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A Method of Matching Skulls with Photographic Portraits Using Landmarks and Measurements of the Dentition

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ABSTRACT: A method of matching and identifying skulls to family snapshots or passport photographs is described. The technique depends on the recovery of teeth, particularly the maxillary anterior teeth, with the skull and the availability of an antemortem photograph showing those teeth. Measurements of the anterior dentition of unidentified skulls are used to determine the magnification factor necessary for the preparation of life-sized transparencies of photographs. Superimposition of dental landmarks in these transparencies leads to correlation of further cranial features, thus enabling a successful positive identification. Suggestions are made for a system of identification based on assessment of visible features of the dentition.

KEYWORDS: odontology, physical anthropology, dentition, superimposition, photography, cranium, photographic superimposition

The successful identification of human skeletal remains has been achieved in a variety of ways. Positive identification has been produced, for example, by the matching of antemortem dental records with missing teeth, restorations, bridges, partial dentures, buried roots, and evidence of pathological conditions in the skeletalized jaws [*1*, *2*]. All too frequently, however, dental records may be incomplete or unavailable, or parts of the jaw or teeth may be missing. Occasionally, the matching of photographs with the skull of a suspected victim has been made by a technique known as photographic superimposition. One of the earliest and most widely recognized applications of this method was made in 1935 by Glaister and Brash in their study of the Ruxton Case [*3*].

Before the use of photographic superimposition in the identification of victims in the Ruxton Case [*3*], several attempts were made to fit tracings or photographs of skulls to painted or photographic portraits of famous or infamous people in history (reviewed in Refs *3* and *4*). Lander compared the skull of an individual of known age, race, and sex with a photograph of the individual, but concluded that "It seems improbable that anyone examining the skull would postulate a type of face similar to that seen in the photograph" [*5*]. The first

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documented use of photographic superimposition appears to have been by Derry (reported in Ref *6*), who demonstrated that tracings taken from the photographs of the head and macerated skull of an executed Egyptian criminal could be superimposed to produce a good fit.

In the Ruxton Case [*3*], Brash used the known dimensions of objects present in snapshots or photographic portraits, including a tiara headdress, the outline of the neckline of a frock, the heights of a door gate and wall, and, in one instance, the known focal length of the camera lens to enlarge the photographs of the murder victims to true life-size.

In the absence of objects of known size in antemortem photographs, several workers have combined the use of anatomical landmarks and anthropometric measurements of the facial skeleton with so-called established values for thicknesses of soft tissues to estimate a magnification factor and, thus, obtain a superimposition by best fit [*7–13*]. In some cases, asymmetrical features of the facial skeleton [*8,11*] or presence of a supernumerary anterior tooth (mesiodens) [*14*] facilitated identification by superimposition. More recently, videotaped recordings of mounted skulls and antemortem photographs of victims have been superimposed using an image mixer to achieve a best fit,[3] enlargement of the photograph being determined by visual assessment rather than through the use of a positive magnification factor.

Relatively few workers have followed the example of Glaister and Brash [*3*] in using objects of known size external to the person to establish a magnification factor for photographic enlargement, presumably because such objects are not always present or clear in antemortem photographs. When present, features of articles of clothing that lie in roughly the same focal plane of the face have been used. Enlargements of snapshots or photographic portraits based on the dimensions of the linear pattern of a tie [*15*], the pattern on the border of a saree [*16*], and the diameter of a button on a sweater [*17*] yielded successful superimpositions and positive identifications. Measurements of a wooden chair present in a photographic portrait also yielded a magnification factor from which an accurate enlargement was made [*16*].

Nevertheless, identifications achieved using photographic superimposition have often been viewed with skepticism by forensic science workers and by counsel, judges, and juries in the courts. The comment of Mr. Justice Wrottesley, in his summing up of the *Rex v. Dobkin* (Baptist Church Cellar Murder) case, is typical: "These photographs do not disagree, and if you take my advice you will not regard that as evidence more compelling than that" [*7*]. Critics of the technique cite the difficulties of enlarging an antemortem photograph to true life-size and the problems of accurately positioning the skull of a suspected victim in the attitude represented in the antemortem photograph. According to DeVore,

> It must be strongly emphasized that this method is for general information *only* and cannot be used for positive identification since the magnification and angulation of the original ... picture are unknown.... This method of photographic superimposition is of more value in exclusion than identification [*18*].

Perhaps because photographic superimposition has received less than enthusiastic support, Bernstein's recent review of the application of photography in forensic dentistry [*19*] omits mention of the technique altogether.

We believe, however, that photographic superimposition can have a positive value. The method we recently used in the case of *Crown v. Lam* (the so-called Jar Murders Case; High Court of Hong Kong, March 1983) overcomes some of the difficulties of previous attempts by using selected landmarks of dental remains to compare with visible, in focus features of the dentition in photographs of suspected victims. This is achieved by establishing an accurate magnification factor from measurements of the dentition *before* the matching process is begun. Although visible features of the dentition have been used [*14,20*] or suggested [*21,22*] to facilitate identification through superimposition, precise, systematic *measurements* of visi-

[3]G. Dalitz and R. Bastiaan, personal communication, March 1983.

ble portions of the dentition have never, to our knowledge, been employed to establish the exact magnification factor required to bring the snapshot to the true life-size of the subject.

Method

When a macerated skull is received, thorough visual and radiographic examinations are carried out to determine its age and sex. Attempts are made to recover all teeth missing postmortem. Family snapshots and passport or identity card photographs (with negatives, if possible) are requested from relatives and friends of the suspected victim. From these are selected one or two examples in which the maxillary anterior teeth, particularly, are clearly shown (see Fig. 1). Features of the dentition, visible in the snapshot, which would serve as points of reference for subsequent measurements, are selected from the available anterior dentition of the skull. Measurements between these reference points are recorded (for instance, the distance between two teeth or the length of the incisal margin of a single, isolated, socketed tooth). A slide transparency or negative of the selected photograph is enlarged in a standard photographic enlarger to bring the dimensions of the image of the visible dentition to the dimensions of the chosen measurements in the skull. If the skull belonged to the individual in the photograph, then all other characteristics of the dentition and skull will fall exactly into place when life-sized transparencies from portrait and skull are superimposed. The life-sized transparencies are prepared with a blue-sensitive, medium-speed, high-contrast radiographic film (Kodak® X-Omat RP). The length of the exposure is adjusted to produce a transparency with good contrast and of a density that allows light to be easily transmitted.

It is very important that the life-sized transparency of the skull is prepared from a photograph taken in exactly the same direction as that of the snapshot selected for examination. This presents some difficulties and to overcome them the macerated skull is mounted on a device specially adapted from a "phantom-head" holder (used by dental students), which permits the skull to be rotated in the three planes of space. A centimeter scale is placed on the frontal bone to facilitate subsequent printing to life-size. The photographs of the skull are taken with a Nikon F3 camera with a Nikkor Micro (120-mm) lens, and fine-grained, black-and-white film (Kodak Plus-X® or Ilford® FP4135) is used. The negative of the photograph of the skull is then enlarged and a positive transparency on radiographic film produced, as described above.

Clearly defined features of the skull, including the anterior nasal spine, orbits, zygomatic processes, and mandibular angles and body are traced on matte acetate (Ortho/Trace) from the transparency of the skull. Similarly, facial contours are traced from the transparency of the enlarged snapshot. These transparencies and tracings are then superimposed and illuminated from below on a radiographic viewing box. Registration of dental landmarks is verified and corresponding features of the facial skeleton and soft tissues of the face are noted. The tracings mounted with the transparencies can be used for demonstration of the superimposition using a viewing box or an overhead projector.

Case Report

In August 1982, the Royal Hong Kong Police requested identification of two skulls from three possible victims in the case known as the "Jar Murders."

Skull Z_7

Skull Z_7 was determined to be that of a female, aged 18 $\pm$ 1 years. The estimated age was confirmed by radiographic assessment of the development of the third molars. The dentition was in good condition although Teeth 15, 11, 21, 22, and 23 were missing at the time of the

FIG. 1—*Antemortem photographs of Victim 1* (top), *Victim 2* (bottom), *and Victim 3* (middle).

postmortem examination.[4] Subsequently, Teeth 15 and 23 were recovered and correctly positioned in their sockets.

A cross-bite relationship between the maxillary and mandibular right lateral incisors was

[4]In the *Federation Dentaire Internationale* (F.D.I.) system, natural, human teeth are identified according to their anatomical positions within the jaws. The toothbearing regions of the jaws are divided into quadrants: from the upper right to the lower right, the quadrants are numbered 1 to 4 in the permanent dentition and 5 to 8 in the deciduous dentition. A tooth is noted by its position in the arch relative to the midline; for example, the maxillary right central incisor is 1,1 (or simply 11), the mandibular left first molar is 3.6 (or 36), and the mandibular left deciduous canine is 7.3 (or 73).

noted on the skeletal dentition. Photographs from a family album were selected because they showed the anterior teeth and, when arbitrarily enlarged, disclosed a corresponding cross-bite relationship. It was then noticed that the tips of the cusps of the maxillary canines were particularly clear on the photograph. Because both canines were now present in the skull, it was decided to use the distance between their tips as the measurement from which a life-sized enlargement would be made.

Transparencies and a composite tracing of both skull and portrait were prepared and superimposed (Fig. 2). This resulted in registration of the following features of the dentition:

(1) outline of the labial surface of right maxillary canine (13),
(2) outline of the labial surface of right mandibular canine (43),
(3) outline of the distolabial angle of the right maxillary lateral incisor (12),
(4) outline of the distoincisal angle of the right mandibular lateral incisor (42),
(5) outline of the labial surface and cuspal margin of the left maxillary canine (23), and
(6) the cross-bite of the right maxillary and mandibular lateral incisors (12 and 42).

The distance between the cuspal tips of the maxillary canines (13 and 23) was not used as an identifying feature because it had been used to establish the magnification factor for the enlargement. Similarly prepared transparencies of the skulls of the other victims did not correspond in any way with the enlarged photograph of this victim. Features of the facial skeleton of Skull Z_7 that corresponded to those in the photograph of the face of Victim 1 are indicated in Table 1.

Skull Z_6

Skull Z_6 was determined to be that of a female, aged 30 $\pm$ 3 years. This skull could have belonged to either Victim 2 or Victim 3, aged 29 and 31, respectively. In Skull Z_6 Teeth 11 and 21 were missing postmortem. A very clear snapshot of Victim 3 was available, but the only photographs obtained for Victim 2 were a passport photograph and snapshots in which the subject was indistinct. Of these, the passport photograph just showed the tips of the incisal margins of the maxillary central incisors (11 and 21) (see Fig. 1, bottom). Postmortem photographs of Victim 2 taken by the defendant showed a partial profile of the face, indicating that the upper teeth could have been protrusive. Artificial teeth were constructed to replace the missing 11 and 21 so that the degree of protrusion of these teeth could be estimated. Indentations on the lower lip made by their incisal margins, shown in the passport photograph, aided the visualization of the correct angulation of 11 and 21. The distance between the mesioincisal angles of the lateral incisors were measured and used as the magnifica-

TABLE 1—*Features of correspondence of the facial skeletons of Skulls Z_7, Z_6, and Z_{20} with the superimposed photographic images of the victim's faces, after the features of the dentition had been matched by measurement and superimposition.*

	Skull Z_7 Victim 1	Skull Z_6 Victim 2	Skull Z_{20} Victim 3
Anterior nasal spine	X	X	X
Zygomatic arches (and surrounding soft tissues)	X	X	X
Orbits (and eyes)	X	X	X
Supraorbital ridges (and eyebrows)	X	X	X
Midline of maxilla (between sockets of 11 and 21)			X
Mandibular angles	X	X	
Mandibular body (and surrounding soft tissues)	X	X	
Midline of mandible (between 31 and 41)	X		
Lip line	X	X	
Hair line (estimated)	X	X	X
Overall outline and thicknesses of soft tissues	X	X	X

FIG. 2—*Superimposition of transparencies and tracings of Skull Z_7 with photograph of Victim 1, giving a positive identification.*

tion factor. This measurement also gave an indication of the space available for the upper central incisors.

Superimposition of the transparency of Skull Z_6 with that of a life-sized enlargement of the passport photograph of Victim 2 (Fig. 3) resulted in registration of several features of the facial skeleton with those of the photograph of the victim's face, as listed in Table 1. The photograph of Victim 3 was enlarged so that her two central incisors fitted the corresponding space on Skull Z_6. Superimposition of the transparencies demonstrated that Skull Z_6 could not have belonged to Victim 3 (Fig. 4).

Skull Z_{20}

Four months after Skulls Z_7 and Z_6 were found and identified, Skull Z_{20} was discovered in a small park by a park attendant. Skull Z_{20} was that of a female, aged 35 $\pm$ 5 years. The mandible and the maxillary anterior and premolar teeth were missing. A left maxillary lateral incisor (22) was later found and, when placed in the appropriate socket, was identified as belonging to the skull. The length of the incisal margin of this tooth was used as the magnification factor.

Superimposition (Fig. 5) resulted in exact registration of the following features of the dentition:

(1) outline of the labial surface of the left maxillary lateral incisor (22),
(2) angulation of 22, and

FIG. 3—*Superimposition of transparencies and tracings of Skull Z_6 with photograph of Victim 2, giving a probable identification.*

(3) sockets of the remaining maxillary incisors with the position of the cervical contours of the anterior teeth in the antemortem photograph.

Listed in Table 1 are the features of the photographic image of the face of Victim 3 that corresponded to those of the facial skeleton of Skull Z_{20}.

Discussion

Identification of human skeletal remains from dental records is a common and well established practice. In the absence of dental treatment or dental records, however, one of the few remaining methods by which identification of a skull can be made is photographic superimposition. Several technical refinements of photographic superimposition have been suggested, but none of these has succeeded fully in lending credibility to the technique. In our consideration of the various methods of superimposition for identification of victims in the Jar Murders Case, attempts were made to determine if nondental landmarks, visible in a snapshot or photographic portrait, could be used as points of reference for calibrating measurements. We found interpupillary distance to be unacceptable because of the uncertainties of accurately locating the pupil in a photograph and of correctly placing the pupil within the outline of the orbit. Use of a standard interpupillary distance of 6 cm was suggested by Sekharan [*16*] as the measurement from which life-sized enlargements of antemortem photographs could be made. We tested this claim by measuring the interpupillary distance on

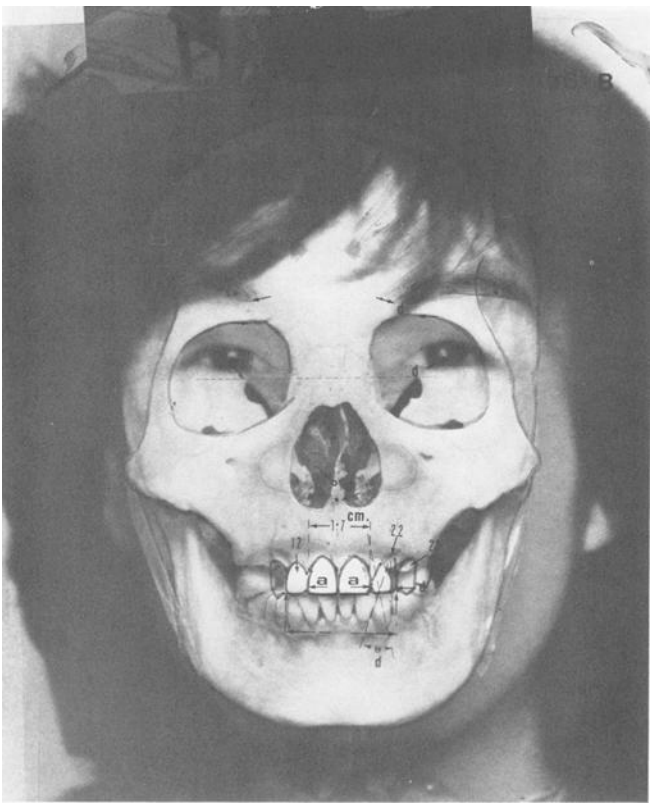

FIG. 4—*Superimposition of transparencies and tracings of Skull Z_6 with photograph of Victim 3, giving a positive elimination.*

75 Chinese subjects between the ages of 19 and 22 years. We found that the interpupillary distance varied widely (57 to 71 mm) in the group sampled. We, therefore, rejected use of an average figure as the basis for photographic enlargement. We also investigated whether correspondence of the lateral canthus of the eye and the lateral margin of the orbit was sufficiently precise to permit use of the distance between the lateral orbital margins of a skull as the calibrating measurement for photographic enlargement. Anteroposterior radiographs of cadaveric heads were taken after small (1.6-mm [1/16-in.]) ball bearings had been inserted into the lateral canthi. Precise registration of the ball-bearing markers in the lateral canthus and the lateral margin of the orbit obtained in only 6 of the 24 heads examined, resulting in our rejection of the lateral orbital margins as reference points for calibrating measurements. Thus, none of our trials using nondental landmarks and measurements proved satisfactory.

In only a few documented cases have intraoral landmarks been used to facilitate identification through photographic superimposition [*14,20*]. Ours is the first study to use clearly visible features of the dentition as reference points for measurements from which life-sized enlargements of antemortem photographs can be made for superimposition.

The photographic superimpositions and composite tracings we prepared as evidence in the case of *Crown v. Lam* were accepted as *positive* identifications by counsel for the defense and the prosecution in the High Court of Hong Kong. Of equal importance, particularly in the context of Chinese culture, was the acceptance of the identifications by the families of the victims.

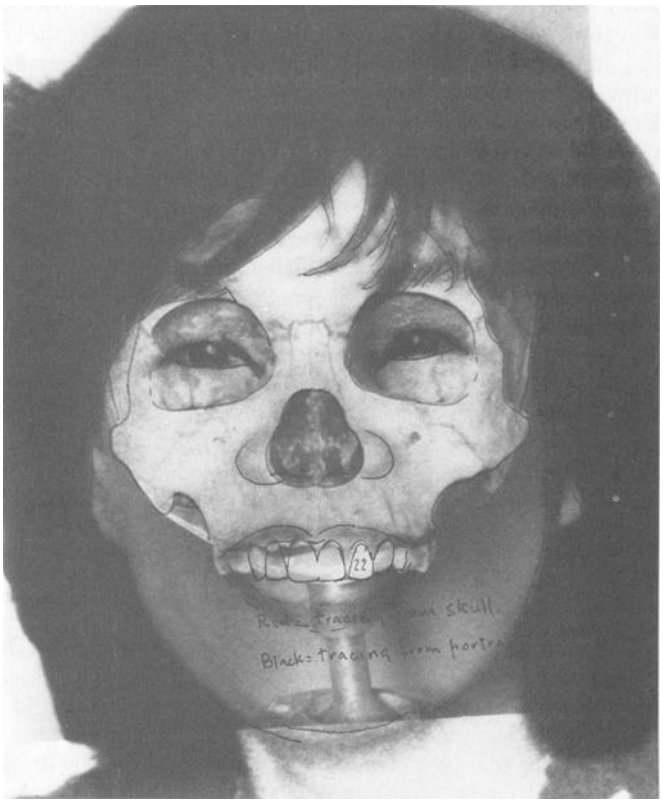

FIG. 5—*Superimposition of transparencies and tracings of Skull Z_{20} with photograph of Victim 3, giving a positive identification.*

The method we describe here for identification by photographic superimposition is reliable, quick, and relatively simple. With this method, truly life-sized enlargements of smiling individuals in photographs can be produced without using objects of known size external to the person to determine a magnification factor. Such objects are frequently out of the focal plane of the camera lens. Furthermore, this method does not rely on the subjective interpretation of anthropometric measurements of the cranium to determine the magnification factor. Photographs showing individuals with toothy smiles are readily available in Hong Kong because of the great popularity of amateur photography. We realize, however, that this situation may not exist elsewhere. In Hong Kong, such photographs have compensated somewhat for the scarcity of dental records in aiding identification of human remains.

Attributes of the human dentition make it highly suitable for use in personal identification. Individual dentitions are unique [B. H. Humble, cited in Ref *23*] and relatively indestructible. Furthermore, as noted by Sprawson, the teeth "may tell one many things about the life-history of the individual which one cannot learn from fingerprints" [*24*]. Although isolated reports of identification by dental means continue to appear in the literature, a system of personal identification based on features of the dentition has yet to be endorsed by medicolegal authorities. A system of identification supplemental to fingerprinting would be highly desirable, especially in cases in which the soft tissues have been mutilated, destroyed by fire, or simply lost through decomposition [*23*].

Variations in the patterns of tooth loss in a dentition alone run into astronomical figures

[25]. Such patterns, combined with information on the morphology of individual teeth, could be used to prove identity. Identification by fingerprints takes advantage of the immense number of possible permutations and combinations of nine basic patterns. Minimum numbers of coinciding features accepted by law have been established over the years in several countries. There seems no reason to doubt that a system of identification based on unique combinations of the features of a dentition would be accepted by governing authorities.

A system of identification based on visible features of dentition would require a photographic record. Even without recourse to amateur photographs, such a record could be compiled with relative ease. Passports with photographs must be carried by international travelers throughout the world. Identification cards with photographs are required in many countries. Although it has been customary to have official photographs taken of an unsmiling subject, we have found no compelling reason to support this practice. If full face photographs were taken of a smiling subject (with maxillary anterior teeth showing), identification of unknown skulls by photographic superimposition would be possible. Photographic superimposition could then be established not only as a method of identification complimentary to fingerprinting, but as means of positive identification in its own right.

Our attempt to influence authorities in Hong Kong to require the subject to smile for the new series of identity cards was met with a polite acknowledgment indicating the difficulties and risks such a request would entail.

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