TECHNICAL NOTE

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Digital Imaging Methods as an Aid in Dental Identification of Human Remains

REFERENCE: Bowers CM, Johansen RJ. Digital imaging methods as an aid in dental identification of human remains. J Forensic Sci 2002;47(2):354–359.

ABSTRACT: The physical comparison of known (*K*) and questioned (*Q*) evidence samples is an accepted tool in numerous forensic identification disciplines (1). A subset of this process is the use of antemortem and postmortem dental radiographs to identify unidentified human remains. This method has been generally accepted for decades (2). The outcome is performed with a considerable degree of accuracy, due in part to a finite pool of possible candidates for identification derived via the NCIC database, passenger lists, and law enforcement Missing Persons reports. This paper describes a dental identification comparison protocol that incorporated digital imaging technology in this process. The computer was used to create digital exemplars of the *K* and *Q* evidence that were spatially and quantitatively compared (3).

The digital mode allowed direct metric and morphologic comparison through the aid of a digital camera, desktop computer, monitor, and printer. The well-known computer program Adobe® Photoshop® 5.0 (4) was used to process the digital information in two forensic cases described in this paper. It is a commercially available digital imaging editing program that is operated on laptop and desktop computers possessing sufficient chip speed and RAM (Pentium II or equivalent and at least 76MB RAM) to open the large-size files generated by high-resolution digital capture devices.

This program accepts raster-based image formats (e.g. .JPG, .BMP). Photoshop® is noted for its diverse imaging functions, which allow the computer monitor to be used as a comparison microscope when *Q* and *K* sample images are tiled side-by-side and/or superimposed. Two and three-dimensional *Q* and *K* evidence samples can be individually digitized and then independently resized to allow two-dimensional comparison. The investigator also has the ability to create magnified images (200% to 300%) when the original digital image has been captured at near photoquality resolution (300 dpi). The visual comparison of physical features on the computer monitor permits a large field of view and robust digital control over image quality. Photographic measurement and enhancement features of Adobe® Photoshop® mimics and in some circumstances surpasses the historic use of conventional photographic manipulation in forensic casework.

This paper presents two cases processed via routine forensic odontology identification protocols. These protocols had minimal results due to limitations described in the case histories. The additional application of digital methods proved useful in the ultimate identification of these human remains.

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Received 24 April 2001; and in revised form 21 June 2001; accepted 21 June 2001.

KEYWORDS: forensic science, forensic odontology, forensic dentistry, computers, Adobe® Photoshop®, digital, radiograph, dental identification, physical comparison analysis

Case One History

The postmortem evidence was a lower right human jaw fragment containing only two molar teeth (Universal numbering system: #30 and #31). Tooth #30 had separate occlusal and buccal amalgam restorations. Tooth #31 had an occlusal amalgam restoration. A check of Missing Persons lists that fit the known physical and circumstantial parameters of the deceased provided one set of antemortem records. These known antemortem records consisted of a written treatment record and four bitewing radiographs. These records predated the discovery of the human remains by ten years. The antemortem radiographs showed Tooth #30 with a buccal (or lingual) metallic restoration (most likely amalgam). These dental restorations provided no help with the identification process due to: 1) the age of the antemortem records and 2) additional restored surfaces seen in the postmortem remains.

Materials and Methods

The postmortem dental remains were radiographed at three different angles. This produced one x-ray that approximated the tooth angulation seen in the antemortem radiograph selected for analysis. The antemortem and postmortem radiographs were placed on a light-box and photographed with a Nikon® CoolPix 950 digital camera. The resultant images were imported into the imaging program via a Scandisk® drive on a Dell® Dimension XPS 7500 computer. Figure 1 shows one antemortem and one postmortem image that were selected for comparison based on their physical similarity and the commonality of both having Teeth 30 and 31 present. Specific menu and keyboard commands will be described in sequence starting with the top menu bar name (e.g., Image > Rotate > Arbitrary).

Once digitized, both images were opened in the imaging program, adjusted to equivalent resolutions (300 dpi), and placed side-by side (tiled) on the computer monitor. Present in both images was the CEJ (cemento-enamel junction) of Tooth #31. This feature was chosen as the mutual horizontal plane of orientation. Figure 2 shows a line connecting the respective mesial and distal CEJ of 31 before digital rotation to the same x-axis. This x-y orientation was necessary to use the image program's digital resizing capabilities.

Each radiograph digital rotation was done using the image program's Measure Tool to achieve the proposed alignment (Image

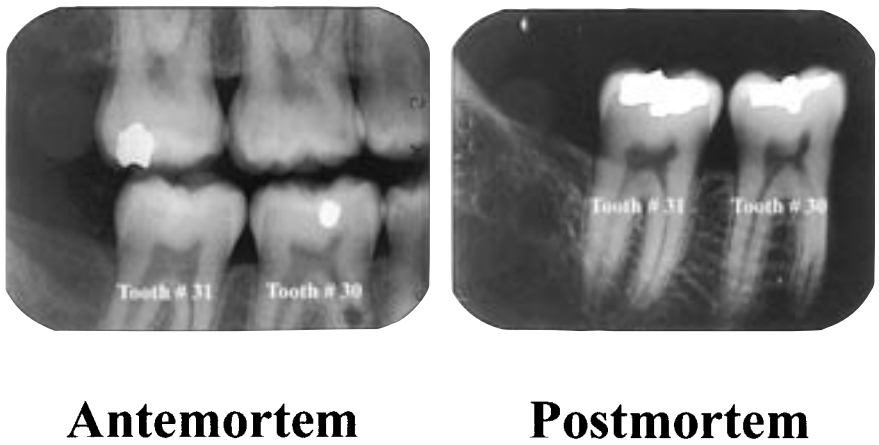


FIG. 1—*Antemortem and postmortem radiographs used for comparison.*

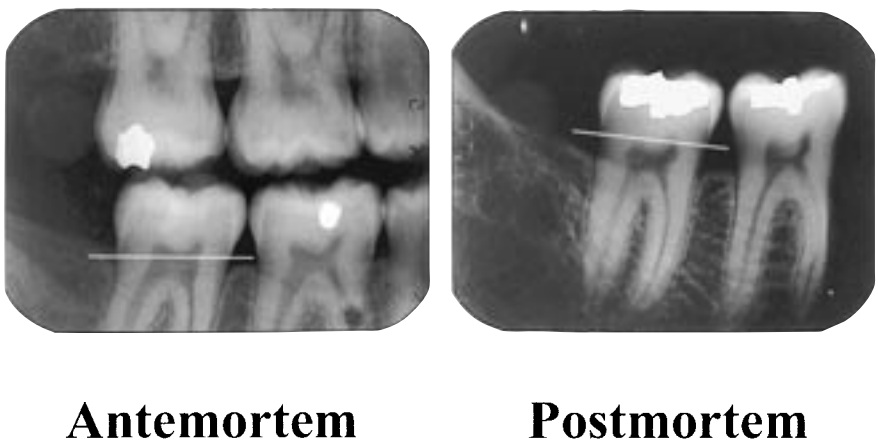


FIG. 2—*Antemortem and postmortem radiographs with white lines drawn through the CEJ of Teeth 30 and 31. These lines defined the x-axis when the images were rotated.*

> Rotate Canvas > Arbitrary). The program rotated each image to create an identical orientation of the CEJs for the antemortem and postmortem evidence (Fig. 3).

The antemortem CEJ dimension "A" was selected as the resize control and calculated in centimeters by the Measure Tool. The postmortem CEJ dimension "a" was similarly measured (Figs. 4 and 5). The ratio A/a was used to resize the postmortem image to match the antemortem CEJ dimension. Metric analysis was carried out for two non-age dependent parameters for each image's root system: 1) root furcation heights, measured from the height of the furcation to the level of the CEJ ("B," "b") and 2) distal root divergence angles ("C," "c").

These parameters were measured for Teeth #30 and #31 in both the antemortem and postmortem radiographs. The results were compared (Table 1).

The postmortem image was moved onto the antemortem image for a shape comparison evaluation (Fig. 6). The images were superimposed using the CEJ planes as the common reference. Changing the opacity of the postmortem (top) layer allows visualization of the similarities and differences between the two images.

Case Two History

The unidentified human remains consisted of a complete maxilla and mandible with all adult teeth present. The only restoration present was a distal pit amalgam on Tooth #3. (Fig. 7). The known dental records obtained for comparison belonged to a female sub-adult dated seven years earlier (Fig. 8). The antemortem radiographs (four bite-wings) showed predominantly primary teeth present with the exception of all four permanent first molars. A distal pit metallic restoration (likely amalgam) was present on Tooth #3. All other teeth present within the radiographs were unrestored and unremarkable. The identification focused on Tooth #3 due to the fact that the primary dentition had exfoliated, the scarcity of restorations present, and the paucity of antemortem records.

The antemortem radiograph was severely elongated due to improper angulation of the x-ray beam. The postmortem radiograph showed a more normal orientation. Despite these differences, the restorations did show similarities in relative shape.

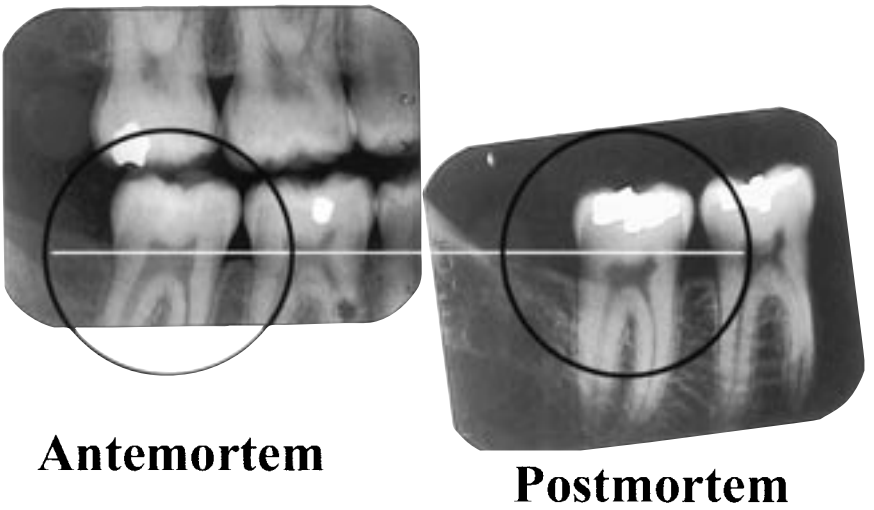
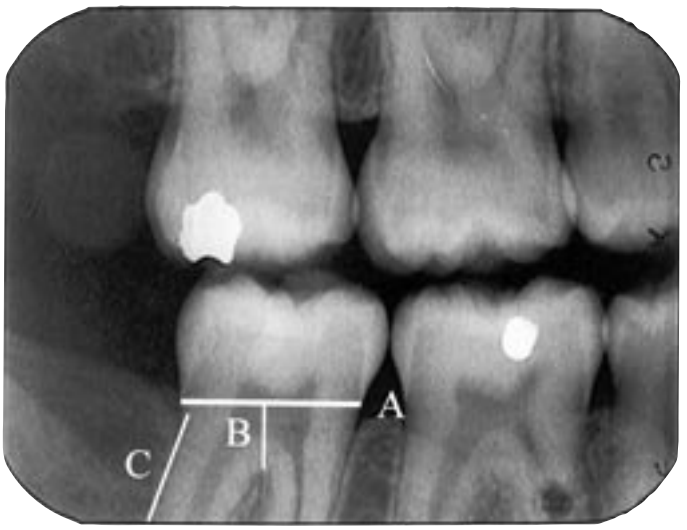


FIG. 3—*Post-rotation images with the CEJ of Tooth 31 defining the x-axis.*



Antemortem

FIG. 4—*Antemortem image showing the CEJ dimension "A," root furcation height "B," and distal root divergence angle "C."*

Postmortem

FIG. 5—*Postmortem image showing CEJ dimension "a," root furcation height "b," and distal root divergence angle "c."*

Materials and Methods

The antemortem and postmortem radiographs were digitized and imported into Photoshop® as described in Case 1. The postmortem radiograph image showed more contrast and therefore was chosen for selection and superimposition over the antemortem radiograph.

The postmortem restoration was selected using the Magic Wand tool at multiple Tolerance settings (32 is the program default setting). With the selections complete, its edges were then slightly smoothed (Select > Modify > Smooth 2 pixels) to eliminate edge irregularities. This selection was filled with a black color (Edit > Fill). The selection was moved onto the antemortem radiograph image by the Move tool.

TABLE 1—*Comparison of results in the antemortem and postmortem radiographs.*

Antemortem			Postmortem		
A	B	C	a	b	c
(cm)	(cm)	(degrees)	(cm)	(cm)	(degrees)
2.24	**0.82**	**70.3**	**2.24**	**1.32**	**88.0**

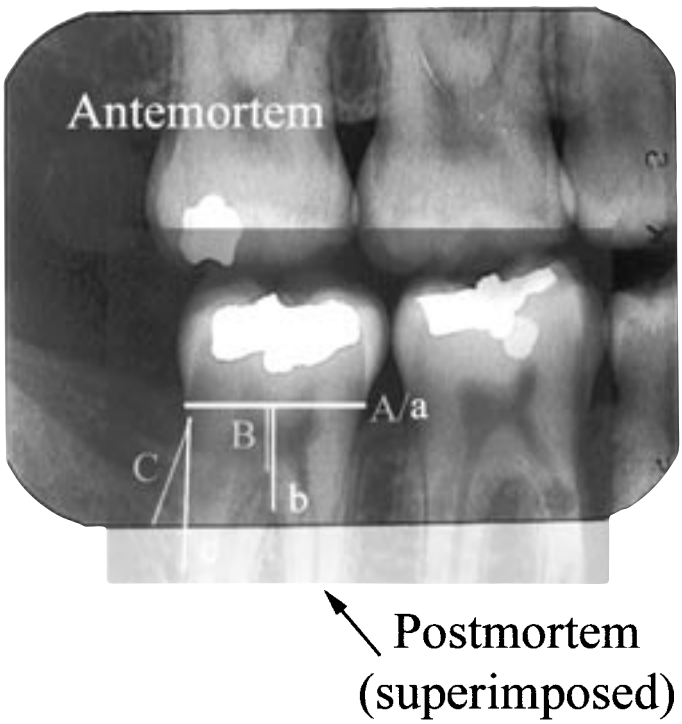


FIG. 6—*Superimposition of the postmortem radiograph onto the antemortem radiograph.*

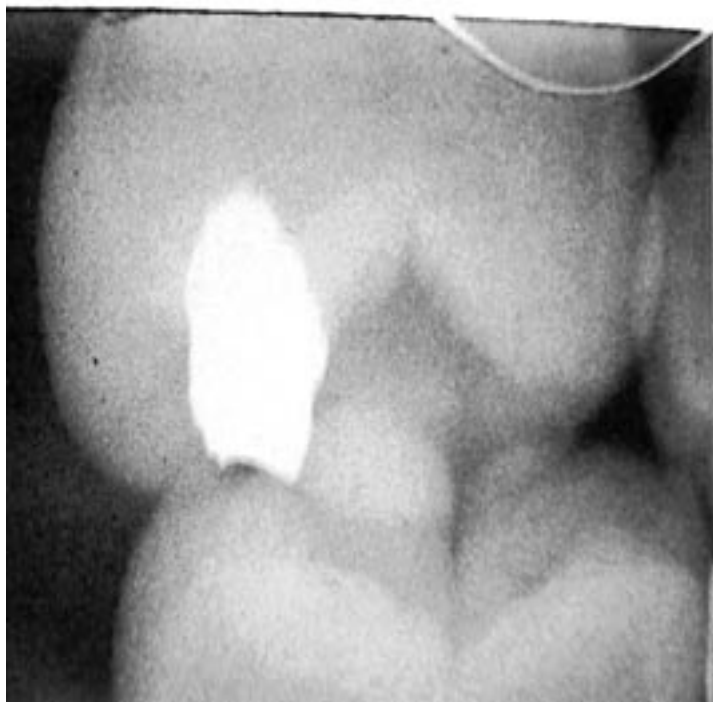


FIG. 8—*Antemortem radiograph showing a metal dental restoration in Tooth 3.*

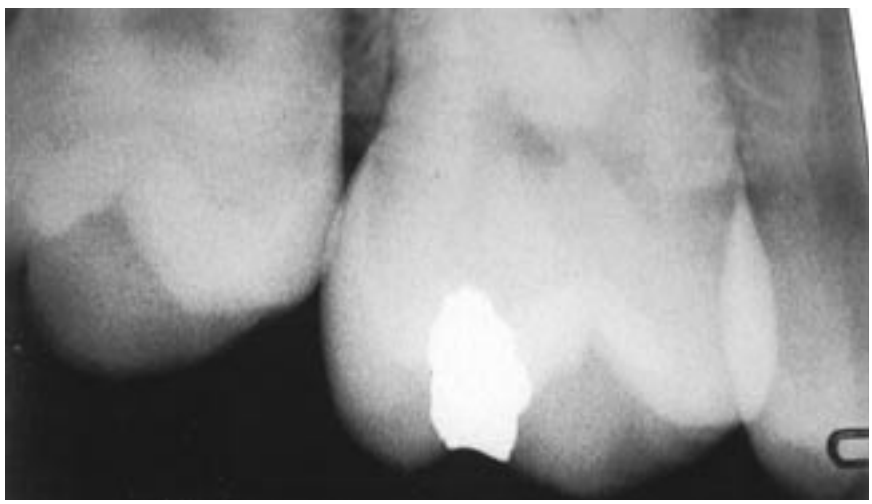


FIG. 7—*Postmortem radiograph showing a metal dental restoration in Tooth 3.*

The next step used Adobe® Photoshop® to digitally elongate the postmortem radiograph to approximate the antemortem radiograph. A Transform box (Edit > Free Transform) was placed around the active layer containing the postmortem restoration. The restoration shape within this box was adjusted via moving the top, bottom, and side anchor points (Fig. 9). The aim of these adjustments is to duplicate theta values along the x and y axes of the antemortem radiograph. The corner anchor points were not adjusted in order to avoid lateral distortion of the image. Placing the cursor outside the transform box displays a double-headed arrow. This arrow was used to rotate the postmortem restoration image to its proper position. This transform procedure was repeated until the postmortem restoration image was oriented within and slightly smaller than the antemortem restoration image. The relative shapes of the antemortem and postmortem restorations could then be compared for concordance and/or dissimilarities (Fig. 10).

Results

Case 1

Initially there were several promising similarities between the antemortem and postmortem radiographs. Subsequent digital analysis, however, revealed significant discordance of dimen-

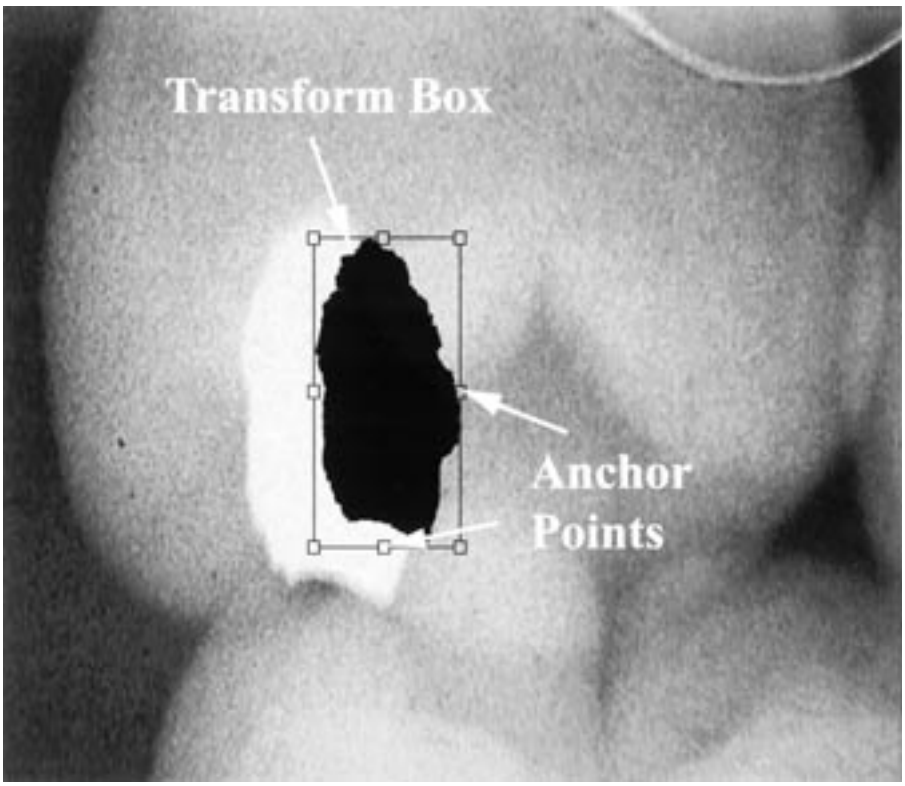


FIG. 9—*The Transform Box anchor points allow shape change of the postmortem (black) restoration along its x, y-axes.*

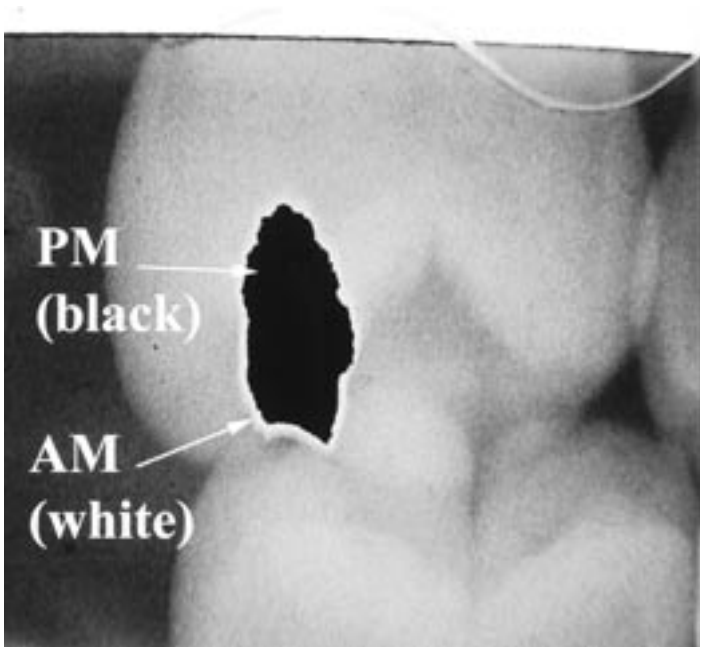


FIG. 10—*PM is the postmortem restoration shape. AM is the antemortem restoration shape.*

sional values. The distal root divergence angle differed by 12.8 degrees. The root furcation height differed by 32%. Based on these factors alone, it was concluded that the antemortem dental records and postmortem dental evidence did not come from the same individual.

Case 2

Similarities in shape were noted when the postmortem restoration image was brought onto the antemortem image and aligned within the corresponding restoration. The edge values for the postmortem restoration remained constant as the Transform adjustment simply elongated the image along the x and y axes and did not affect the transverse outline of the restoration. It was concluded, based on the spatial comparison of the restoration on Tooth #3, and the physical characteristics of the human remains (sex, age, height, etc), that the antemortem and postmortem dental evidence originated from the same individual.

Conclusions

These cases demonstrate some of the difficulties that can be encountered when the antemortem and postmortem evidence are chronologically diverse. The ability to digitally resize antemortem and postmortem radiographs enables the investigator to accurately measure and superimpose static physical dental features seen in the *Q* and *K* samples. This information can be helpful where there are few restorations and limited antemortem radiographic documentation. The comparison of dental anatomy is particularly subtle when root shape is the only common reference between the postmortem and antemortem evidence.

In total, these digital imaging methods have proven to be useful tools in equivocal cases involving dental identification of human remains.

References

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4. Adobe Systems, Inc., 801 N. 34th St., Seattle, WA 98103. Photoshop 6.0 version is currently available.

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