Review

History of facial reconstruction

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Abstract. We briefly describe the history of facial reconstruction in the deceased, starting from the skull. Facial reconstruction has passed through many phases and has been variously motivated, from religion and ancestor worship, through anthropology, to the identification of lost persons for forensic purposes. Renaissance artists used this technique for modelling and teaching. Techniques changed over the centuries but the ultimate goal was to create a convincing likeness of the dead. The two current activities are forensic facial reconstruction and reconstructing the personal appearance of ancient people. (www.actabiomedica.it)

Key words: Reconstructing facial appearance, craniofacial reconstruction, history

Introduction

Faces are fascinating and faces from the past are particularly intriguing. Reconstructions help to solve problems but they also generate interest and answer questions in a much wider context. Skulls can survive for centuries, even millions of years, and can provide an unrivalled means of identification. In the past, facial reconstruction from skull was used for recognition of the deceased and more recently, for teaching anatomy. In forensic art and medicine, the face of a deceased individual is built onto the skull for the purpose of identification.

Here we briefly discuss the fundamental goals, procedures and techniques of facial reconstruction, and the results obtained in this field.

Facial structure

The bones of the skull are a key determinant of facial appearance. They form the basic framework to which other tissues are attached, and how a person looks depends on all these factors together – skin, muscle, fat and bone. In human beings, the basic look is similar, but we are very sensitive to the small differences that can be used for identification purposes.

Farkas et al (1994) (1) describe how the variability of facial proportions ensures the individuality of the human face.

First appearance in History: the Neolithic Age

In the past, bones or mummies of the dead were regarded by some cultures as objects of reverence to be preserved, whereas people of other cultures felt revulsion or phobia. Thus people have developed different attitudes and practices towards the dead. At one extreme, the corpse was cremated leaving only ashes and small pieces of bone, while on the other hand, elaborated attempts were made to preserve the body for eternity, as in ancient Egypt. Between these, a multitude of different traditions are present.

The first evidence that the skull was used for remembering the dead dates from the Neolithic Age. At that time the inhabitants of Jericho, in the Jordan valley, normally buried their dead under the floors of their houses. They also followed the custom of separating the skull from the skeleton, often without the lower jaw and burying it separately. The absence of the mandible is most easily explained by the fact that it falls away from the cranium as the soft tissue decomposes. It would appear that this is evidence of a form

of ancestor worship. In the ancient world there are many examples of how special respect was provided to the severed head or skull. This practice was taken one step further in Neolithic times in the Levant, for example in Byblos, Jbeil, Jericho, Lebanon and Palestine. Skull plastering apparently was followed by the pre-pottery Neolithic A culture in Jericho, around 8500 to 8000 BC, and enjoyed a relatively brief trend among the pre-pottery Neolithic B culture (7500-5500 BC). Excavations in 1953 in Jericho found two deposits beneath house flooring in the "Pre-Pottery Neolithic B" levels. Nine skulls had faces built up in plaster over the bone, with shells set into the eye-sockets for eyes. Another single skull was found in 1958 at the other end of the site and similar artefacts were discovered in other sites of the same area. Only one of the Jericho skulls had the lower jaw; on the others the chin was modelled over the upper teeth, making the heads appear somewhat thickset (2).

Although each had their own characteristics, the Jericho heads did not show a true physical likeness. Lack of concern to include such a relevant part of the face such as the mandible, suggests that physical exactitude was not the main objective, and that the symbolic aspect was more important. However, direct work on the skull brought the artist to retain the correct facial proportions (except of course for the lower jaw). Intentionally or unintentionally they were the first artisans known to have reconstructed faces.

Another early Neolithic site in the region is Nahal Hemar Cave located on a cliff near the southern end of the Dead Sea just northwest of Mt. Sedom, and excavated in 1983. Interesting skulls were found whose crania were embellished with a lattice-work of asphalt strips; in the same site, two painted stone masks (2) were excavated. The oldest known glue in the world, carbon dated to 8310-8110 BC, was also found on common artefacts such as rope baskets, embroidered fabrics, nets, wooden arrowheads, bone and flint tools, and on ritual objects including the stone masks and decorated human skulls. Many artefacts were covered with what seemed to be asphalt from nearby deposits. The glue was used as a protective, waterproof covering for rope baskets, containers, and embroidered fabrics, and also to hold different parts of tools together. It was also used to make a criss-cross design on skulls (2). It may also have been used on objects used for outdoor ceremonies, as done among some nomadic Middle Eastern groups today. However, very little is known about the Neolithic people who invented and produced this adhesive (3). Another early symbolic example of a face modelled upon a skull was from the New Hebridean Islands (AD 1700) (4).

*Death mask*s

Death masks of various types have been used in many cultures: this may have been one of the purposes of the Jericho skulls. The results were realistic and individual, however, they were modelled upon the superficial features of the face and thus they had more in common with a sculpture created from the outside inwards rather than built outwards from the bones.

The Middle Ages

Identification of people, in particular criminals or missing persons has always been a problem. In the Middle Ages, dead bodies were lain out for identification in public streets. Later on, only the head was displayed under spirit to avoid decomposition (5). Techniques for identifying the dead by building over the skull came later.

The Renaissance

Death-mask art was most appreciated during the Italian Renaissance. Artists from northern Italy were the first to provide wax models for doctors and surgeons. In the fifteenth century human dissection was practiced to study anatomy, and in the same period interest in how the body moved and was constructed, began. Andrea del Verrocchio and Michelangelo are known to have used wax models, either for documentation or for preliminary studies. Andrea Vesalius (1514-64) radically transformed anatomy teaching, making wax models commonplace in medical schools, and life-size waxes became substitutes for cadavers (4).

The Eighteenth Century

Other artists were Giulio Gaetano Zumbo (1656-1700) and Abraham Chavet (1704-1790). In the seventeenth century in Italy, wax modelling of the anatomy, or *anatomica plastica,* was born. This art, which constructed the whole body using the skeleton as a framework, was developed by Ercole Lelli (1702-1766) whose work is on display in the anatomy museum in Bologna. Lelli created anatomical masterpieces by modelling muscles onto full skeletons for use in medical teaching. He and his colleagues pioneered the development of scientific art and were the first sculptors to realize that the skeleton is the ideal frame upon which to build the musculature and the body (4). These artists can be credited with pioneering the theory behind facial reconstruction: that is, from the shape and proportions of the skull can be inferred how the muscles were attached and shaped, defining the parameters of the face; anatomical correctness was important, rather than an exact likeness.

The Nineteenth Century

Crime detection began to play a more sophisticated role in the nineteenth century. Prior to that, methods for incriminating the suspect were practical and crude. The basic method were to torture suspects until they confessed, or to throw the suspect into water and if he drowned, he must have been guilty. Other methods were to drag the suspect towards their presumed victim and he was proven guilty if the corpse's wounds bled. Identifying an unknown body was sometimes a problem. This occurred, for example, in March 1875, when a night-watchman at Horseferry Wharf, on the Thames, discovered a severed head lying in the mud of the river bank. The head was then carefully washed, the hair combed, and was staked in St Margaret's Churchyard in Westminster, in the hope that someone would recognize it. As decomposition set in, the head was placed in a jar of spirit, and left for further viewing for anyone who might have been able to identify it (5).

Nowadays the idea of exposing a severed head in the street seems barbaric, but a less dramatic equivalent has been used. In 1980 police in the UK displayed photographs of a head built up from a skull with clay. This skull belonged to the decomposed body of an unidentified man found near Camberley, Surrey. Anatomists at Manchester University reconstructed his probable facial features, in the hope that someone would come forward with an identification. For the same purpose, photographs of unidentified murder victims are often displayed in posters (5).

First scientific reconstructions

Anatomists were the first to become interested in facial reconstruction as an academic exercise. To authenticate the remains of famous people, comparison of portraits and sculptures became common practice. The anatomist Welcker (1884) compared what was thought to be Raphael's skull with a self portrait, and compared the supposed skull of Kant with his death mask, and found that the respective correlations were too good for chance. Welker used two-dimensional techniques; he provided accurate orthogonal perspective drawings as an outline of the skull and the death mask, and then attempted to superimpose the outlines, while making allowance for the outer tissues. Welker also did the first documented research, in 1883, on facial tissue depth as an accompaniment to the facial reconstruction technique (4, 5).

The famous German anatomist His (1895) was the first to record any scientific endeavour in this field. His aim was to identify the supposed remains of Johann Sebastian Bach (1685-1750). He took measurements of facial tissue from a small number of cadavers; using this data he modelled a bust onto a plaster cast of the skull of Bach. The final reconstruction was favorably compared with contemporary portraits and busts of Bach (2).

His and the anatomist Kollman employed sculptors to produce further 3D facial reconstructions: Sefner worked with His, and Buchly worked with Kollman. Kollman (1898) reconstructed the face of Dante from his purported skull, and from the likeness obtained he authenticated the skull as indeed that of Dante. Kollman also reconstructed the face of a stone-age woman from Auvenier, France. This reconstruction is considered to be one of the first real scientific

reconstructions. Kollman measured flesh thickness from hundreds of women from that area and produced technical drawings, which were then brought to life by Buchly (4, 5).

In Europe numerous reconstructions were made. Tandler (1909), used Welker's method to identify the skull of Haydn, before it was interred and a plaque erected to honour the composer in the Bergirche Mausoleum. Fortunately, he determined that the skull was really Haydn's.

Various anatomists and anthropologists produced many further reconstructions of early hominoids such as Neanderthal and Pithecanthropus, and others of the stone age.

In 1908 a well preserved Neanderthal skull was found in the Chapelle oux Saint, in France, and was the subject of reconstruction for anthropologists from America, Russia, Poland and so on. The results markedly differed from each other. In 1910 the anatomist Solger constructed the head of an old Neanderthal male from the cave of Le Moustier, France. In 1913 anthropologists Martin and Von Heggeling at the Anatomy Department of Jena University, produced different reconstructions of a Neanderthal face from the same skull. Heggeling experimented on how the soft tissues could influence the features of a face built up from a skull and believed that different races could be identified through reconstruction. To test this theory he obtained a male cadaver, made a cast of the head to obtain an objective likeness, and measured the thickness and disposition of the soft tissues. Two sculptors then performed facial reconstruction upon the same skull, knowing its soft tissues data, but the results were totally different. The result of Heggeling's experiment was that many people considered facial reconstruction unreliable (2).

The twentieth century: technical developments

For many years anatomists have been able to determine the sex and race of a skull and the approximate age at death of the individual to whom it belonged, but it was not until the beginning of the twentieth century that medico-legal experts began to seriously consider the possibility of reconstructing the features of a dead man upon the facial bones.

The first attempt in the USA at such a reconstruction took place in New York in 1916, and was judged remarkably successful. In the same year, bones were discovered in a Brooklyn cellar and brought to the mortuary; measurements taken indicated that they were probably those of an Italian. The neck was reformed out of rolled up newspapers, brown eyes were fitted into the eye sockets, and coloured plasticine moulded over the bones of the face was then finished professionally. When the head was displayed, several local Italians immediately came forward and recognised the dead man as Domenico La Rosa who had disappeared some time before. Apparently, apart from la Rosa's fuller face the image was precise. Although the La Rosa case was a turning point in forensics, facial reconstruction professionals suggest that the sufficiently exact likeness achieved may have been a little bit lucky (6).

The Russian School

Many hitches beset the reconstruction technique and it was not until almost twenty years after the La Rosa affair, through the dedication of one man, Mikhail Gerasimov (1907-1970), that they were largely overcome. Gerasimov took an early interest in archaeology and palaeontology, and was also fortunate to gain the patronage of Professor A.D. Grigoriev, holder of the chair of forensic science, University of Irkutsk, Siberia, who encouraged Gerasimov in his interest in the morphology of the human skull.

Gerasimov's task was intricate: he first had to create a routine or system for quantifying those parts of the skull where the overlying tissue is thinnest and would be most invariant and reproducible. He then had to develop a way to determine the muscular structure of an individual head. Gerasimov thus created what was referred to as the Russian method. This was based mainly on anatomical aspects, where the development of the skull and neck musculature is considered fundamental. In particular, he claimed that the musculature, even though varying with each individual in shape and size, could be determined and faithfully rebuilt from the traces of muscle anchorage left on the skull. He reconstructed faces in two steps, basic reconstruction and final modelling, but introduced

a note of subjectivity when stating that the later phase required extensive experience and training. He claimed that particulars of the nose could be determined from the nasal bones, the brow from the skull, the mouth from the teeth and maxillary bones, and the eyes from the nasal root, orbital bones and tear ducts (4). He also determined the ears from the mastoid process, the ramus of the mandible and the auditory meatus. His drawings were produced without tissue depth indicators (4, 6, 7). He reported that his method had been successful in 150 forensic cases and numerous historical reconstructions, among them prehistoric ancestors and historical subjects such as Ivan the Terrible and Schiller (2). In 1950, under his direction, the Laboratory for Plastic Reconstruction was founded at the Ethnographical Institute, USSR Academy of Sciences in Moscow.

The American School

The Russian method is in stark contrast with the American technique which relies on carefully measuring the thickness of tissues overlying the bone. McGregor of Columbia University was the first to carry out facial reconstruction in the United States, and from 1915 onwards his faces of prehistoric man modelled on skull casts, were a feature of the Natural History Museum in New York. However, it was probably Wilder (1912), a pioneer in forensic anthropology who brought the European method of facial reconstruction to the attention of the North Americans, and reconstructed the faces of many native American skulls. Wilder and McGregor provided many valuable tips and guidelines for facial reconstruction (4).

Facial reconstruction was seriously taken up only in 1946 when the anthropologist Wilton Krogman reexamined it, and with the aid of the sculptors McCue and Frost he studied the accuracy of the technique. For his first study, in 1946, Krogman selected a cadaver head and photographed it before it was defleshed (5). The skull was then handed to McCue who reconstructed the face using tissue depth data appropriate for sex, age and racial origin of the individual. The resulting reconstruction, compared to the photograph, showed that the procedure gave a good resemblance to the individual and that the method could be useful for forensic identification. Krogman continued to work with many artists (7).

The American 3D method, as it is now known, grew from Krogman's collaboration with forensic artist Betty Pat Gatliff and physical anthropologist Clyde Snow (8). Their first joint work was on reconstructing the face of a Native American man. Using mirror images, Gatliff built up a complete face, but in doing so she realised that facial asymmetry is important for subtle differences in facial appearance. After further experience, Gatliff and Snow concluded that 3D facial reconstruction could be useful for forensic identification.

The American method involves the use of tables of average facial tissue thickness data relating to age, ethnic group and gender. The skull is mounted in the Frankfurt plane, then layers of flexible synthetic rubber are shaped, following the most appropriate parameters, and glued to the bone (5). Taylor (2001) (7) split the reconstruction method into two phases: a technical one involving information collection, skull preparation, tissue depth application and facial contour production, and an artistic phase involving sculpture of the facial features and finishing of the head. The anthropologist Karen T. Taylor was invited to present the new method at an international symposium on the forensic aspects of mass disasters and crime scene reconstruction at the FBI academy in Quantico, Virginia, and details were published in the proceedings of the conference (7). In January 1992, in the Journal of Forensic Sciences, anthropologist Duglas Ubelaker of the Smithsonian Institution and Gene O'Donnell of the FBI, suggested a method of computer-assisted facial reproduction in which they use tissue depth markers. The American method can be found in Taylor (2001) (7). There are a many facial reconstruction artists currently working in the United States and they have a vast record of identifications from faces recognized.

The UK Manchester Method

Interest in facial identification in Britain stems chiefly from the use of superimposition techniques. Over the last half century in Europe, Helmer in Germany (1984) and Neave (2) in Britain have been lead-

ers in facial reconstruction. Helmer followed the American method, but at Manchester University, R. Neave developed a new method, combining the Russian and American techniques to create a new procedure now widely used, for example, by Taylor and Hangel (1998) in Australia, and Hill et al (1993, 1996) (9, 10) in Scotland (4). Neave's method uses the detailed traces of muscle insertion on the skull to ascertain facial detail and form, and relies on tissue thickness data, as in the American method, to model soft tissue depth. Although tissue depth information is important, it should be noted that the tables of data give mean values that may not render correctly the individual characteristics of each face.

Facial reconstruction aims, of course, to produce a likeness that is recognizably close to that of the deceased person. This may result in their being recognized and lead to the unearthing of further evidence. In Italy, for example, craniofacial reconstructions have been carried out in the Laboratory of Forensic Anthropology and Odontology, Institute of Legal Medicine, University of Milan, created in 2004 by C. Cattaneo, and in Turin on an Egyptian mummy (11).

Computerized facial reconstruction

Over the last decade, various systems using computer software have been developed for facial reconstruction. These systems have brought increased flexibility, efficiency and speed. Reconstruction by hand depends subjectively on the skills and experience of each individual modeller. Modelling by computer should eliminate this subjectivity. The most suitable system would involve three steps: scanning to gather information from the skull, input of details such as age, sex, ethnic group and stature, and computation to produce a gallery of the most probable facial outcomes.

A computer technique for forensic purposes was first developed by Moss and his colleagues (12, 13) at University College, London, in Britain and was based on a system used for cranial reconstructive surgery. The system was developed for 3D surface data acquisition of the human face, involves limited manual intervention, and is subject to minimal human error. The subject/skull is acquired with a laser video camera interfaced with a computer or with computed tomography scanning. Skull data are then imaged as a fully shaded 3-D surface and sites over the skull are chosen where the appropriate tissue depths are applied to the surface (14). The subjective skill of the operator in placing the landmarks is, however, involved.

A single-blind test of a known skull was carried out to compare the manual technique and the computer technique (15). The reconstructions were compared to a photograph of the individual to whom the skull had belonged. The results showed that both the techniques can be useful for identification, although the manual technique produced a more realistic and more recognisable face. The manual technique was found to be time consuming, and the face was more difficult to modify later. Problems with the computer technique were the limited library of facial features and over-reliance upon a small number of facial tissue depth data (15). Composite systems provide images of uniform quality and style, both of which can be highly variable in hand-drawn sketches (7).

Nelson and Michael (1998) (16) described a system of computer facial reconstruction named Volume Deformation. This system started with MRI, and its greatest limitation was that it used a face that the end result would ultimately resemble and therefore was only as close to the real face as the sample face.

De Greef and Willems (2005) (17) also worked on computer-aided reconstructions, especially for the eyes and mouth. Many other computerized facial reconstruction systems have been developed and proposed, with varying degrees of success (17-20).

Many other facial reconstructions have been performed using different methods on skulls of famous subjects and or archaeological remains (2, 4, 7).

New fast flexible and objective 3D reconstruction computer programs are in full development, faster computer aided reconstruction and new methodology have been proposed (17, 20, 22, 23).

Discussion and conclusions

Reconstruction of faces from skulls is at present only used in forensic sciences and archaeology. Recent literature in these fields has been reviewed under

the headings of skull anthropology, reconstruction techniques, soft tissue depth data, facial soft tissue features and computer aided 3D cranio-facial reconstruction (17). Since the first reconstruction attempts in the late 19th century, the literature has been extensive. Books have been devoted to the different methods (2, 4, 7), as well as comprehensive reviews (5, 14, 17, 24, 25).

Research on human facial reconstruction based on the skull is moving in many directions (26). Medical image technology and computing have advanced, making it possible to produce more accurate soft tissue depth charts, and to develop new criteria and protocols. Computerized 3D cranium facial reconstruction is also improving and is starting to integrate facial anatomy and facial feature guidelines.

Facial reconstruction methods and their traditional guidelines present some inaccuracies. The challenge of the coming years will be to increase the accuracy of facial reconstruction especially by questioning and improving our knowledge on facial details that can be extrapolated from the bony skull (27). The literature reveals that major methods of facial approximation depend on both facial anatomy and average soft tissue depths and new research results and paradigms are suggested (28).

Cranio-facial reconstruction, performed manually or with computer software, should be used to stimulate the memory of the public in searching for crime suspects. Stronger connection with the psychological sciences should be sought in achieving more accurate reconstructions (29). The cognitive approach is based on principles of how the mind works, our memory and cognition/perception, and the social dynamics of how people communicate (8). Above all in forensic recognition, the reliability of the recognition process is fundamental, and all the techniques are focused on this goal (30).

Stephan et al. (28, 30, 31) have published data on the reliability of forensic anthropology and the frequent lack of relationship between facial approximation and resemblance ratings. They found that a reconstruction need not closely resemble a suspect, to be identified as the specific person.

Finally, facial reconstruction has been proposed to illustrate disease and trauma in archaeological human remains and to portray a diseased or impaired individual in life as a visual reconstruction (32).

In conclusion, over the centuries faces have been reconstructed from skulls for different reasons: religion, teaching, and more recently forensics, anthropology and archaeology of ancient or more or less famous people. The techniques are changing, and new more reliable methods are being studied. Nevertheless, it is clear that facial reconstruction methods and their traditional guidelines present some inaccuracies, and the challenge will be to increase the degree of accuracy of facial reconstruction.

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