranial specimens at the Smithsonian Institution were also used by the team of scientists to show population variation of the frontal sinus[51]. Angyalet al.presented cases from Hungary showing how frontal sinus radiography and features were performed.Though trends were recognized at the earliest, comparative studies on the frontal sinus morphology, metrical, and more complex statistical treatments were also implemented[52]. Kirk et al. introduced a metric approach documenting the vertical and horizontal sinus expression. They declared the corresponding measurements to be less than 5 mm apart. The authors alsodocumented using pattern recognition and metric analysis for positive scientific detection in their retrospective analyses of thirty-nine cases in Ontario's Chief Coroner's Office.Furthermore, it was noted that the probability of recognition using this function was not influenced by adult age, sex, and cause of death[53].Christensen and his team used Elliptic Fourier analysis to determine the individualization of the frontal sinus in the light of the increasing demands of the legal arena for increased quantifying and likelihood assessment of the features of identity. As indicated in the earlier publication, this application indicates a consistent methodology to human positive scientific identification by evaluation of the frontal sinus morphology[54].

Post Cranial Remains

There are also ample anatomical features used for the identification of skeletal remains from the post-cranial skeleton, where subsequent antemortem radiographs can be sited. Animal scavenging, and other post-mortem factors may influence post-cranial bones. Trabecular general bone patternsand ossic contours, abnormalities, and radiodensities may provide specific identifying features.Clavicle, thorax area, hand and wrist, patella, and foot defects were the key points for post-cranial detection approaches[55]. Unconventional medical conditions are important because radiographs with skeletal anatomical information can be connected to them.

The Anthropometric American method/ tissue depth method

This technique was first introduced by Krogman in 1946. This method uses data from soft tissue depth collected by employing needles, X-rays, or ultra-sonic analysis. Muscles of the face are adequately recorded anatomically. This is not a favoured approach now a few days because it needs highly skilled professionals[56].

Conclusion

Forensic analysis in skull detection and facial reconstructions is highly beneficial and an alternative approach in the identification process in generating images where no other evidence is offered and accessible. Nevertheless, the options taken by the team of investigators such as forensic anthropologists, forensic dentists are centred on the method of facial reconstruction. The facial reconstruction aided by computers has many advantages compared with conventional approaches. It simplifies the process and significantly reduces the time taken to propose a face model. Various models can be shifted in many ways improving the likelihood of individual recognition. Although the techniques employed for skull detection and facial reconstruction are dubious, these techniques also demonstrate to be a significant tool for the team of forensic analysts in detection when the source of substantiation is not available.

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