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Skull-Photo Superimposition and Border Deaths: Identification Through Exclusion and the Failure to Exclude*

ABSTRACT: We report on the application of video skull-photo superimposition as an identification method in a case from Ajo, Arizona in which five individuals died after crossing into southern Arizona from Mexico. Initial analyses at the Pima County Forensic Science Center in Tucson, Arizona determined that the disarticulated skeletal remains represented two adult Hispanic males and three adult Hispanic females. Based on biological profiles, both the males and one of the females were tentatively identified and assigned names. The other two females were too similar in age and height, making skeletal separation and identification difficult. As a result, the Michigan State University Forensic Anthropology Laboratory assisted in the identification efforts by performing video skull-photo superimposition on the two unknown females. The skulls were compared to a photograph reported to be one of the missing females. By evaluating facial proportionality and by comparing a number of morphological features of the face and skulls, one skull was excluded as a possible match and one skull was not excluded as a match to the antemortem photo. Because this case was presumed to be a closed disaster, the exclusion of one skull and the failure to exclude the other represented circumstantial identifications.

KEYWORDS: forensic science, forensic anthropology, identification, skull-photo superimposition, border deaths

Over the last decade, there has been a dramatic increase in the number of deaths among illegal border crossers trying to enter the United States along the Mexican border (1). Many of the individuals in these cases do not have antemortem X-ray or fingerprint records, making identification extremely challenging or impossible. As a result, when identifications in border death cases are made, they are often of the circumstantial variety. Typically, these circumstantial identifications are established through consistencies between antemortem and postmortem records, such as scars, dental features, tattoos, and other healed traumata (2). Skull-photo superimposition can also be a very useful identification technique in border deaths in the event that an antemortem photograph can be located. Identifications in such cases can be the result of either the exclusion of the skull as a match to the photograph or the failure to exclude the skull as a match to the photo.

Case Report

In February 2003, commingled human bones and personal effects were discovered by a hiker in a remote desert area near the southern Arizona town of Ajo. The Pima County Sheriff's Department responded and led a search team that included rangers from the Bureau of Land Management. The scene, located on the lower slope of a mountain, was rocky with sparse desert vegetation consisting mainly of mesquite and palo verde trees, ocotillo, and various forms of cacti. The search took place over a 2-day period and resulted in the recovery of five human skulls, numerous human postcranial skeletal elements, five backpacks, four personal identification cards, and clothing, all scattered over a 50–100 yard radius.

Using the evidence collected at the scene, investigators at the Forensic Science Center in Tucson, Arizona and the Pima County Sheriff's Office worked with the Consulate of the Republic of Mexico in the attempt to identify the deceased. Through these multi-agency cooperative efforts, the names of the five missing persons were established. Because of the level of certainty of this list of names, the situation was considered a closed disaster. A closed disaster is one where the names of victims are known, such as a flight manifest that lists all passengers and crew.

The five individuals believed to be traveling together in this case are listed as follows: Felipe V., 33 years old; Ricardo T., 42 years old; Reyna S., 32 years old; Elia R., 38 years old; and Amalia L., 22 years old.

The commingled skeletonized human remains were analyzed by forensic anthropologist Walter Birkby, Ph.D., at the Pima County Forensic Science Center in Tucson, Arizona. According to Dr. Birk-by, the remains represented two adult Hispanic males and three adult Hispanic females. The biological profiles he generated from the skeletal material are as follows:

Male #1: 30–45 years old, Hispanic, 5′4′–5′7′ tall.
Male #2: 35–50 years old, Hispanic, 5′3′–5′6′ tall.
Female #1: 30–40 years old, Hispanic, 5′2′–5′5′ tall.
Female #2: 30–40 years old, Hispanic, 5′1′–5′4′ tall.
Female #3: 20–25 years old, Hispanic, 4′6′–4′9′ tall.

Males #1 and #2 were identified through DNA analysis. In addition, it was possible to segregate the remains of Female #3 because of the comparatively young skeletal age (20–25 years). These remains were presumed to represent the missing woman Amalia L., who was 22 years old at the time of her disappearance. However, it was not possible to segregate Females #1 and #2 because of the similar skeletal age ranges (30–40 years) and stature ranges

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(5′2′–5′5′ and 5′1′–5′4′), and the similar ages of Reyna S. (32 years) and Elia R. (38 years). Fortunately, during the investigation, a known photograph of Reyna S. was obtained (Fig. 1).

At this point in the investigation, the two unidentified skulls and the photograph of Reyna S. were mailed to the Michigan State University Forensic Anthropology Lab and the authors were asked to assist in the identification efforts by performing video skull-photo superimpositions comparing the two skulls with the photograph.

Review of Skull-Photo Superimposition Methods

The use of skull-photo superimposition as an identification tool has transformed in methodology since its inception. The earliest method which involved overlaying the photographic negative of a skull on a positive facial photograph (3), were modified by Helmer and Grüner (4) to include the use of video superimposition equipment. This method employing the use of two video cameras, an electronic mixing device, and a viewing monitor has been successfully used by a number of researchers (5–11) and with some modification by Iten (12), who suggests using three viewing monitors.

The most recent modifications of skull-photo superimposition methods integrate the use of computer technology. Computer programs allow the researcher to quantitatively assess the fit between a skull and a facial photograph in two dimensions (13–15) and in three dimensions (16). Aside from enabling quantitative assessment of fit, software can be used to import images from a video monitor for digital comparison and manipulation (10,17,18), or to confirm the results of a video comparison in an effort to avoid false positives (19).

Within the forensic community, methods employing the use of two video cameras, an electronic mixing device, and an additional screen for viewing have proven successful (5–10). Such equipment allows for a more objective comparison between the bone and soft tissue through the use of image wiping and fading capabilities (20,21). Use of this method, however, is not without complications. To accurately and successfully employ this method, proper sizing of the photograph and positioning of the skull must be obtained.

Sizing of the photograph involves establishing a reliable magnification factor for photographic enlargement. In a number of cases, linear measurements of objects of known size present in the photograph have been used to establish a magnification factor (22–24); however, such objects may lie outside the parallel zone of the face, resulting in either an over or under exaggeration (25). Others have relied on anatomical landmarks (23), including measurements of interpupillary distance (26,27) and anterior dentition (28–30) to establish a scale correlation. Aside from establishing scale correlation, the unique characteristics of dentition may allow for positive identification in rare cases of unknowns (31). Once the photograph has been properly sized, correct positioning of the skull becomes critical for accurate and successful employment of the video superimposition method. This involves positioning the skull in

FIG. 1—*Submitted antemortem photograph (L) and close-up of face from the same photo (R).*

correspondence with the angle of the face in the photograph. Anatomical landmarks may be marked and used as reference points (20); however, a number of authors indicate that repositioning of the skull by way of trial-and-error has proven most successful when attempting to find an exact fit between the position of the skull and that of the face in the photograph (11,20,32).

In an effort to address these complications, modifications to the method have been developed. Such modifications include calculating new indices to correlate the skull with the facial photograph (33) and use of software programs that compare the symmetry of the face with that of the skull (34). Others, such as Brocklebank & Holmgren (35), have developed equipment that allows for controlled manipulation of the skull, a modification that addresses the complications associated with positioning.

In addition to method advancements, a number of validation studies have demonstrated the reliability of skull-photo superimposition (10,11,36–38). In accordance, within the forensic community skull-photo superimposition continues to be regarded as a reliable method for the identification of an individual.

Methods: Skull-Photo Superimposition

The Michigan State University Forensic Anthropology Laboratory employs video skull-photo superimposition. The analyses in this case were completed using the following equipment: two video cameras, a video mixer, a TV monitor, a video cassette recorder, and a desktop computer with image capturing software similar to that suggested by Austin-Smith and Maples (11). The superimposition process at Michigan State University begins by placing appropriate tissue depth markers on the skulls (39) (Fig. 2). Once this is completed, the "dynamic orientation process" is used to arrive at the best fit possible in the alignment of the skull with the antemortem photo. Our dynamic orientation process begins by positioning the antemortem photograph under one of the two video cameras so the image fills most of the TV monitor. Next, the skull is placed under the other camera. Using the mixer and monitor, the skull image is sized so that it can be superimposed on the image of the face. Once the skull and antemortem photo are satisfactorily adjusted for size and basic orientation, the cranio-facial proportions in the skull and the face can be evaluated and compared. This is accomplished by manually adjusting the skull so that the key skeletal landmarks align with corresponding landmarks on the face (Fig. 3).

In the ideal situation, the first step in the dynamic orientation process is to align the skull and photo at porion. Porion on the skull is established by inserting Q-tips into both external auditory meati, and porion on the face is indicated by the left and right tragi of the ears. In the second step, the left and right Whitnall's tubercles (40), a bony eminence of the zygomatic located on the lateral margin of the eye orbit, are aligned with the left and right

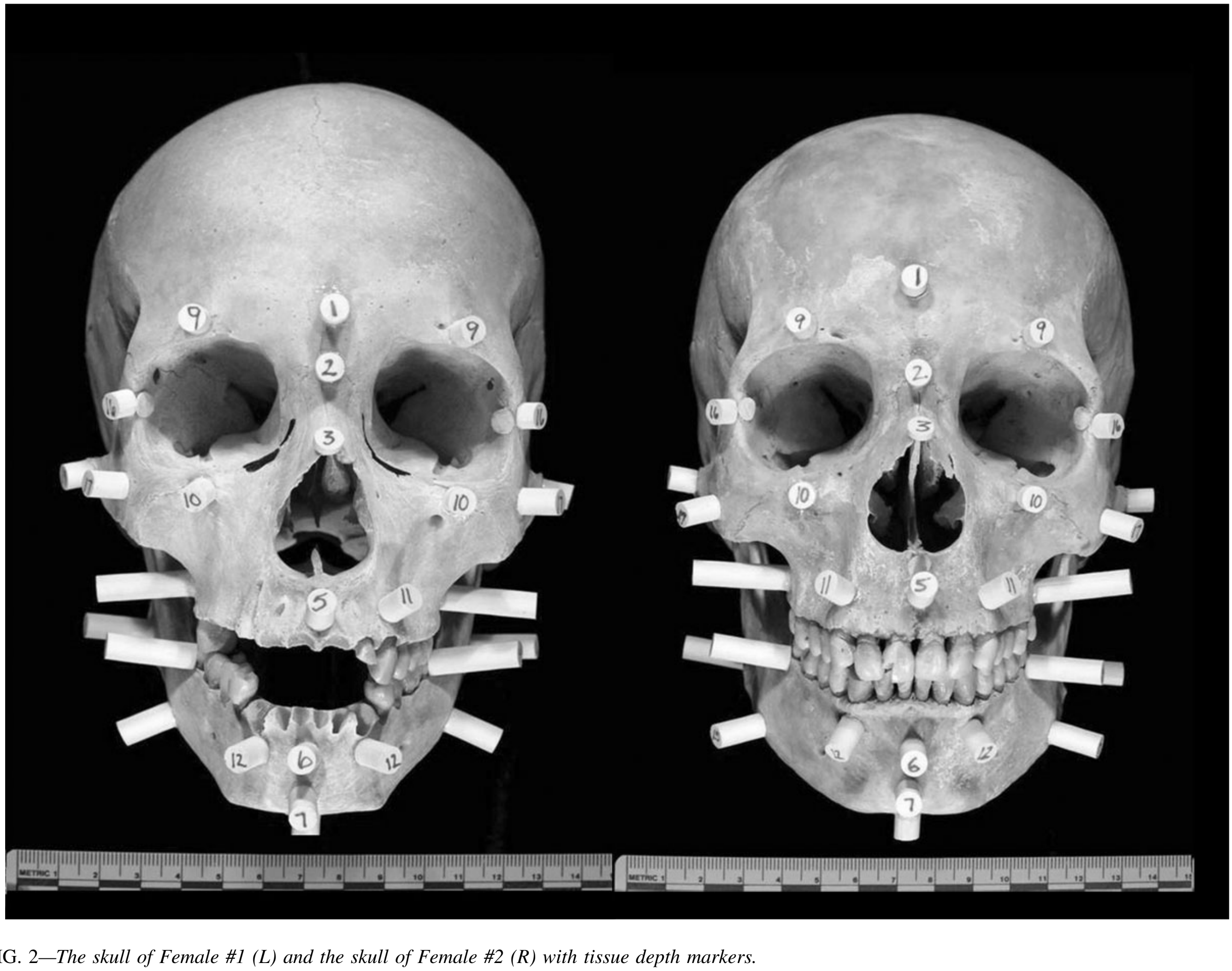

FIG. 2—*The skull of Female #1 (L) and the skull of Female #2 (R) with tissue depth markers.*

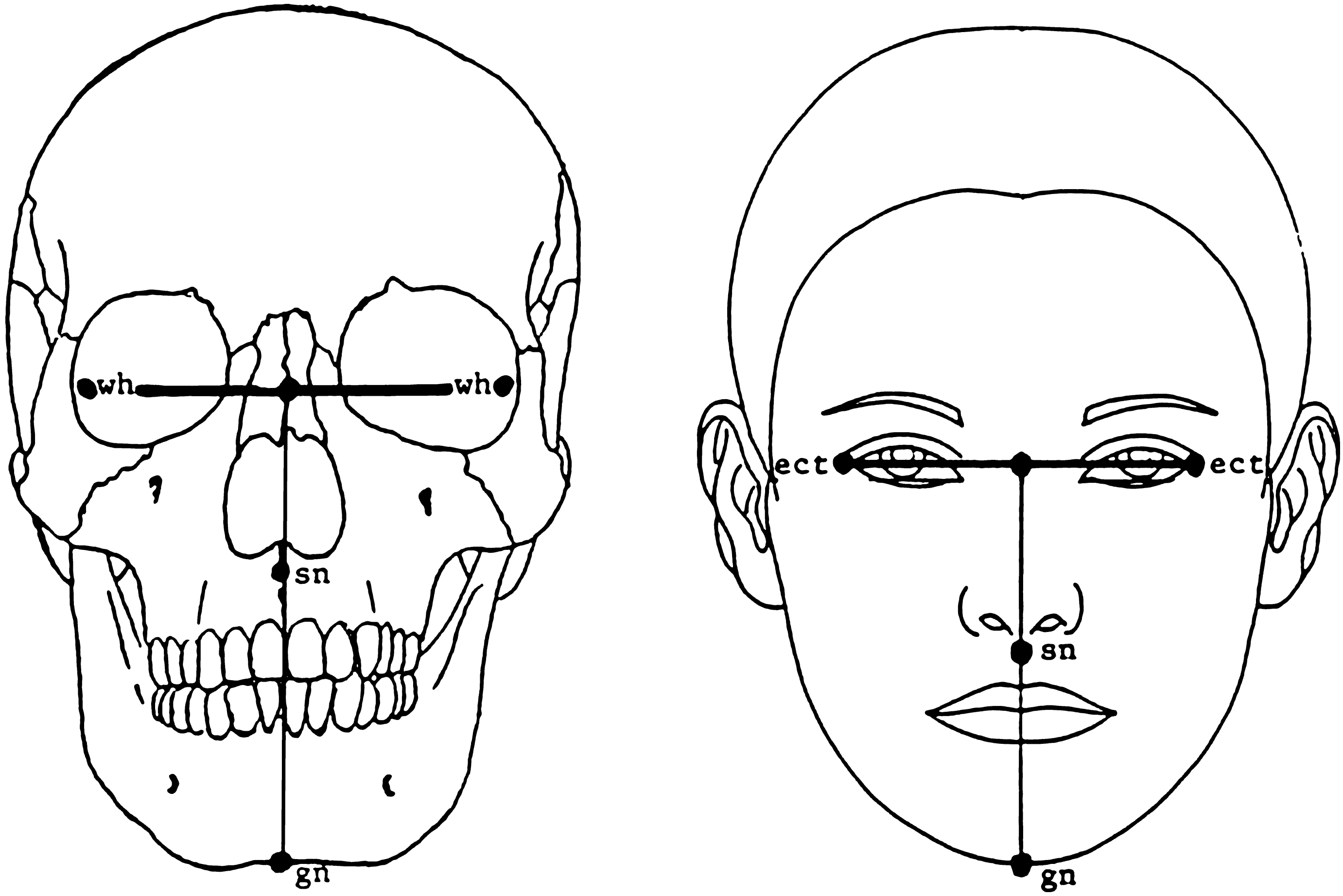

FIG. 3—*Diagram of skull and face with landmarks used during initial dynamic orientation process.*

ectocanthion points of the face. These first two steps are critical in setting the skull at the correct angle of inclination and declination so that it approximates the angle of the face in the superimposition. In the third step, the subnasal point of the skull is adjusted to align with the subnasal point of the face. And in the fourth step, gnathion on the skull, the inferior most point of the mandible in the midline, should align with gnathion on the face in the antemortem photo.

It is important to note that the dynamic orientation process is a very challenging and time-consuming part of the skull-photo superimposition technique. Correctly adjusting the size and orienting the images can take several hours to complete. The inability to properly align the facial and cranial landmarks is often the first clue that the skull and photo do not match.

Finally, systematic evaluation of the correspondence of morphological features between the face and skull is performed. This is an equally important component in the skull-photo superimposition technique employed at Michigan State University. When possible, the authors utilize the Austin-Smith and Maples (11) list of morphological requirements for establishing a consistent fit between the face and the skull. Specifically, Austin-Smith and Maples recommend that 12 morphological features in the frontal view should correspond in the superimposition. In some cases, however, not all of their recommended features are visible on the photograph because of the presence of hair. By evaluating the concordance between identifiable anthropometric landmarks and morphological features, judgments can be made about inclusion or exclusion of the skull with the photograph.

Identification Through the Failure to Exclude

Austin-Smith and Maples (11) and Glassman (21) have commented on the reliability of skull-photo superimposition for positive identification and its inappropriateness as a tool for positive identification. According to Austin-Smith and Maples, "using only one photograph, a 9% chance of false identification was found in the superimposition of unknown human skulls" (1994:453). It is our opinion as well that in the absence of clear images of unique dental features (31), skull-photo superimposition does not yield a positive identification akin to X-ray analysis, fingerprints, or DNA (11,21,32). More typical outcomes are "exclusion" or "failure to exclude" (21,36,41). In a closed disaster, however, when a skull is known to represent one of two individuals, exclusion of one individual is tantamount to identification.

Our approach to skull-photo identification is to adapt the Popperian notion of falsifiability. We maintain a position consistent with the literature (11,26) that the skull-photo superimposition may only rarely provide a positive identification. However, it is quite feasible to eliminate the individuals when no match is possible. Thus, we begin each analysis with the assumption that the images in question (e.g., a skull and photo) represent the same person. If inexplicable differences in the position and proportionality of anthropometric landmarks are observed, we reject the assumption. On the other hand, if we are unable to identify substantial differences in such features, we then conclude that the images may represent the same individual.

Identification of Reyna S. and Elia R.

In the identification of Reyna S. and Elia R., it was informative to begin the analysis with a side-by-side comparison of the submitted skulls before attempting to match either of the skulls to the photograph. In Fig. 4, horizontal lines were drawn through selected landmarks of both skulls revealing significant differences in cranial proportions. By drawing horizontal lines through Whit-nall's tubercles and gnathion, it was possible to observe differences between the two skulls in the distances between subnasal point and alveolare, and subnasal point and gnathion. Specifically, the skull of Female #1 displayed a much shorter distance between subnasal point and alveolare.

The skull-photo superimposition analysis began by superimposing an image of the skull of Female #1 onto the known photograph of Reyna S. (Fig. 5). This superimposition represented a test of the first hypothesis (i.e., the skull Female #1 is Reyna S.). During the dynamic orientation process, careful attention was paid to aligning the left and right Whitnall's tubercles of the skull with the left and right ectocanthion points of the face, the subnasal points of the skull with the face, and the tissue depth marker at gnathion with the skin at the base of the chin.

In this superimposition, the following morphological features, taken directly from the Austin-Smith and Maples (11) guidelines, displayed good correspondence between the skull of Female #1 and the face in the photo of Reyna S.:

1. The length of the skull fits within the face.
2. The width of the cranium fills the forehead area of the face.
3. (The temporal line was not visible in the photo.)
4. The eyebrow generally follows the upper edge of the orbit over the medial two-third.
5. The orbits completely encase the eye including the medial and lateral folds; the point of attachment of the medial and lateral palpebral ligaments (Whitnall's tubercles align with the folds of the eye).
6. (The lacrimal grooves were not observed on the photo.)
7. The breadth of the nasal bridge on the cranium and surrounding soft tissue is similar.
8. The external auditory meatus opening lies medial to the tragus of the ear.
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.
11. (The oblique lines of the mandible were not identified on the photo) and
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. (The statements in parentheses are the authors'.)

In addition, the overall correspondence between the outline of the face and the tissue depth markers on the skull was excellent.

FIG. 4—*A comparison of facial proportionality illustrating the differences between the skull of Female #1 (L) and the skull of Female #2 (R). In particular, note the difference in the distance between the subnasal point and alveolare.*

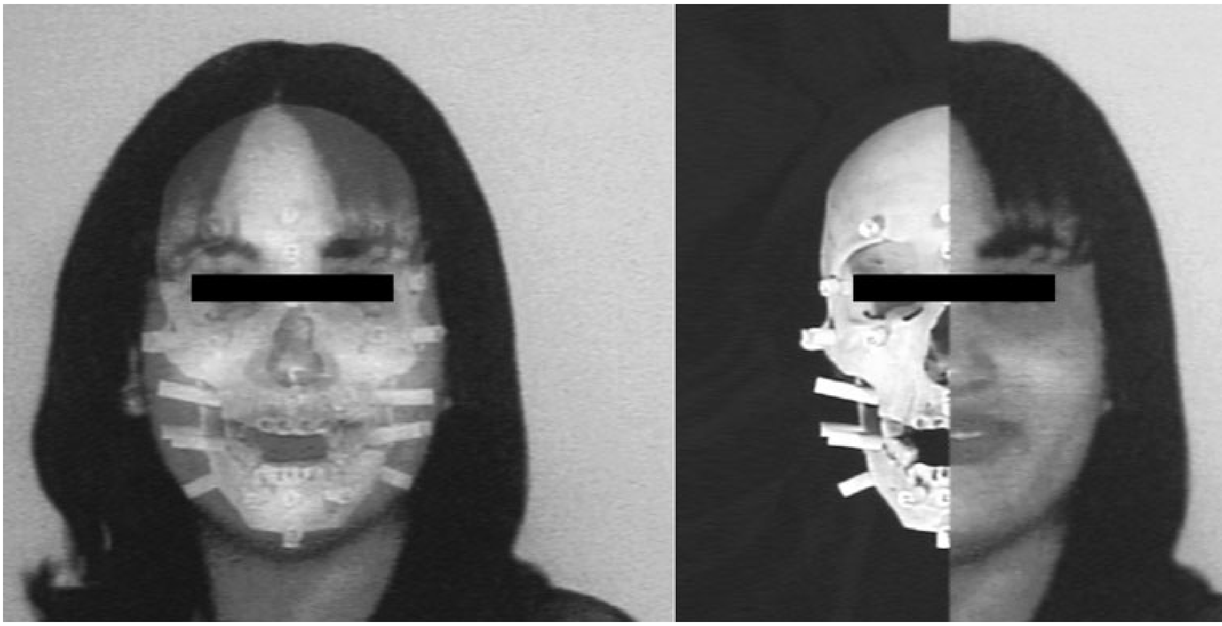

FIG. 5—*Superimposition of the skull of Female #1 with the submitted antemortem photo.*

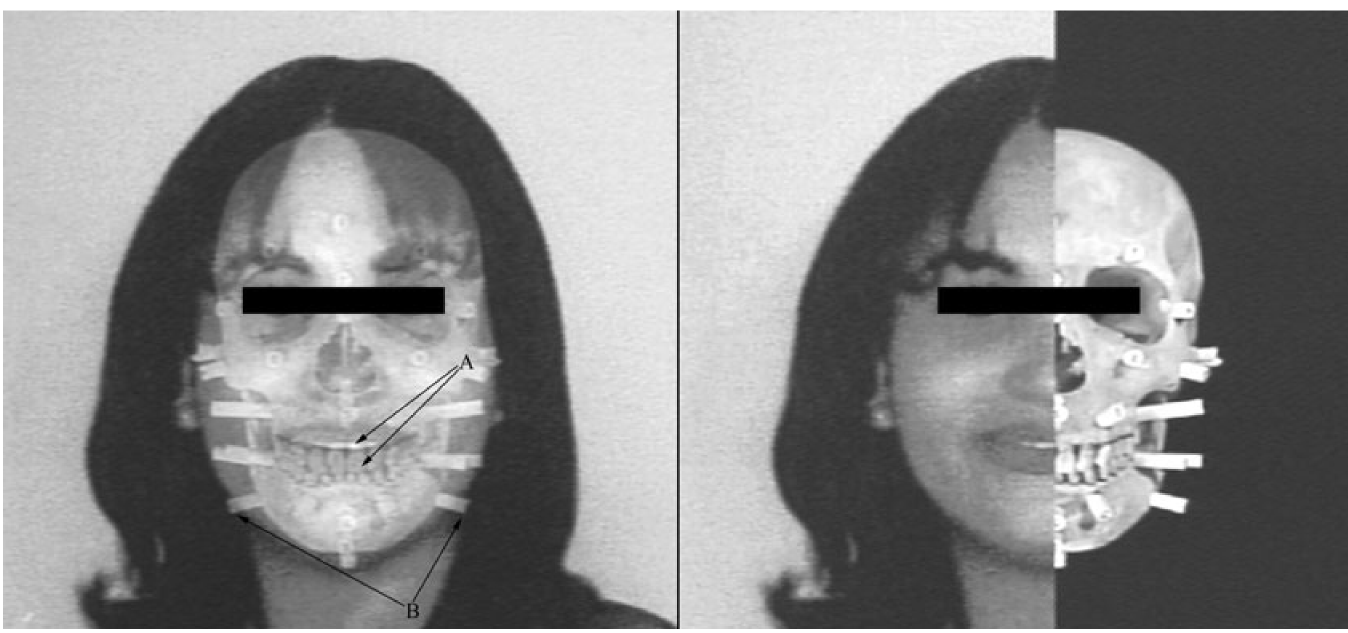

FIG. 6—*Superimposition of the skull of Female #2 with the submitted antemortem photo. (A)* depicts the mismatch of the anterior teeth and (*B*) depicts the mismatch between the tissue depth markers and the contour of the cheek.

There were no instances where the tissue depth markers projected further than the face. Finally, differential shading and lighting allowed us to evaluate the correspondence of certain contours. For example, the cheeks identified in the photograph superimposed directly upon the zygomatics; and the slight brow eminence evident on the photo superimposed precisely on the brow ridge area of the skull. In addition to these correspondences, there were no inconsistencies between the skull of Female #1 and the photograph of Reyna S. It was therefore impossible to reject the hypothesis that the skull of Female #1 is Reyna S.

Next, the image of the skull of Female #2 was superimposed onto the photo of Reyna S. This superimposition evaluated the second hypothesis: the skull of Female #2 is Reyna S. Again, the face in the antemortem photo was positioned over the image of the skull using the dynamic orientation process, which focused on the alignment of specific landmarks (left and right Whitnall's tubercles with left and right ectocanthion, subnasal point, and gnathion) (Fig. 6). Because of proportionality differences between landmarks and facial features, we were unable to adequately superimpose the photo onto the skull. When the "best fit" was agreed upon, there were still a number of features that did not match. For example, the anterior teeth were not aligned, and the tissue depth markers protruded from both sides of the lower cheek (Fig. 6). Because of the lack of conformity between skeletal and facial landmarks and between tissue depth markers and the face, we rejected the second hypothesis. In other words, the skull of Female #2 was not Reyna S.

Because this case was a closed disaster, the inclusion of the skull of Female #1 and the exclusion of the skull of Female #2 as possible matches with Reyna S. resulted in the identification of the skull of Female #1 as Reyna S., and the circumstantial identification of the skull of Female #2 as Elia R. Of course, the strength of this identification is only as strong as the information provided by the investigators regarding the roster of persons believed missing in this case.

Summary

In this case of multiple border deaths, two unidentified adult female skulls and a photograph of a missing Hispanic female were submitted to the Michigan State University Forensic Anthropology Laboratory. Using video skull-photo superimposition analysis, the authors excluded one skull as a match, and included (failed to exclude) the other skull. These results were based on extensive comparisons of cranio-facial proportionality, as well as the comparison of a number of morphological features of the face and skull. Because this case was a closed disaster with a known roster of missing persons, the exclusion of one skull and the inclusion of the other represented the circumstantial identifications of two individuals.

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