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Digital Analysis of Experimental Human Bitemarks: Application of Two New Methods

ABSTRACT: Bitemark determination in forensic odontology is commonly performed by comparing the morphology of the dentition of the suspect with life-sized photographs of injury on the victim's skin using transparent overlays or computers. The purpose of this study is to investigate the suitability of two new different methods for identification of bitemarks by digital analysis. A sample of 50 volunteers was asked to make experimental bitemarks on the arms of each other. Stone study casts were prepared from upper and lower dental arches of each volunteer. The bitemarks and the study casts were photographed; the photos were entered into the computer and Adobe Photoshop software program was applied to analyze the results. Two methods (2D polyline and Painting) of identification were used. In the 2D polyline method, fixed points were chosen on the tips of the canines and a straight line was drawn between the two fixed points in the arch (intercanine line). Straight lines passing between the incisal edges of the incisors were drawn vertically on the intercanine line; the lines and angles created were calculated. In the painting method, identification was based on canine-to-canine distance, tooth width and the thickness, and rotational value of each tooth. The results showed that both methods were applicable. However, the 2D polyline method was more convenient to use and gave prompt computer-read results, whereas the painting method depended on the visual reading of the operator.

KEYWORDS: forensic science, forensic odontology, bitemark, study cast, digital analysis, identification, incisal edges, intercanine line

Bitemark records in forensic odontology occasionally facilitate the identification of assailants by comparing their dentition through bitemarks left on victim's body or food stuff, relying on the fact that no two mouths are alike (even identical twins are different), and that teeth may leave recognizable marks. A bitemark, however, is not an accurate representation of the teeth. A lot depends on the mechanics of jaw movement and use of the tongue. Inside the mouth, the lower jaw (mandible) is movable and usually delivers the most biting force, whereas the upper jaw (maxilla) is stationary, holds, and stretches the skin. Some bitemarks usually show curvatures where the upper and lower teeth made impressions (1).

The most common methods for determination of bitemarks include techniques to compare the morphology of the dentition (shape, size, and position of teeth, together with the shape of the dental arches) with similar traits and characteristics present in life-sized photographs of the injury using transparent overlays or computers (2–4). Other comparison methods include the direct comparison of the suspect's study casts with photographs of the bitemark, comparison of test bites produced from the suspect's teeth with the actual bitemark, and the use of radiographic imaging (5) and scanning electron microscopy (6,7).

In the present study, we investigated the validity of computer-aided digital methods of comparison on experimental human bitemarks. The final goal of the study was to identify the suspect from his bitemark on the skin of a living human victim.

Materials and Methods

The sample consisted of 50 volunteers who were dental students; their ages ranged between 21 and 25 years. All volunteers signed consent before their participation in the present project. The participants were asked to bite the arms of each other with moderate force without causing serious injury to the tissues. The total number was 50 bitemarks "victims" and 50 "suspects."

After the bitemark was created, photographs were taken using a digital camera according to the standards and guidelines adopted by the American Board of Forensic Odontology (8–10), in which two perpendicular rulers were placed at the same plane of the bitemark and the digital camera was placed at a fixed distance using a special holder positioning the back of the camera in the same plane to the bitemark and the two rulers. Distortion of the image was avoided as much as possible. Two light sources from two directions were fixed to avoid any shadow in the photographs. Several photos were taken for each bitemark to select the most appropriate photo for the comparison procedure.

Following photography, alginate impression was taken for the bitemark. This was done by mixing the alginate to a soft texture and placing in a special acrylic tray. After setting of the alginate, the impression was removed and photographed. The impression was poured with stone, and a study cast (model) was prepared and photographed. Finally, alginate impression was taken for the suspect's dentition and a study cast was prepared and photographed (Fig. 1*a–c*). All parameters used in the present study were labeled in such a way that only one investigator knows the key.

Photos and study casts of the 50 bitemarks on the "victim's" body and the 50 "suspects" were stored in the digital camera.

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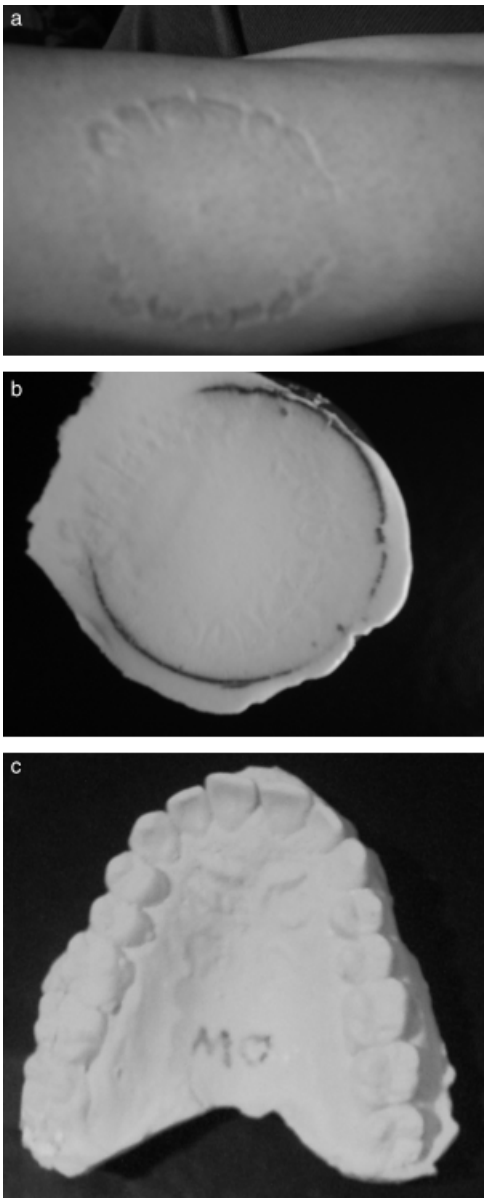

FIG. 1—*(A) bitemark, (B) alginate impression of the bitemark, (C) study cast (stone model) of the suspect upper "maxillary" dentition.*

All the photos from the digital camera were transferred to the computer.

Two analytic methods of comparison were applied.

2D Polyline Method

In this method, a special software program (Adobe Photoshop) was used. Using the tools of this computer program, fixed points were chosen digitally on the tips of the canines and a straight line was drawn between the two fixed points in the arch (intercanine line). Straight lines passing between the incisal edges of the incisors were drawn vertically on the intercanine line. Then, straight lines were drawn on the incisal edges of each incisor; each line indicated the mesiodistal width of the tooth. Accordingly, 13 variables in each arch (four lines, eight angles, and the intercanine distance) that can be measured mathematically were available in both the suspect and the victim (Fig. 2).

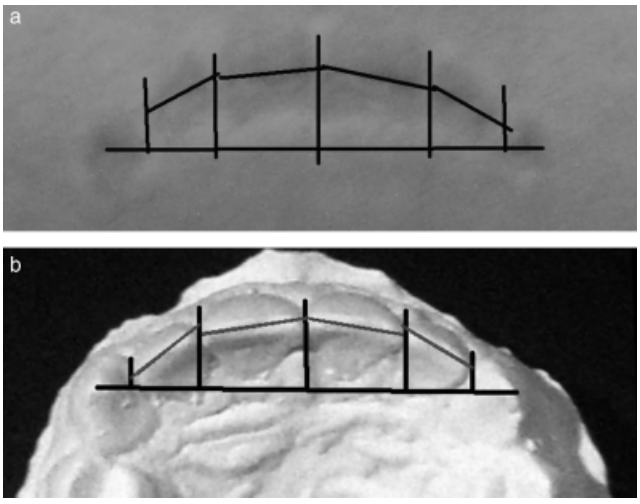

FIG. 2—*2D polyline method: digitally created lines and angles on (A) bitemark, (B) study cast.*

A computer-generated overlay was established to compare the variables in both the study cast and the bitemark. The comparison was made by overlapping the two digitally created figures. The lines and angles in both geometrical figures were measured and the comparison was peformed mathematically.

Painting Method

Study casts from the suspect's dentitions were prepared and incisal edges were painted with red glossy paint (Fig. 3). The painted models were then photographed and transferred to the computer. The software program used in this method was also Adobe Photoshop. A negative filter was used to simulate the histograms of both the bitemark and the cast (Fig. 4).

Identification by this method was based on the following criteria:

1. Canine-to-canine distance.
2. Tooth width (mesio-distal).
3. Rotational angles of each tooth (measured in degrees).

The canine-to-canine distance was considered as one variable. Tooth width (four incisor teeth) was considered as four variables.

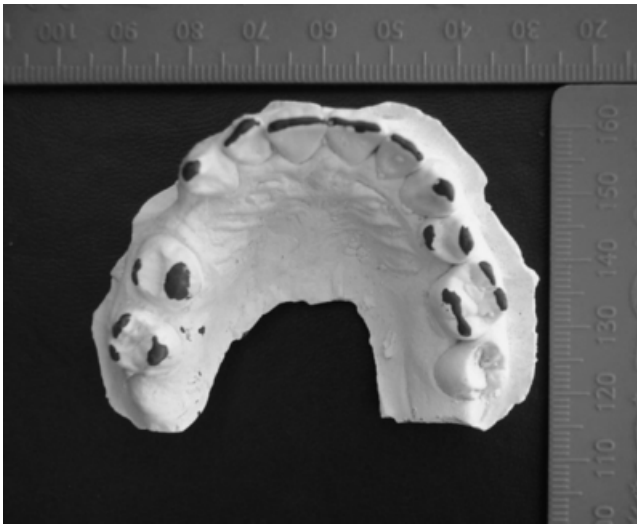

FIG. 3—*Painting method: painting the incisal edges before photography.*

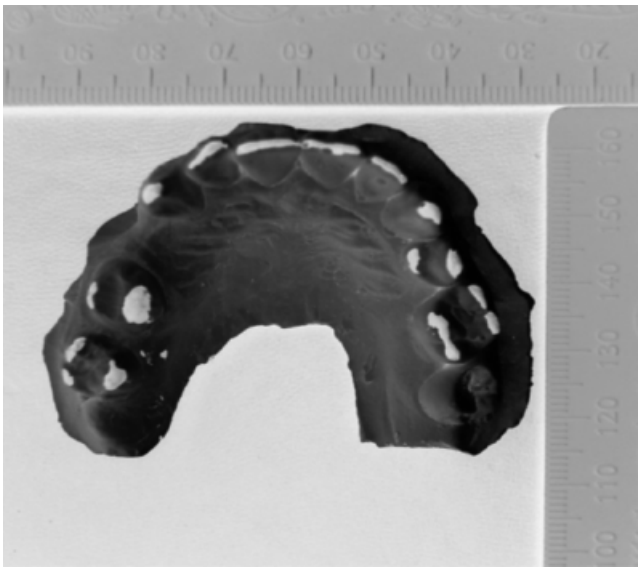

FIG. 4—*Painting method: the painted cast after negative filter application.*

Rotational angles of these teeth added eight variables. Accordingly, the total no. of variables became 13 in each arch.

In this method, the variables were compared visually (Fig. 5) and the matching variables were calculated in both the study cast and the bitemark photos.

Results

After the application of the 26 variables on the suspects according to both the 2D polyline and painting methods, the number of matched variables were divided into groups of five (Figs. 6 and 7).

These groups were subjectively named according to the number of variables as "definite, probable, possible, weak and excluded." The number of matched suspects who scored maximum variables (between 21 and 26) was two in the 2D polyline method and four in the painting method, whereas the number of matched suspects who scored minimum variables (between 0 and 5) was 30 in the 2D polyline method and 25 in the painting method (Tables 1 and 2).

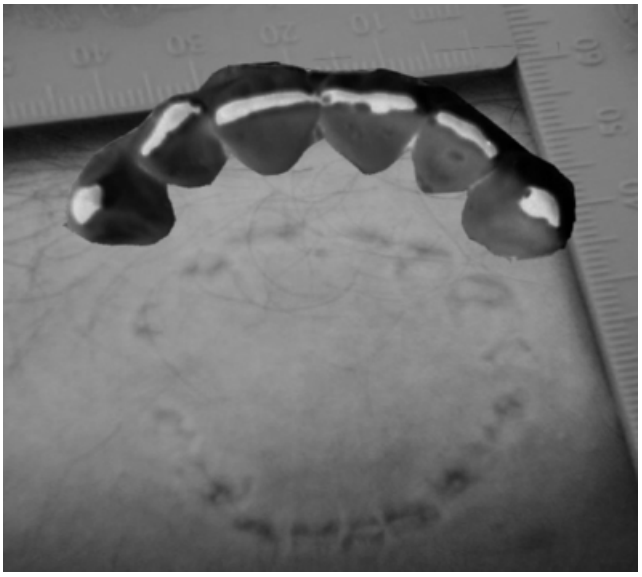

FIG. 5—*Painting method: comparing the incisal edges of the anterior teeth of the study cast with the bitemark.*

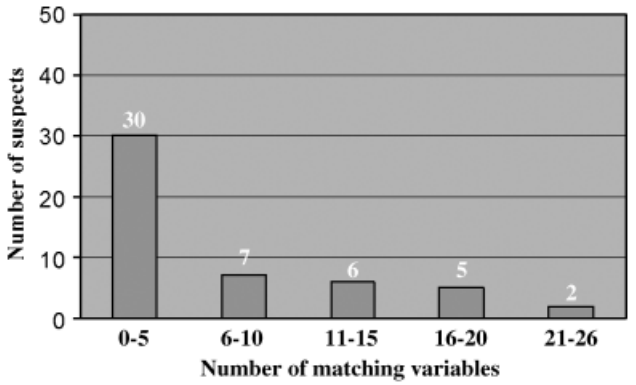

FIG. 6—*Distribution of suspects according to the number of matching variables in the 2D polyline method.*

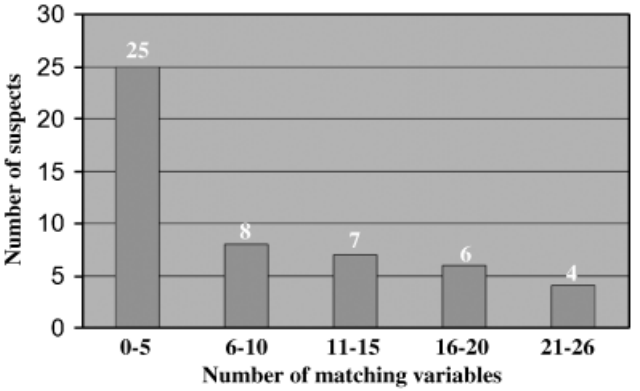

FIG. 7—*Distribution of suspects according to the number of matching variables in the painting method.*

Discussion

Bitemark is one of the tools of identification in forensic odontology. The possibility of errors or mismatching makes this important tool less reliable. The main factors that affect the accuracy of bitemark identification are as follows:

1. Time changes of the bitemark on living bodies.
2. The effects of the anatomical topography of different parts of the body on the shape of the bite.

TABLE 1—*Summary of the 2D polyline method.*

	Amount of Acceptable Difference between Bitemark and Cast				
Level	Upper and Lower Intercanine Distance (mm)	Width of Lower Incisor (mm)	Width of Upper Incisor (mm)	Rotational Angle	Matching
1	0.5	0.5	1	2°	Definite
2	1	1	1.5	4°	Probable
3	1.5	1.5	2	6°	Possible
4	1.5	1.5	2	8°	Weak
5	>1.5	>1.5	>2	>8°	Excluded

TABLE 2—*Summary of the painting method.*

Level	Score	Matching
1	21–26	Definite
2	16–20	Probable
3	11–15	Possible
4	6–10	Weak
5	0–5	Excluded

3. Distortion of the soft tissue caused by the force of the bite.
4. Gross similarities in dentition among individual.
5. Technical problems in photography, impression taking, and measurement of the distances of the dentition.

Precise and reliable methods became necessary for accurate identification of bitemarks. In the present study, two computer-aided programs are described: the 2D polyline method and the painting method.

The 2D polyline method depends on the measurement of lines and angles in individual teeth and arches, whereas the painting method depends on overlaying the images of the incisal edges.

The painting method is a modification of the method described by Sweet et al. (3). This modification was by painting of the incisal edges of the study cast before introduction into the computer.

From the results of the present study, one can conclude that the two described methods are applicable and reliable. However, the 2D polyline method was more convenient to use and gave prompt computer-read results whereas the painting method depended on visual reading of the operator. The bias of the visual examination in the painting method was excluded when the 2D polyline method was used because the measurements in the arches were performed by overlaying the lines and angles of the editable photos of the bitemark and the study cast. The present work is based on methods tested on bitemarks made by and on volunteers; these bitemarks are different from those made by assailants on victims or vice versa in terms of tissue damage and shape of the bitemark, which make the measurements more difficult. However, the methods described in the present investigation are obviously more accurate than those described previously and can be conveniently applied in real forensic cases requiring identification of bitemarks.

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