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The Reliability of Skull/Photograph Superimposition in Individual Identification

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ABSTRACT: The accuracy of video superimposition methods for identifying unknown human skulls was examined. Three identified human skulls were each compared to 97 lateral view and 98 frontal view "mug shot" photographs using two television cameras, an electronic signal mixer, and a video monitor. The skulls were not from individuals represented by the photographs. All comparisons were done without using anterior dentition.

The results found that 9.6% of the lateral view and 8.5% of the frontal view superimpositions were classified as a consistent fit based on the criteria that were identified. The incidence of false matches was reduced to 0.6% of the sample when a frontal view and lateral view photograph of the same individual were both compared to one skull. It was concluded that without anterior dentition, skull/photograph superimposition is reliable when two or more photographs, clearly depicting the facial features from different angles, are used in the comparison.

KEYWORDS: forensic science video superimposition, skull/photograph comparison, human identification

Anthropologists and anatomists have explored the relationship of human skulls to antemortem likenesses for more than one hundred years. Although techniques have varied, soft tissue thickness, position of the skull, size adjustments of the skull and the facial outline, and the relationship of the bony elements to the overlying soft parts have remained the primary concerns of investigators.

Comparisons with Busts, Portraits and Death Masks

Superimposition methods were first developed and applied to confirm the identities of historical figures. Comparisons that predated photographic documentation were made using portraits, busts, and death masks [*1–4*]. His reconstructed a clay bust from the purported skull of John Sebastian Bach and compared it to portraits [reported in *2*]. Karl Pearson compared the skull of Robert the Bruce VIII, King of Scotland, with engravings and coins depicting the King [*3*]. Pearson later compared the skulls of Thomas

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Browne, Henry Stewart, Jeremy Bentham, and George Buchanan to portraits of those individuals [*4*].

A head claimed to be of Oliver Cromwell was compared by Pearson and Morant in 1934 with numerous paintings, busts, coins, and life and death masks of the English Lord-Protector [*1*]. The head was found to be consistent with life masks and death masks made of Oliver Cromwell [*1*].

Photographic Superimposition

The invention of photography led to comparisons using antemortem photographs. One of the earliest and most famous cases was the Ruxton murder case, involving two unknown, dismembered bodies believed to be Mrs. Ruxton and her maid, Mary Rogerson [*5,6*]. A comparison of antemortem photographs of the two missing women with the partially macerated skulls was performed. The portraits were enlarged to life size, approximated by attaining and measuring an object visible in the photographs. Tracings from the photographs of the skulls and portraits were overlain for the final comparison [*5,6*]. Superimposition accomplished by using tracings made from photographs was also reported by Prinsloo [*7*], Pearson and Morant [*1*], Devore [*8*], and Simpson [*9*].

A visual representation of superimposition has been created by printing closely bound negatives of the face and skull onto one sheet of photographic paper [*2,10–12*]. Correct positioning of the skull has been achieved by marking the salient anatomical features of the head on ground glass and placing the glass in front of the camera lens where it could be seen upon looking through the viewfinder. The skull was then aligned with the markings [*11,12*].

Additional methods to situate the skull include applying an optical bench, a perspex plane, and a sighting device [*13*], use of a beam splitter [*14,15*] use of a goniometer [*16*], and the measurement of distances between anatomical landmarks thus supplying the pitch and deflection movements of the head [*17,18*].

The correlation of the size of the head and skull has been an important consideration to superimposition specialists. It has been argued that 1:1 enlargement of the two negatives must be accomplished to achieve scientific objectivity [*10*]. Also, without knowledge of the magnification and angulation of the antemortem photograph, it is possible for two faces with similar skeletal features of different size to result in misidentification [*8*].

Articles visible in the photographs have been sought and measured to facilitate enlargement of the faces to life-size [*5,6,10,18*]. Other scale correlation methodology has included enlargement of the face to a size convenient for work [*7,19*], measurement of interpupillary distance [*11*], size of dentition [*12,20–23*], and the marking of anatomical landmarks with pins [*20–22*] or by drawing [*12*].

Video Superimposition

Electronic video equipment has simplified the superimposition process. The methodology, which uses two television cameras and an electronic mixing device to overlay an image of a photographed human face over an image of a skull, was suggested by Snow [*24*] and other investigators worldwide [*2,13,19,25–32*].

A technique has been reported [*33*] that used computer digitalization to compare skulls with facial photographs. Photographs were digitalized in pixels and the skull digitalized in a three-dimensional mesh that was transformed into two dimensions with perspective projection. Using four anatomical landmarks, the computer visually depicted the superimposed results. The final image was reviewed by a forensic specialist to ensure the sizing, exact positioning, and alignment of landmarks of the skull fit the photograph [*33*].

In another study, computer-assisted video superimposition has been accomplished us-

ing an IBM PC and a printed circuit board [*34*]. The method involved digitization and storage in the computer of images of the photograph and skull. The skull was aligned using a tracing of the important anatomical landmarks found in the photograph. The digitized images were superimposed and the software allowed for any mixing of bony and photographic images, including removal of soft tissue to view the skeletal structure beneath [*34*].

Superimposition practitioners have not presented a consensus on the reliability of the technique for definite identification. In many countries, video identification has been accepted by the courts as a legal identification [*27–29*], yet others have used the technique only as corroborating evidence [*5,6,11,14,18,20–22,26*].

One subjective experiment and three objective tests of skull/photograph video superimposition can be found in the literature [*17,27,29,31,32*], however, a comprehensive evaluation of the technique has not been accomplished. The twofold objective of this investigation was to subjectively assess video superimposition, as applied by an experienced forensic anthropologist, and to determine if this technique can be used as a sole means of positive identification. The possibility of a false identification (designation of a skull as a person who it was not) was of particular importance because of the significant impact such a mistake would have on a forensic investigation.

Materials and Methods

Three human skulls of known identity were each compared to 98 frontal view and 97 lateral view photographs of non related individuals, yielding a total of 585 superimpositions. The relationship of the overlying soft tissue to skull was evaluated as either a consistent or an inconsistent fit.

Superimposition was achieved using two Ikegami model ITC-410 television cameras, one Panasonic system switcher (mixer) model 3500, one video monitor Panasonic model WV-5410, and one Panasonic VHS model AG-2400 portable video recorder (Fig. 1). Cameras were mounted vertically on stands made from photographic enlargers. Vertical space was used to reduce the amount of room necessary to operate the superimposition equipment, as the distance between camera and skull or photograph can reach several feet. The enlarger stands had a pulley counterweight system that enabled the cameras to be moved up and down with ease.

Vertical camera mounts also allowed the photograph to lay flat against the table. The skulls were place on a cork flask ring which eased manipulation and precluded a sophisticated clamping device. The mandible was attached by placing a small amount of utility dental wax between the maxillary and mandibular molars and in the mandibular fossa.

A skull was placed under one video camera and a photograph was placed under the other. The images were sent, via the mixer, to the monitor. The mixer allowed the likenesses to be superimposed or wiped vertically or horizontally (Fig. 2). In the wiping of images, one camera image is under the other and by turning a knob on the mixing board the topmost image can be eliminated in a continuous fashion from left to right or top to bottom revealing the image underneath. A Shintron video pointer model 380 was used to highlight specific areas on the monitor screen.

The skull sample in this experiment consisted of three white males aged 19, 57, and 81. The photographic sample was 100 sets of mug shots from the Alachua County, Florida Sheriff's Office. Each set contained one frontal view and one lateral view of the same individual. All subjects were white males with ages from 18 to 60 years old. Two frontal and three lateral photographs were not suitable for comparison due either to noticeable anterior dentition or improper cropping.

The procedure for a superimposition was as follows:

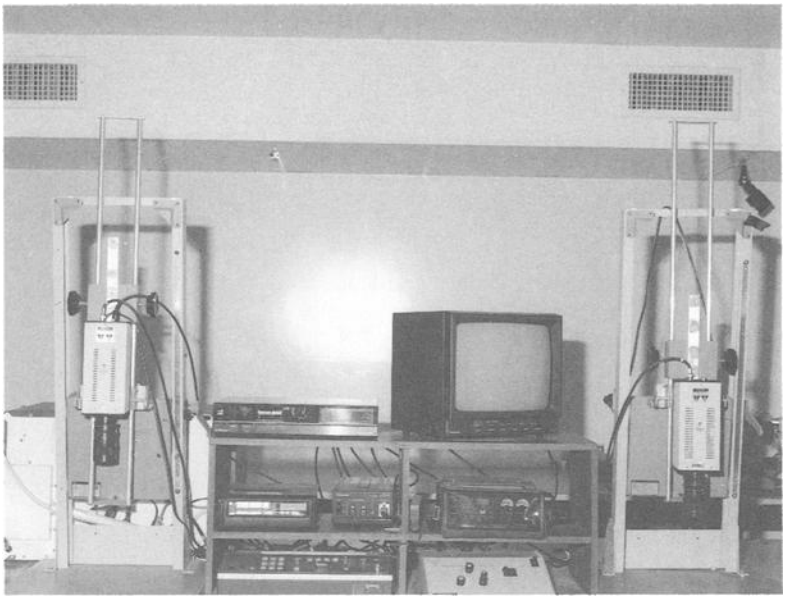

FIG. 1—*Equipment used in video superimposition.*

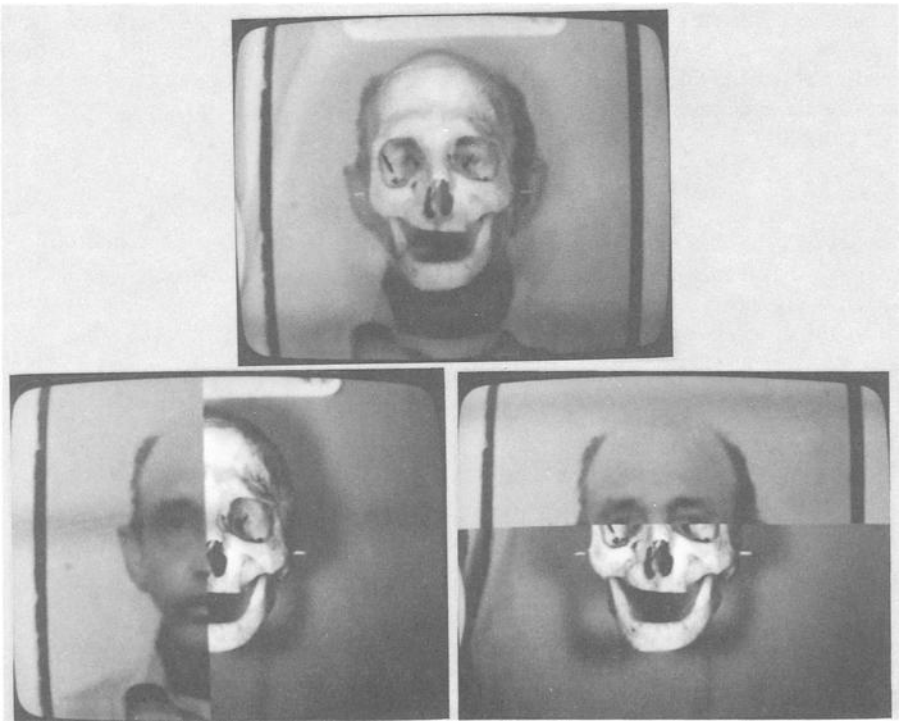

FIG. 2—*Example of a good match:* (top) *superimposed view can be faded from one image to the other* (bottom) *horizontal and vertical wipes.*

TABLE 1—*Percentage of acceptable identifications.*

View	Number of comparisons	Percent acceptable identifications
Lateral	291	9.7
Frontal	294	8.5
Total	585	9.1

1. A photograph was placed under one of the cameras and the face was focused so that it filled the monitor screen as fully as possible.
2. Tissue thickness markers were positioned on the skull at the appropriate anatomical landmarks. The tissue thicknesses used were determined by ultrasound on living subjects and ranged from thin to obese individuals [*25*].
3. The position of the head in the photograph was scrutinized and the skull was placed on the cork ring in an estimate of that position. Judgement of the distance between a horizontal projection from the lateral angle of the eye and another from the external auditory meatus was approximated (modified from Sekharan [*17*]).
4. The skull was put under the second video camera, the size was adjusted so the tissue thickness markers fell within the outline of the face, and the proportion of the anatomical features was maintained.
5. Exact positioning was determined by trial and error manipulation of the skull.

The areas of particular importance for comparison in lateral photographs included the curve of the forehead, the depth of the nasal bridge, the shape and projection of the nasal bones, the lower face and chin prominences, and the height of the vault. In the frontal photographs, the orbital size and shape, the breadth of the nasal bridge, the width of the nasal aperture, the total facial length and width, the ratio of mid-face to upper or lower face length, and mandibular shape were of the greatest concern.

Results

It was established that an experienced specialist in superimposition will sometimes conclude that a cranium and a photograph of two separate individuals are the same person. Fifty-three of 585 comparisons or 9.1% were found to be consistent fits despite the fact that the skull and photograph were not from the same individual (Table 1). The consistent fits resulted from 28 of 97 lateral comparisons (9.6%) and 25 of 98 frontal comparisons (8.5%) (Table 2).

The photograph sample in this investigation contained a front view and a side view of each face. There were only two skull/face superimpositions (0.6%) that resulted in a consistent fit for both views.

Experience with the several dozen skull/photograph superimpositions of positively identified individuals encountered in forensic practice supplied information on the exact

TABLE 2—*Number of acceptable identifications.*

View	Skull A	Skull B	Skull C	Total
Lateral	15	9	4	28
Frontal	8	7	10	25
Total	23	16	14	53

relationship between specific bony areas and surrounding soft tissues. This information was lacking in previous studies with the notable exception of Caldwell's work on macerated cadavers and accompanying death masks [*35*] and limited data supplied by radiographic techniques [*29*]. In the present investigation, the following requirements were used for a consistent fit between skull and face:

Lateral View

1. The vault of the skull and the head height must be similar.
2. The glabellar outline of both the bone and the soft tissue must have a similar slope although the line of the face does not always follow the line of the skull exactly. There may be slight differences in soft tissue thicknesses that do not relate to nuances in the contour of the bone.
3. The lateral angle of the eye lies within the bony lateral wall of the orbit.
4. The glabella, nasal bridge, nasal bone area is perhaps the most distinctive. The prominence of the glabella and the depth of the nasal bridge are closely approximated by the soft tissue covering this area. The nasal bones fall within the structure of the nose and the imaginary continued line, composed of the lateral nasal cartilages in life, will conform to the shape of the nose except in cases of noticeable deformity.
5. The outline of the frontal process of the zygomatic bones can normally be seen in the flesh of the face. The skeletal process can be aligned with the process seen in the face.
6. The outline of the zygomatic arch can be seen and aligned in those individuals with minimal soft tissue thickness.
7. The anterior nasal spine lies posterior to the base of the nose near the most posterior portion of the lateral septal cartilage.
8. The porion aligns just posterior to the tragus, slightly inferior to the crus of the helix.
9. The prosthion lies posterior to the anterior edge of the upper lip.
10. The pogonion lies posterior to the indentation observable in the chin where the obicularis oris muscle crosses the mentalis muscle.
11. The mental protuberance of the mandible lies posterior to the point of the chin. The shape of the bone (pointed or rounded) corresponds to the shape of the chin.
12. The occipital curve lies within the outline of the back of the head. This area is usually covered with hair and the exact location may be difficult to judge.

Frontal View

1. The length of the skull from bregma to menton fits within the face. Bregma is usually covered with hair.
2. The width of the cranium fills the forehead area of the face.
3. The temporal line can sometimes be distinguished on the photograph. If so, the line of the skull corresponds to the line seen on the face.
4. The eyebrow generally follows the upper edge of the orbit over the medial two-thirds. At the lateral superior one-third of the orbit the eyebrow continues horizontally as the orbital rim begins to curve inferiorly.
5. The orbits completely encase the eye including the medial and lateral folds. The point of attachment of the medial and lateral palpebral ligaments can usually be found on the skull [*36*]. These areas align with the folds of the eye.
6. The lacrimal groove can sometimes be distinguished on the photograph. If so, the groove observable on the bone aligns with the groove seen on the face.
7. The breadth of the nasal bridge on the cranium and surrounding soft tissue is

similar. In the skull, the bridge extends from one orbital opening to the other. In the face, the bridge spreads between the medial palpebral ligament attachments.

8. The external auditory meatus opening lies medial to the tragus of the ear. The best way to judge this area is to place a projecting marker in the ear canal. On superimposition, the marker will appear to exit the ear behind the tragus.

9. The width and length of the nasal aperture falls inside the borders of the nose.

10. The anterior nasal spine lies superior to the inferior border of the medial crus of the nose. With advanced age the crus of the nose begins to sag and the anterior nasal spine is located further superiorly.

11. The oblique line of the mandible (between the buccinator and the masseter muscles) is sometimes visible in the face. The line of the mandible corresponds to the line of the face.

12. The curve of the mandible is similar to that of the facial jaw. At no point does the bone appear to project from the flesh. Rounded, pointed, or notched chins will be evident in the mandible.

Discussion

When anterior dentition is recovered with the skull and a smiling photograph with the teeth in focus is available, the shapes of individual teeth and their position in relation to each other are considered sufficiently distinctive to base an identification [*12,23*]. Close-up video should be used in such cases, in addition to the standard full face views. It should be noted that positive identification has been made by comparing misalignment of anterior dentition without doing a superimposition [*37*].

The case often arises, however, where either no smiling photograph is available, the subject is wholly or partially edentulous, or the teeth have been lost postmortem. "Mug shot" photographs seldom show a smiling subject, but school book and family photographs are usually smiling. If anterior dentition is not used, the comparison is between the skull, which exhibits defined outlines, and the face, which usually gives only a general idea of the bony shape beneath. This research indicates that there is a 9% chance of misidentification if one photograph is used for the comparison, but diminishes to less than 1% if multiple photographs from widely different angles to the camera are used.

Specific exceptions to this could include facial trauma, or anomalous deformities, severe enough to give a remarkable distinction to the skull. For example, one case studied in the C. A. Pound Human Identification Laboratory, consisted of a white male who had sustained facial fractures that resulted in deviation of his nose to the left and displacement of his chin to the right. These features were evident in both the skull and antemortem photograph. The individual was completely edentulous and had no antemortem medical records. Identification was made by superimposition of one frontal view photograph with the skull, supported by the fact that his body was found in his home.

In fact, the C. A. Pound Human Identification Laboratory has used video superimposition to corroborate many of the identifications made in the lab since the equipment was purchased in 1986. Several of the identifications were strongly influenced by the information supplied by the superimposition. To date, no skull/photograph identification from this laboratory has been presented in a court of law.

When using skull/photograph superimposition to establish an identification, especially if there are no other means, it is imperative to inform the investigating team of the need for multiple photographs of the individual. Many times police file "mug shots" are available and they often contain a frontal view and a lateral view. Most photographs will not be straight forward or lateral poses, but instead will represent the head in some degree of deflection from center. It is not the angle of the head in the photograph that matters, rather it is the presence of two or more photographs with significant differences

in angle of the head to the camera lens. The present research used photographs separated by approximately 90 degrees. An identification based on photographs that differed by that much falls within scientific certainty (greater than 99%). The more photographs there are available for comparison, the more certain may be the identification.

Proper positioning of the skull continues to be a critical issue. Slight misalignment can lengthen or shorten a critical area of the skull. Tremendous energies in the form of sophisticated skull holders [*16*] and precise measurements [*17*] have been extended in this area to get the skull in exactly the correct position. However, we found a cork flask ring to be both a suitable support for the skull and an accommodating means for skull manipulation.

We found the maximum and minimum tissue thicknesses over 34 landmarks of Caucasoid skulls presented by Helmer [*25*], provided additional confirmation for positioning of the skull. The range between minimum and maximum thickness was marked on dowel pins and adhered to the skull. In the acceptable matches the soft tissue outline of the face fell within the expected area in the final superimposition. Additionally, viewing the predicted soft tissue outline on the skull gave a better understanding of the overall relationship of the skull and surrounding soft tissues. Knowledge of this relationship can be applied not only to video superimposition, but is useful in facial reconstruction—either drawing or sculpture—as well.

Conclusions

Using only one photograph, a 9 percent chance of false identification was found in the superimposition of unknown human skulls. Two or more photographs, representing a difference of about 90 degrees in the angle of the face to the camera, resulted in less than 1 percent probability of false identification. These data apply to superimpositions done without using anterior dentition.

Conditions have been presented for frontal view and lateral view comparisons that must be met to designate a good match between skull and facial features. It must be stressed that discriminatory power is gained over time with this technique. The guidelines presented here for a superimposition require practice to gain experience in determining the relationship between skull and overlying soft tissue before attempting to make identifications.

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