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An Introduction to Facial Reconstruction

SUMMARY

Late in the 19th century, anatomists, anthropologists and forensic odontologists began to study the correlation between the surface soft tissues of the face and the underlying bony structure of the skull. All the techniques of facial reconstruction rely upon this hypothesized relationship. The ultimate aim of all facial reconstructions for forensic purposes is to recreate an in vivo countenance of an individual, normally when no other identifying evidence is available, bearing a sufficient visual resemblance to the missing or deceased person, so that it may contribute to their recognition and lead to identification via the discovery of new evidence.

This article refers to the techniques of facial reconstruction, including plaster skull reconstruction, computerized reconstruction and video superimposition. A description of the previous methods is made, followed by a discussion about their application in archaeology and criminology, their reliability and future progress.

Keywords: Human Identification; Plaster Scalp Reconstruction; Skull/Photo Video Superimposition; Computerized 3D Facial Reconstruction

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Introduction

Facial reconstruction is a technique used to aid in building an "alive" face out of skeletal remains. The reproduction of facial features is based upon the soft tissue thicknesses over the underlying bony structure of the skull[1,2]. The skull itself is the armature upon an objective muscle-by-muscle and feature-by-feature approach of how a person looked like is made. How important bones to all living creatures are, has been marked out since the late second century AD by the great Roman doctor Galen, who wrote: "As poles to tents and walls to houses, so are bones to all living creatures, for other features naturally take their form from them and change with them"[3,4].

In modern times, facial reconstruction has been developed in order to help archaeologists in their attempts to demonstrate the appearance of the early man. It has also been used to identify skeletal remains thought to be those of specific well-known persons, such as the skull of the German poet and playwright Schiller (1795-1805), the skull of the Italian Renaissance painter Raphael and the skulls of Ivan the Terrible, Phillip II (father of Alexander the Great) and King Midas. Last but not least is the use of facial reconstruction in forensic science in order to produce an image from a skull, which offers a sufficient likeness of the living individual. The image will facilitate identification of skeletal remains by stimulating memories of relatives, friends or witnesses. The image being generated can be presented to public *via* mass media and posters. We should understand that the reconstruction itself does not identify the subject being reconstructed, but it becomes the last solution when it results in remembering a forgotten detail[4-7].

History

Facial reconstruction - making faces - is an old story. In ancient Egypt, great efforts were made by scientists to preserve as many details of their ancestors as they could. In 1953, the excavations made in Jericho brought to light the first examples of facial reconstruction. Plaster skulls with shells into eye-sockets to simulate eyes were found under the floor of houses aged about 7500-5500 BC (the Pre-Pottery Neolithic B Period). Another example represents the death masks, which have been used in many cultures and have much in common with a sculpture built from the outside inwards. According to Pliny, Lysistratos was the first taking plaster casts direct from face as bases for portrait sculpture in the late fourth century BC[4].

The first scientific reconstruction was brought off in 1895 by the anatomist His[8]. He was the first person who collected soft tissue thickness measurements so as to be able to identify the supposed remains of Johan Sebastian Bach, whose grave had been discovered in Leipzig in 1894. His effort was confirmed in the mid 1920's by a complicated system developed by the British biometric school of artists in London. The anatomist Kollman and the sculptor Buchly used his measurements and combined them with theirs[9].

Meanwhile, in 1946, the American anatomist Krogmann formulated 5 general principles to standardize methodology in reproducing the unpredictable soft tissues of the facial features, which defined the relation of the eyeball to the orbit, the shape of the tip of the nose, the location of the ear, the width of the mouth, and the ear length[10,11]. In 1981, Caldwell assured the value of 3-dimensional reconstructions through a questionnaire. The last 20 years, Professor Galina Lebedinskaya, former pupil of Gerasimov, has been gathering data from faces of different ethnic groups, such as Koreans, Buryats, Kazakhs, Bashkirs, Uzbeks, Armenians, Abkhazians, Russians and Lithuanians, using the ultra-sonic measuring technique of flesh thicknesses on living people. In early 1980's, new soft thicknesses data for male and female Caucasians were published in 1984 by Professor Richard Helmer in Germany[4,5,12-15].

Michail Gerasimov

The title of the father of the technique of facial reconstruction deserves to be awarded to the Russian palaeontologist, Professor Michail Gerasimov. In 1924, he developed the "Russian method" in which the development of the musculature of the skull and neck is regarded as being of fundamental importance. That's why he created a repetitive system of measurements of thicknesses of soft tissues of the heads. Eventually, sufficient reliable data had been assembled in order for him to attempt a reconstruction. Gerasimov reconstructed over 200 heads of our prehistoric ancestors and worked on the faces of the earliest known fossil men: Neanderthaloid and Pithecanthropus. As he was perfecting his work, he was awarded the unique degree of Doctor of Facial Science. He also had the opportunity to exercise his skills in the solution of a murder case and afterwards he managed to complete his celebrated reconstruction of Tamerlane's, the Great head. In 1950, he founded the Laboratory for Plastic Reconstruction at the Ethnographical Institute of USSR Academy of Sciences in Moscow, called nowadays Laboratory of Anthropological Reconstruction at the Institute of Ethnography and Anthropology of the Russian Academy of Sciences[4,16-18].

Richard Neave

A man, therefore, who has been creating miracles for some time is Richard Neave. Neave is a leading medical illustrator of the Department of Anatomy at Manchester's University Medical School. He has been following the footsteps of the Russian Gerasimov in reconstructing the faces of many historical figures and enjoyed great success with the head of Phillip II (given in 2 different aspects, with and without treatment of his eye wound). In collaboration with his colleague at Manchester, Dr John Prag, keeper of Archaeology at the Museum, he reconstructed the King Midas's head. But the very special talent of Richard Neave and his team is used nowadays by the police, in an attempt to put identities to skeletal remains of possible murder victims or unrecognizable victims of natural disasters (Fig. 1)[4,16].

Figure 1. Richard Neave who has built reconstructions of numerous historical figures (King Philip II, Father of Alexander the Great, King Midas of Phrygia, etc). His forensic work has assisted police forces in many occasions throughout the UK to give names to previously unidentifiable bodies.

In 1990, he enjoyed remarkable success in the case of Karen Price. Karen Price, a 16-year-old teenager, was found 10 years after her murder in the back yard of a house, which was being renovated. Her dead body was tied in a carpet with electrical flex. When the forensic experts examined the remains, they found out that rotting particle of clothing still draped round some of the bones, blonde curls were visible around the skull and a pair of gilt earrings was found nearby. The remains of her clothing helped to assure the chronology of her death and many clues about her age and origin came from the examination of her denture[19]. The great contribution of dentistry in such cases is due to the fact that all physiologic variations, pathoses, and the effects of dental therapy may be recorded in the hard tissues of the remaining dentition throughout life, testifying the key in enabling identification of the dead[20]. When Neave was conducted, he viewed the task of recreating "Miss X" as a great forensic challenge. He received the skull, which was undamaged, on December 18 and set to work. After 2 days, he was more than satisfied with what he had in front of him. On January 8 1990, the outcome of the reconstruction was evaluated and 48 hours after the nationwide appeals went out, the girl was identified. Her killers were found and jailed for life. The procedure which Neave followed to carry out the reconstruction was based on "building" the face muscle-by-muscle, using measurements on muscle depth and skin type based on figures of real people (Fig. 2)[5,19].

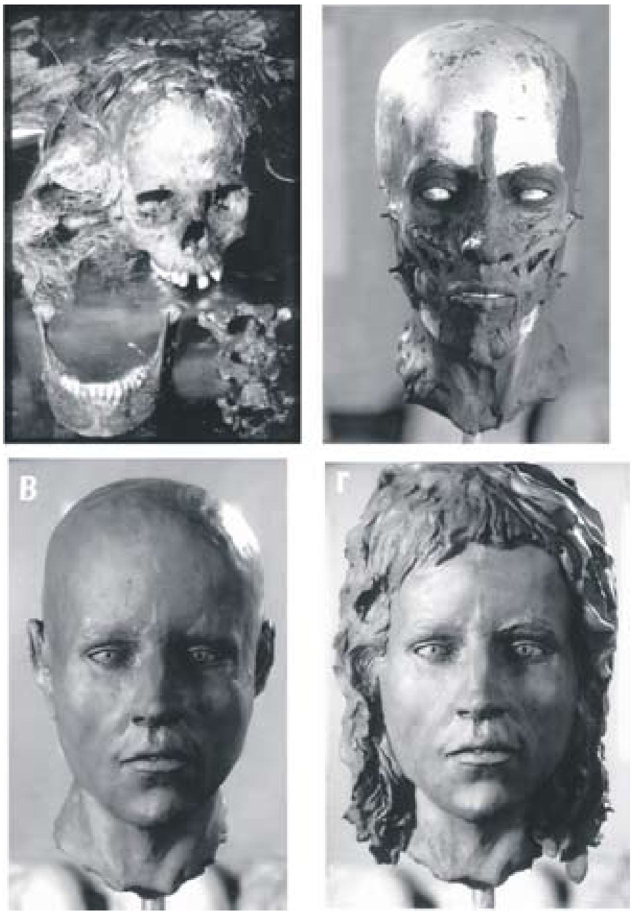

Figure 2. The skull of Karen Price. The model of the skull begins to take shape by R. Neave with wooden skewers inserted to determine the correct depth of flesh and skin. The rebuilding of the head was completed in 2 long days (courtesy of Mr R. Neave).

Plaster Scalp Reconstruction

The traditional technique of facial reconstruction is disarmingly simple. Its tools consist of clay modelling tools and a packet of cocktail sticks. It also requires the eyes and hands of an artist and the specialized knowledge of an anatomist.

Method

The process starts with a cast of the skull made in a compound called alginate. It's preferable to cast the cranium and mandible together and fit the false eyes before casting. When the 2 halves of the mould are opened and the alginate peeled away, the replica of the skull is revealed. Then, the position of the skull should be decided[16]. The pegs of 3mm in diameter are fitted to the distance according to the thickness of the soft tissues regarding the age, sex, ethnic group and mainly the appropriate set of measurements. The medial and lateral canthi of the eyes is marked with a copper pin. 1 or 2 pegs project from the nasal aperture.

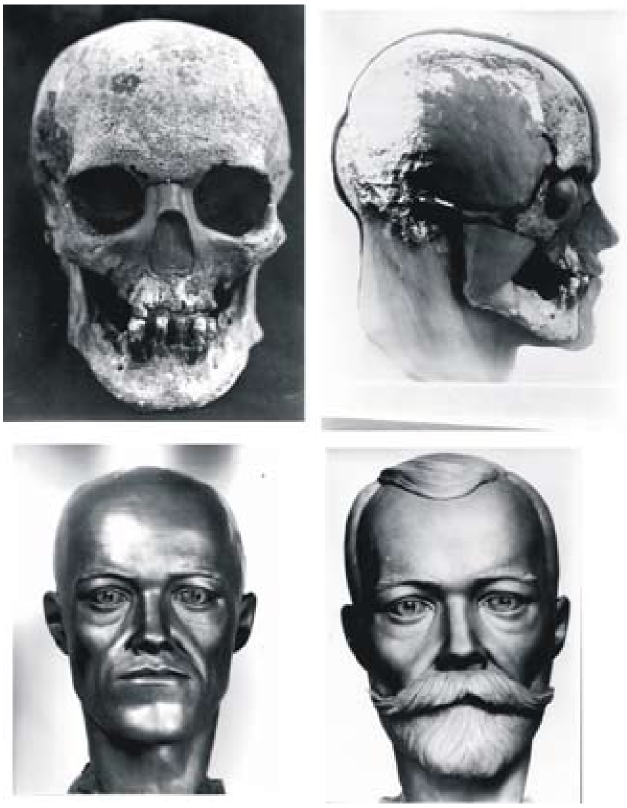

Figure 3. Facial reconstruction of Tsar Nicholas II from the model of the skull (courtesy of Mr S. Nikitin)

The main muscles are built by using cornish pot clay with fine grog from the surface of skull outwards. The position and strength of the muscle insertions should be noted. The progression of muscle building is: temporal muscle, masseter, buccinator, orbicularis oris. The width of the mouth is determined by the outer borders of the canine teeth. When the teeth are missing, the width is same to the distance between the inner borders of the iris. Expression's muscles are added: levator anguli oris, levator labii superioris, zygomaticus major and minor, depressor labii inferioris and the depressor anguli oris. The space between them should be supported to prevent them from collapsing later. The next step is the configuration of general size and shape of the nose. It has been proven that the width of the nasal aperture in the skull is equal to the three-fifth of the overall nose's width. The angle at which the eyes appear to slant can be determined from the skull. Now or even earlier the turn of the neck is to be built. The next stage is to cover up the whole by a layer of clay to simulate the outer layers of subcutaneous tissues and skin. The layer is applied as wide strips. The modelling of the superficial features makes a face look alive. Ears and mouth are the most speculative features. The mouth has to be created in harmony with the rest of the face. Ears are not very important. According to statistics, nobody pays much attention on ears when they try to recognize a suspect. When everything is ready, the surface of the skin is smoothed off (Fig. 3). Any subjective element that could confuse a probable recognition is out of the question. Then reconstructions are usually publicized through the news, media and posters. The average success is considered to be between 50% and 60%[3,4,6,7,20,21].

Reliability

As it has been mentioned, the technique of plaster face reconstruction has a long story. Although many efforts for progress were made, the opponents of the technique tried with their articles to detract all the achievements. Eggeling (1900) claimed that no individual's likeness could be recreated by reconstructing it on the individual's skull and the Czech scientist Suk (1935) that a skeleton offers no clues for any reconstruction that is true to life[4].

Most of the methods are based on the knowledge of facial soft tissue thickness measured at selected anatomic landmarks, as well as knowledge of particular morphologic features. Between 'landmark' sites the depths are interpolated. We must also have in mind that there are many facial variations, particularly according to the nutritional status and the different rates and intensities of ageing[22].

Furthermore, the details of the nose, eye, ear, lips and chin cannot be constructed exactly from the skull and are largely guesswork[23-26]. Secondary characteristics, such as hair, could only be predicted if enough soft tissue remains to help predict these features. Easily predictable features are enhanced and other uncertain remain enfeebled. The shape of the nose could be predicted with only about 60% accuracy and the shape of the tip with only about 40%. Thus, facial reconstruction is a blending of science and art that eventually results in a reproduction of a face that may lead to identification[1,2].

The tissue depth measurements used tend to be those collected from cadavers in the early part of the twentieth century or before. These measurements are biased because they come from small samples, because a dead person's tissues are not the same as those during life and because they take only limited account of the average differences known to occur between people of different age, build and sex, and between the major human diversity aggregates. However, this problem has been solved in recent years with the use of Computed Tomography (CT) scanning and Magnetic Resonance Imaging (MRI) and the creation of large computerized image datasets[27-29].

Skull/Photo Video Superimposition

This method is useful when ante-mortem photographs of 1 or more possible decedents are available (Fig. 4). It entails the careful superimposition of key anatomical landmarks of a facial photograph of the subject upon a photograph of the properly oriented skull[14].

Figure 4. Sergei Nikitin and Sergei Abramov used video superimposition to compare the skull of Tsar Nicholas II with antemortem photographs. The successful superimposition had all the anatomical features matching.

In the identification process, it is critical to establish the correct enlargement factor of the photograph to the skull. This enlargement factor has been based on the linear measurements of fabric on a victim, items within a room in which the photograph portrait was taken or the focal length of the camera lens. The results are more satisfactory when the anterior teeth are clearly visible in the ante-mortem photograph. With a magnification factor established from the anterior teeth, life-size transparencies of the photograph are superimposed with the skull's dental landmarks and subsequently, skeletal and facial features. This method was first described by McKenna[30]. The difficulty in establishing correct enlargements is compound by the need for establishing a correct angulation of the skull to the photograph[31] .

Method

The materials needed in superimposition are a skull and an ante-mortem photograph, supplemented with a skull radiograph. Extraneous soft tissue and foreign matter should be removed from the skull[31].

The skull is mounted on an adjustable support which allows movement in 3 dimensions. A high resolution video camera is aligned at right angles with the ante-mortem photograph. The centre of the lens must be at the same level as the horizontal centre of the photograph. A second video camera, similar to the one above, is aligned with the skull in the same manner as the first camera with the photograph. The 2 images from each camera are processed in a vision mixer, so that a variety of functions (for example, horizontal and vertical wiping, superimposition and negative stimulation) can be performed.

It was mentioned before that if the teeth are present, they are of great help because the enlargement is carried out until the teeth in the ante-mortem photograph exactly overlap the teeth in the superimposed video picture. If the teeth are not present, estimation should be made. This estimation is made by adjusting the vertical height of the photograph to that of the skull. With correct enlargements and skull orientation the anatomical features of both the skull and ante-mortem photographs can be superimposed. Successful superimposition should have all the anatomical features matching. The resulting image is viewed on a monitor and ultimately recorded on a VCR[30-33].

Reliability

The 2 most important factors in superimposition are the enlargement of the ante-mortem photograph and the alignment of the skull with the photograph. Video superimposition will provide quicker and greater flexibility in both these areas than other techniques, if no dental or other landmarks are available in the ante-mortem photograph. If the anterior teeth are present in both specimens, the technique of McKenna is more accurate in establishing correct enlargement.

Inherent in all superimposition procedures are estimations that have to be made of the bony anatomical features on the ante-mortem photograph. The average thicknesses of tissue over bone have been recorded and therefore a calculation can be made of the soft tissue outlines of the skull.

Of great advantage with the video technique is the operator's ability to fade either the skull or the ante-mortem photograph in and out of the video screen. This allows for careful overall assessment of how well the two specimens match[30,31,34]. The value of superimposition is challenged because alignment and enlargement factors are too variable. The possibility that other skulls could fit all the facial features of a photograph could occur and therefore the technique is best used in exclusion rather than identification, and to supply corroborative evidence.

The reliability of the method is also based on the quality and the details of the photographs of the deceased. The most useful photograph is one of a person smiling and showing their teeth. Some hairstyles, headgear or beards may reduce the value of a photograph.

When only a single facial view of the face is available, such as the front view of the face, a skull from someone else -the wrong skull- may seem to fit in about 8-10% of the cases if the skull is complete and unreconstructed. When 2 different views of a face are available, the chance of an error by an experienced person is less than 1%. Close up comparisons of the teeth in skulls and clear photographs can greatly improve reliability.

In Australian courts of law, video superimposition has been accepted as a means of identifying skeletal remains. Its value is highlighted when other methods of identification are not possible or reliable[31,33,34].

Computerized 3D Facial Reconstruction

Facial reconstruction has emerged as an increasingly important tool in forensic pathology and anthropology. In this field, computers for many years were mostly used to store and retrieve images from facial databases. More advanced software proposes to modify the presence of facial hair or features of a given reference facial image using 3-dimensional (3D) digitized image capture, graphical modelling and animation. Those programmes, however, do not treat the problem of reconstruction of a skull[22,23].

Computerized methods for 3D facial reconstruction have been attempted to be established. These methods employ computer programmes to transform laser-scanned 3D skull images into faces. Although the results are more reproducible than sculpted reconstructions, some subjectivity could remain in the 'pegging' of a composite facial image onto the digitized skull matrix. The use of such a standardized image will reduce the influence of the individual shape of each skull, which is, after all, fundamental to the person's appearance. Computerized methods may be repeatable, fast and precise, but as long as they employ the old data, the quality of the reconstruction will be undermined[25-28].

Method

The general goal that the computerized method wants to achieve is to have a model-based reconstruction of the face of a given skull. A database of head models (both skulls and faces) and soft tissue depth with their personal characteristics (age, sex, race, and nutrition status) is required. By using the same relationship between soft tissue depth and the underlying bone -as used in clay reconstruction- the computer generates an image[5].

The remains of the deceased are first unrestricted examined by a team of a forensic pathologist (post-mortem examination), a forensic anthropologist (osteological study), and a radiologist (radiographs and CT scanning). The information provided by the osteological analysis, such as the determination of the sex, age, ethnic identification, metric and dental analysis is utilized by the model in order to choose the appropriate skull and soft tissue templates[5,25,26,35].

The design of a computerized facial reconstruction system is inevitably constrained by the limitations of the available hardware and software. The Cyberware colour laser scanner and the graphic software are used to generate a representation of the scanned skull as a matrix made up of a number of latitudes and longitudes. The skull is positioned in a padded head holder. As the skull rotates on the platform the longitude changes and the 'radius' (the distance from the centre of the platform to the surface of the object nearest to the scanner) is measured for each latitude. Thus a 'wire-frame' of 256×256 radii is constructed. It is this wire-frame matrix of the skull which must be transformed, using tissue depth measurements to generate the foundation of the facial reconstruction. Digitized images of facial features, not predicted by the skull contours (nose, eyes, and mouth), must then be added with separate means to generate a wire-frame face, onto which colour and texture can subsequently be rendered. Finally, the generated image can be presented in several ways. The use of animation facilities allows the display of a moving image in a variety of lighting conditions and a range of versions of the reconstruction. Output can be achieved *via* display to the VDU monitor by printing a 2-dimensional colour image or by downloading a videotape. Alternatively, these images can be available on the Internet to any agency with an appropriate password and suitable software[5,27,28,35].

Much of the difficulty with the 3D technique lies in the database of tissue depths used in the reconstruction. CT and MRI are the latest scanning methods used to precisely detect the margins of bone and soft tissues of various kinds and to make accurate measurements of tissue depths. The existing database of stored scanned images is already very large. Also, with computer imaging techniques skeletal remains could be preserved digitally for immediate and future research [5,36].

Quatrehomme[22] recommends a different method and does not use tissue depth. He chooses from the skull/facial database the most 'similar' head as a reference in such a way that the given and the reference skulls should have the same characteristics. Under the assumption that "if skulls have similar forms, the corresponding faces should have main characteristics in common", he proposes a face of a given skull whose reconstruction is guided by the reference head[22,23].

Reliability

It is important to point out that 3-D imaging does not create new data; creating 3-D images allows for the exploration of more data (already present but not observable), better presentation of the data and directs attention to further investigation[35,37].

Computer assisted facial reconstruction has many benefits compared to the classic method. First, it surely eases the procedure of the reconstruction itself. Of course the procedure is not fully automatic, but the amount of time spent by forensic scientists on proposing a facial model is greatly reduced. The second benefit lies in producing several possible models from a given skull depending on varying parameters[22,23]. Also, it decreases the amount of artistic subjectivity found in various methods and improves the reproducibility of the reconstructions[5,28]. Finally, the 3-dimensional model produced could be moved under several angles, observing all aspects and, thus, increasing the probability of identification of an individual[22,23,35,37]. In some cases, the use of 3D imaging to analyze cranial fractures in skeletal remains of homicide victims serves to refine fracture measurements and detail patterns of trauma. This information can lead even to the conviction of the perpetrator of the homicide[35]. Until recently, there is 1 problem with these ways of displaying faces - these facial surfaces have lacked pigmented "features", making it difficult to be identified[36,37].

However, one cannot help but think that by making use of traditional depth data, the end results are going to suffer from most of the problems of the plastic sculpture technique. Another problem is that the technique is being developed using C++, a programming language which is fairly inaccessible to the non-specialist, and for this reason efforts are made to create a Windows type application. This will enable anyone with an access to a PC to work on this area[5]. One difficulty is potential warping of the image. In some experimental work, 5-10% of warping occurred. As Oliver et al[37] pointed out, warping may be overcome with more research and experimentation of validation methods.

Discussion

Judging from the success of the efforts in actual cases and controlled experiments, there is no doubt that a skilled practitioner of this technique could produce a reasonably accurate portrait of the unknown individual from the skull. The chances of the effort leading to the positive identification of the decedent depends largely upon the extent that the reconstruction is circulated in the news media. It is hoped, of course, that some newspaper readers or television viewers will recognize the reconstruction as that of the person known to be missing and will notify the proper authorities[5,14,20,21,29]. It should be stressed that, alone, facial reconstruction cannot be used for positive identification since the method is inherently inaccurate and many individuals are sufficiently similar in facial features. However, facial reconstructions are means of seeking possible victims or allow the exclusion of a particular individual[5,14,25-28].

To date, the scanty statistics available indicate a success rate of about 10-20%. It is long shot but, especially in homicide cases, it is well worth taking when all other attempts to identify the victim have failed[14].

Several forensic scientists have criticized facial reconstruction for the accuracy of the method and its failing to create exact replicas of an individual. One should have in mind that facial reconstruction will only ever produce images that are a gross approximation. However, it is desirable to minimize the error to the greatest possible degree[1,2,5].

Tyrell et al[5] maintain that very little is actually understood about the nature of the relationships between the hard and soft tissues of the face and that only when these relationships have been explored in much greater detail, might a sufficient level of accuracy be attainable in reproducing the faces of unknown individuals.

Conclusion

In conclusion, facial reconstruction techniques are a major tool in the identification of human remains for both legal and humanitarian reasons. Throughout the years, many scientists supported the method and others criticized it. We must have in mind that facial reconstruction is a combination of science and art based upon well documented anatomical rules. The use of computers and specialized software have created a new era and increased all the abilities of the method.

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