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Uniqueness of the Dentition as Impressed in Human Skin: A Cadaver Model*

ABSTRACT: Bitemark interpretation assumes that the human dentition is unique and that its attributes can be accurately transferred to skin. A cadaver model was used to investigate whether the correct biter could be determined from similarly aligned dentitions once the dentitions were impressed in human skin. One-hundred dental stone models, which were measured and determined to be unique, were divided into 10 groups based upon similarities of mal-alignment patterns. One model was randomly selected from each group and bites were produced on unembalmed human cadavers. Metric/angular measurements and hollow volume overlays of the models were compared with the bites made. The percentage of dentitions from each group as well as the 100 dental model population that could not be excluded as the biter was determined. Results showed difficulty distinguishing the biter from individuals with similarly aligned dentitions and in some cases, an incorrect biter appeared better correlated to the bite.

KEYWORDS: forensic science, forensic odontology, bitemarks, bitemark research, skin, dental uniqueness

Bitemark comparison is based on two fundamental assumptions. The first is that the human dentition has class characteristics of shape, size, and pattern, as well as individual characteristics within the arch alignment that render it unique (1). The second is that the skin records those characteristics with sufficient resolution to identify, include, or exclude the perpetrator (1–4).

Published studies on the uniqueness of the dentition stress differences between sample dentitions (5–7). Some of these differences can be minute (7). Indeed, some of the reported differences used to describe the individuality of the dentition can equate to a few degrees of rotation or small spatial measurements between teeth. The question then becomes whether these small differences are sufficient to distinguish between dentitions when the teeth are impressed on skin.

Previous work demonstrated distortion ranges of up to 80% in angle of rotation between teeth, 27% in inter-canine distance, and 42% in mesial to distal dimensions in a bitemark as compared with the dentition that caused the injury (8–10). Those studies showed instances of dramatic differences in bitemark appearance based upon body location and/or post-infliction postural movement (8,10). If, for example, the definition of uniqueness between two dentitions is a 5% difference in measurable parameters and the effective distortion is 20% for those parameters, then the distortion after impression in the skin exceeds the defining measurement of dental uniqueness; in other words, the defining measurement of uniqueness would be lost in this circumstance.

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Skin with its varying biomechanical properties is less than ideal to accurately record the dentition (10–16). Further, it is indisputable that a degree of distortion is always present in a bitemark on this medium. The amount of distortion can vary significantly based upon skin tension lines, anatomical location, underlying tissue structure, movement during and after bitemark infliction, and clothing among other factors (4,10–16). These variables can alter the transference of dental characteristics to skin including tooth size, inter-canine distance, and rotation of teeth (10,17–21). Thus, as a dentition is impressed into skin the resolution of the representation of the dentition is reduced. There is, therefore, a potential for bitemark perpetrator misidentification in a broad population of similarly aligned dentitions.

Studies have revealed the frequency of mal-alignment in a population (22). Dental crowding, especially of lower anterior teeth, is frequently encountered and may be classified into discrete common patterns. In a study of 7000 individuals, 15–50 years of age, it was shown that 50% of the population had a zero mandibular incisor irregularity index, 23% had clinically significant irregularity, and 17% had severe irregularity (23). Thus on the basis of the 2000 U.S. census, there may be *c.* 56 million individuals in the U.S. who are 15–50 years of age with clinical crowding and *c.* 24 million with severe crowding (23).

These numbers suggest a large population with the potential for similar dental patterns. Furthermore, following orthodontic treatment, the anterior dental pattern becomes much more homologous, creating a large group of similarly aligned dentitions. As orthodontic treatment is further utilized, one may expect this population to increase. This added difficulty in bitemark perpetrator identification from pre- to postorthodontic treatment was confirmed in a study by Dorion (4,24).

One goal of this study was to determine perpetrator identity within groups of similarly aligned dentitions. Does skin distortion allow for multiple suspects that cannot be excluded as perpetrator? The second goal was to determine how many individuals from a larger sample population of varied alignments could not be ruled out as perpetrator. Thirdly, is pattern distortion sufficient to rule out the biter, yet include a non-biter?

Materials and Methods

Human Subject Review Board (HSRB) exemption was granted for this project for both polyvinylsiloxane (PVS) impression collection and cadaver use. Three hundred and thirty-four upper and lower PVS impressions were randomly collected at the State University at New York School of Dental Medicine. These impressions were from the patient pool at the dental school clinic and were taken for fabrication of dental prostheses. The clinic patient pool represents a varied demographic cross-section of ages 18–90+ years. Because this was a random collection, age, gender, and race were unknown to the authors. Of these impressions, one hundred lower impressions were selected. The criteria for inclusion were an impression that satisfactorily recorded the lower anterior dentition (#22–#27) and that that the dentition had a full complement of teeth from #22 to #27.

All one hundred lower models were poured in Jadestone (Whip mix, Louisville, KY). The material was spatulated with a power driven mixer under vacuum (Vacuspat; Whip mix). Jadestone was selected for its accuracy of reproduction (50 μm ± 8) and compressive strength (97 MPa) (25). The models were allowed to set for at least 2 h prior to removal from the impressions. The models were scanned on a flatbed scanner (Hewlett Packard 6100/CT) at 300 dpi. Using Adobe Photoshop®, the scanned images were sized 1:1 and hollow volume overlays constructed (26–28).

Metric/angular analysis was performed with Adobe Photoshop® (26). Mesial to distal width, inter-canine arch distance, and angle of rotation was measured and recorded for teeth #22–#27. The angle was measured by differences in rotation of the mesial-distal axis between teeth.

Mal-alignment patterns were evaluated with frequency recorded ranging from a relatively straight dental arcade to severe lower anterior crowding. The models were then subjectively grouped by similarity of mal-alignment pattern by consensus of two investigators who were both dentists with dental experience of 10 and 24 years, respectively. The distribution resulted in 10 categories (Table 1).

One biter was randomly selected from each group. Each selected lower model was mounted on a hand held vice grip with a single upper cast used for all bites. The bite indentations of the upper model were not measured.

Three cadavers were acquired following rigor mortis, stored at 4°C, and allowed to warm to ambient room temperature with condensation removed. Bites were impressed on the arm, forearm, and thigh. Following bitemark infliction on naked skin, it was photographed in the same position of occurrence thus avoiding postinfliction distortion resulting from bodily movement. All photography occurred within 10 min of bite production.

The resultant indentations were photographed with a Canon Rebel XTi 10.1 MP digital camera with an ABFO No. 2 scale placed in all photographs. Using Adobe Photoshop®, metric and angular analysis was performed on each photographed bite (26). The buccal to lingual measurement was not used as many bites incorporated portions of the lingual surface that was at times difficult to delineate. The bite measurements were compared with the dentition in each test group and percentage differences in measured parameters calculated.

Each dental overlay from the group was compared with the bite. In addition, hollow volume overlays from the entire 100-model sample were compared with each bite. Bitemark overlays that closely resembled the biter's dentition were chosen by one examiner. A subsequent examiner was asked to determine which dentitions could not be excluded as the biter from the sample provided. The samples were shown to no less than 10 individuals whose experience ranged from dental student to dentists with many years' experience in forensic odontology. The percentage of suspects that could not be excluded is listed in Table 2.

Results

The degree of distortion varied between bites. Areas of the body were chosen to minimize distortion as determined in a previous study (10). Thus muscular areas such as the arm and leg were used as bites in muscle showed the least amount of distortion (10). Table 2 lists the degree of distortion for inter-canine width, mesial to distal width and angle of rotation between teeth. The percentage of individuals for each group as well as within the 100-sample population that could not be ruled out as the biter, was calculated.

In some instances, distortion merely constricted or elongated the bite pattern. Bites were inflicted both parallel and perpendicular to tension lines. The bites that appeared constricted were inflicted parallel to skin tension lines. Two of the bites were inflicted parallel to tension lines. Eight bites were inflicted perpendicular to tension lines. The distortion patterns were consistent with results from previous studies (10,29,30).

In some instances, the distortion was enough to suggest a different appearance to the biter's arch pattern. Figure 1 shows a bite inflicted by a dentition that appears to have the central incisors rotated mesially, giving a "v" shape configuration. Indeed, tooth #24 (lower left central incisor) appears to be almost perpendicular to the curvature of the arch. In Fig. 2, an overlay with a severely rotated #24 is placed on the bite. Figure 3 demonstrates a "v" shape central incisors' alignment; however, the bite was not produced by either dentition. Figure 4 shows the biter overlay to the bitemark photograph. Tooth #24 is only slightly mesially rotated while teeth #26 and #27 are slightly wider than the arch form of the bite. There is no distortion in the inter-canine width for this bite.

Figure 5 shows a bite with a lingually placed #25 and three "similar" dental overlays. Although the biter, as seen in Fig. 6, possesses a lingually placed #25, this is not as lingually placed as suggested by the bite.

TABLE 1—*Group number, number of models in each group, and mal-alignment type.*

Group Number	Number of Dentitions in Group	Mal-Alignment Pattern
1	7	Mesially rotated central incisors
2	9	Incisors alternating buccal and lingual
3	10	Central and lateral incisors with a left incisal slant
4	11	Mildly mal-aligned
5	8	Moderately mal-aligned
6	7	Significantly mal-aligned
7	9	Mildly mal-aligned with a rotated right canine
8	8	Mildly mal-aligned with significant occlusal wear
9	23	Relatively straight
10	8	Relatively straight with buccally displaced lateral incisors

TABLE 2—*Direction of bites inflicted according to existing tension in skin, changes in measurements, and percent of population that could not be ruled out as the biter.*

Bite Number	Parallel or Perpendicular to Tension Lines	Mesial to Distal Difference	Angulation Difference	Inter-Canine Difference	Percent from Group %	Percent from Sample Population %
1	Parallel	18% decrease	32% steeper	0%	86	12
2	Parallel	13% decease	23% steeper	4.2% decease	22	3
3	Perpendicular	15% decrease	16% flatter	8.5% decrease	50	11
4	Perpendicular	14% decrease	8% flatter	6% increase	67	16
5	Perpendicular	46% decrease	28% flatter	13% increase	71	7
6	Perpendicular	Could not measure	–	–	–	–
7	Perpendicular	4.2% decrease	0.5% flatter	0.7% increase	11	6
8	Perpendicular	Could not measure	–	–	–	–
9	Perpendicular	11% increase	11% flatter	11% increase	75	12
10	Perpendicular	10.3% increase	30.7% flatter	6.9% increase	19	4

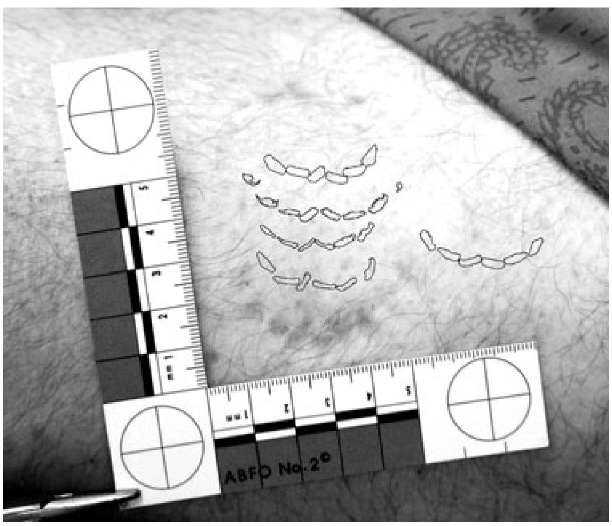

FIG. 1—*This bite suggests a "v" shaped appearance to the lower central incisors. There are four overlay patterns above the bite and one to the right of the bite.*

FIG. 2—*An overlay with #24 lingually angulated from the mesial is placed on the bite. This is not the biter.*

Figure 7 suggests a diastema, missing tooth, or a tooth that does not meet the horizontal plane of adjacent teeth. In Fig. 8, one such pattern is placed on the bite with fairly good correlation, however

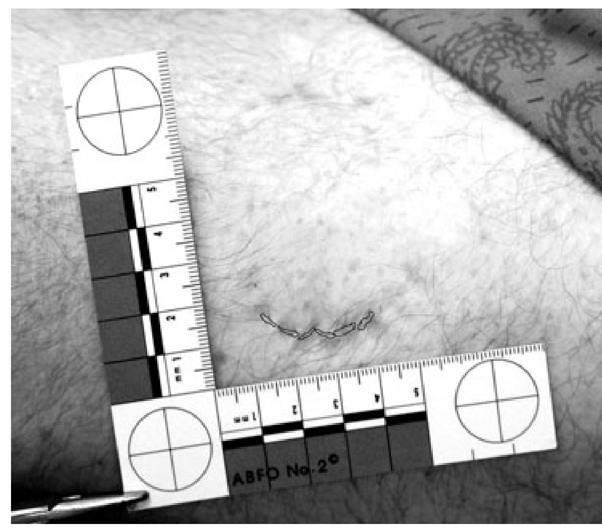

FIG. 3—*An overlay with a "v" shaped, mesio-angular mal-alignment to the central incisors is placed on the bite. This is not the biter.*

FIG. 4—*The overlay of the biter. Note only a slight mesio-angular rotation to the central incisors.*

this is not the biter. Figure 9 shows the actual biter who possesses neither a diastema nor a discrepancy of the occlusal plane. However, the biter does possess a pointed incisal edge to #23 that could account for bite appearance.

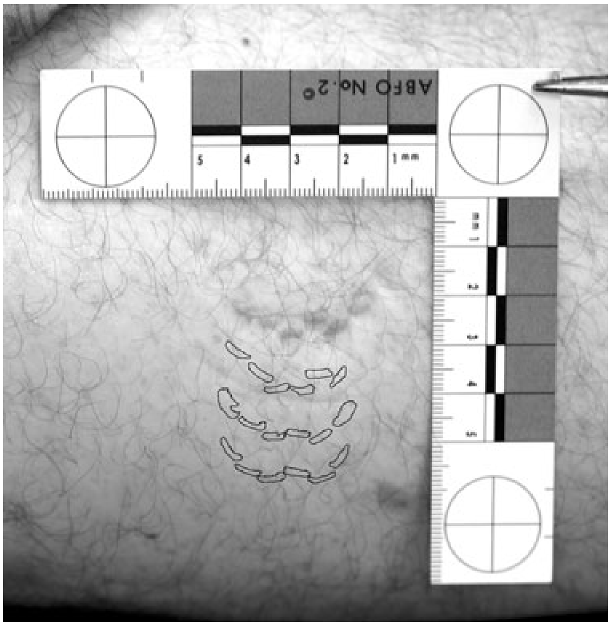

FIG. 5—*This bite suggests that the right central incisor has a significant lingual displacement*.

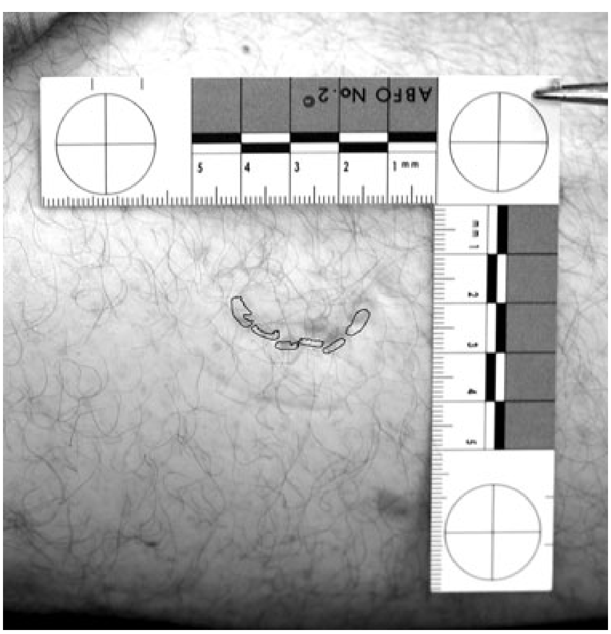

FIG. 6—*The overlay of the biter. Note the right central incisor is lingually displaced, but not on the scale suggested by the bite*.

Figure 10 demonstrates a confusing pattern. The dentition that caused the bite had incisal wear on teeth #22 to #27, creating a "ring" of enamel surrounding a depression of dentin. The resulting indentation pattern might suggest mal-alignment with a buccally displaced #24, or even a double bite. The overlay of the biter is placed above the bite in this figure.

Bite distortions in groups 6 and 8 could not be calculated. The bite created with the dentition from group 6 was highly mal-aligned and that from group 8 had significant occlusal wear. Both of these dentitions failed to produce, in multiple attempts, clear measurable indentations despite the ideal laboratory conditions.

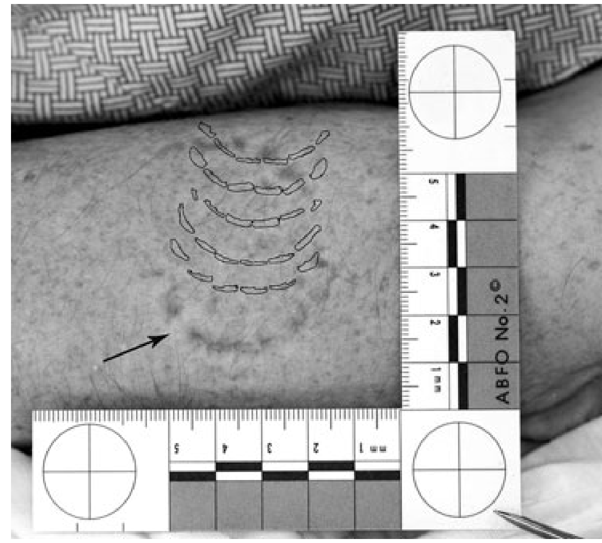

FIG. 7—*Five overlays are placed above the bite. A diastema, tooth out of the occlusal plane, or a missing tooth is suggested on the left in the area of tooth #23 (arrow)*.

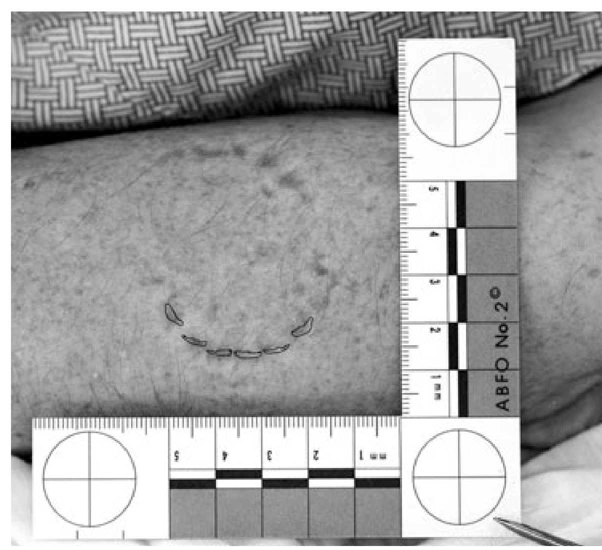

FIG. 8—*An overlay with a diastema between tooth #22 and #23 is placed on the bite. This is not the biter*.

Discussion

The dentition can be measured with certain accuracy; however, the uniqueness of the dentition cannot be perfectly transferred to skin. Thus, distortional effects as well as other factors ultimately contribute to a reduction of resolution in the transference of dental details. This article demonstrates how human skin affects the ability to recognize unique dental features in a bitemark.

The experimental results indicate that similarly aligned dentitions cannot be ruled out as the biter in all cases. In addition, when comparing the entire 100-sample population of nonsimilar mal-alignments, certain dentitions could be included as the biter, thus allowing for the possibility of exclusion of the biter and inclusion of an innocent person. Indeed, some dentitions appear to "fit" better than the biter's dentition with a resultant false positive. It should

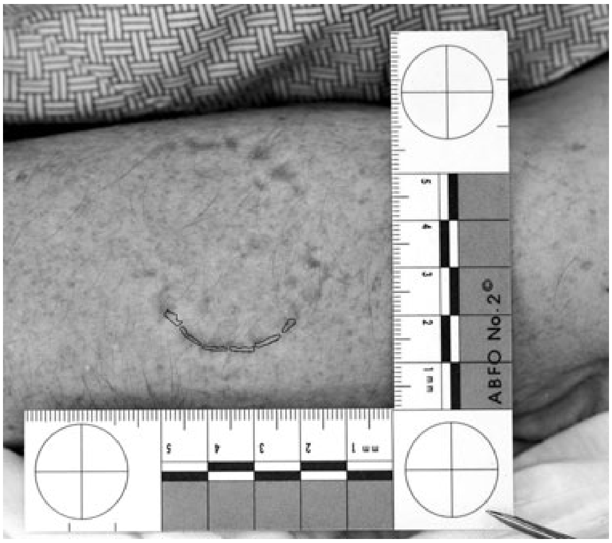

FIG. 9—*Overlay of the biter is placed on the bite. There is no diastema between #22 and #23. Also note the discrepancy for the placement of the canines.*

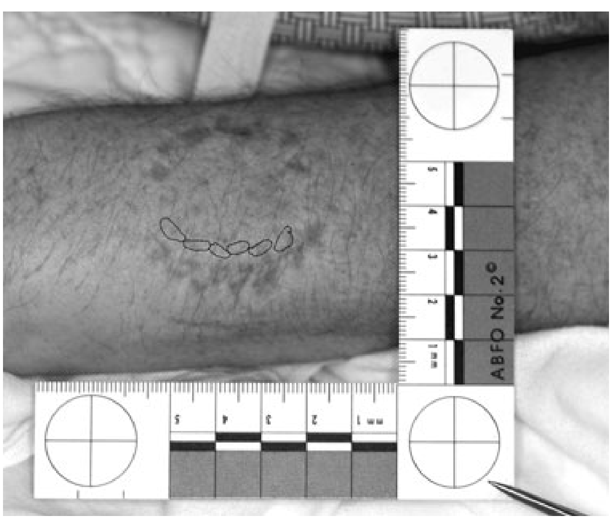

FIG. 10—*Nondistinct bitemark. It is difficult to clearly delineate the outline of specific teeth. The overlay of the biter is placed above the bite.*

be noted that this research was not designed as a proficiency test among forensic odontologists. Thus intra- and inter-observer effects were not studied. The experiment described represents one of the first steps in providing a basic understanding of loss of resolution due to distortion in a bitemark when impressed in human skin.

It is acknowledged that cadaver skin differs from living tissue with its lack of inflammatory response and potential subcutaneous bleeding (17–20). These additional parameters could provide supplementary information for perpetrator identification. However, the use of cadavers has a benefit in that clear indentations were produced in most cases that could be used for measurement and comparison purposes.

Also, this was a single arch study. There could be additional perpetrator information had it included the upper arch. The authors further understand that this open population study may differ from an actual closed population bitemark case such as in child/spousal/elderly abuse.

The analysis was two-dimensional, without benefit of other photographic techniques, excision, trans-illumination, three-dimensional dental, and bitemark impression analysis. Although two-dimensional analysis does provide measurable and therefore comparative metric/angular analysis, the teeth and substrate have three dimensions. Evaluation of a photograph, scan, or overlay solely, may cause important information to be overlooked. Valuable information that might be related to discrepancies in pattern development can be found through three-dimensional evaluations of the models, such as height discrepancy in teeth. As the longer teeth engage the tissue first, they not only create a pattern, but also begin to further pull or distort the medium before the next teeth engage. This will leave a patterned injury less consistent with the two-dimensional overlay pattern. It is the authors' intention to emphasize that all aspects of evidence collection and analysis must be considered to render an opinion in a bitemark case.

It is important to stress that two of the 10 experimental dentitions did not produce clear bitemark indentations for measurement purposes. This suggests that there may be situations in which a dentition may produce a poor representation of itself, not so much because of distortion of the skin, but rather the specific alignment and tooth configuration of the dental arch.

Bitemark analysis has recently come under scrutiny resulting from well-publicized DNA exonerations. Critics point to the lack of scientific studies that test its fundamental precepts. Although studies have addressed dentition uniqueness, more are needed on skin and underlying tissue effect.

In conclusion, the result of this study suggests that an open population postmortem bitemark should be carefully and cautiously evaluated particularly if limited exclusively to two-dimensional overlay comparison. This is due in part to distortion and loss of resolution in the transference of arch and dental characteristics to skin.

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