LITERATURE CITED

Aiello L, and Dean C (1990) An Introduction to Human Evolutionary Anatomy. London: Academic Press.
Arwill J, Myrberg N, and Soremark R (1965) Penetration of radioactive isotopes through enamel and dentine. 1. Diffusion of 22 Na in fresh and coagulated dental tissues. J. Dent. Res. *44(6)*:1299-1303.
Callens FJ, Matthys PFA, Verbeeck RM, and Martens LC (1986) Contribution of the CO_3 and CO_2 radicals to the asymmetric ESR signal near G-2 in human tooth enamel. Zobozdrav. Vestn. *41(Suppl. 1)*:79-97.
Carlstrom D, Glas JE, and Angmar B (1983) Studies on ultrastructure of dental enamel. V. The state of water in human enamel. J. Utrastruct. Res. 8:24-29.
Đurić S (1996) Interview, Belgrade.
Đurić-Srejić M, Letić V, and Pejković B (1992) Variability of some morphological traits and epigenetic characters of the skulls of medieval Serbs. Rivista di Antropologia (Roma) *70*:159-169.
Doi Y (1986) ESR studies of tooth enamel. Zobozdrav. Vestn. *41(Suppl. 1)*:43-58.
Elliot JC (1969) Recent progress in the chemistry, crystal chemistry and structure of the apatites. Calc. Tiss. Rec. *3*:293-307.
Elliot JC (1986) The structure and function of hydroxylapatite. Zobozdrav. Vestn. 41*(Suppl. 1)*:25-42.
Ferguson S, and Chesnut DB (1978) A magnetic resonance spin label study of human dental enamel. Arch. Oral Biol. *23*:85-90.
Garland AN (1987) A histological study of archaeological bone decomposition. In A Boddington et al. (eds.): Death, Decay and Reconstruction. Manchester: Manchester University Press.
Milićević V (1994) Tooth Color Matching by Digital Image Analysis; M.A. Thesis, Belgrade.
Tihaček-Šojić Lj (1996) Research of diffusion process of organic and inorganic molecules on the retention teeth for a partial skeletal prosthesis. Ph.D. Dissertation, Belgrade.
Trussel HJ (1993) DSP solutions run the gamut for color systems. IEEE Signal Processing Magazine *4*:8-23.

DIAGNOSTIC CHARACTERISTICS OF HUMAN BITE MARKS: A REVIEW OF SOLVED CASES

ROSANNE CARRERO
Department of Anthropology, Arizona State University, Box 872402, Tempe AZ 85287-2402, U.S.A.

ABSTRACT Despite their non-standardized documentation and interpretation, human bite marks are very useful in the legal arena. A literature review of case histories was undertaken to search for some basic dental traits that characterize bite marks successfully used to identify suspects in forensic cases. Information for eighteen cases indicated that the two dental traits that occurred most frequently, diastema and malposition of teeth, were usually sufficient to identify a suspect. The relative simplicity of these findings suggests questioning the necessity and cost-effectiveness of lengthy and complex analyses in many forensic cases.

INTRODUCTION

Human bite marks have been accepted as evidence in courts in the United States since the 1870s. Their utility is based on the distinctiveness of individual dentitions (Rothwell, 1995). The legal value of bite mark evidence lies not only in its uniqueness, but also in its frequent occurrence in crimes. Bite marks are found on victims or perpetrators of sex crimes, child abuse, assault, and homicide (American Board of Forensic Odontology, 1986).

Regardless of the specificity of bite mark evidence, many legal, clinical, and forensic authorities question its accuracy. Sources of error can be numerous and vary with the many techniques (e.g., computer tomography scan, scanning electron microscopy, dusting and various overlay and casting procedures, photographic techniques) used for preservation and analysis. Training and verification of odontological expert witnesses is haphazard and non-standard. Disagreement occurs even among respected authorities (Weigler, 1992).

The American Board of Forensic Odontology (ABFO) devised standards for bite mark analysis in 1986, but no general agreement yet exists about national or international standards for bite mark comparison (Rothwell, 1995). The ABFO system employs information about demographics of the victim, anatomical location and shape of the body surface involved, the shape of the bite, and other soft tissue observations, such as the presence of abrasions and lacerations. An important part of the system is the ABFO score sheet, a lengthy itemized list of tooth-by-tooth matches between traits of the bite mark and the suspect's dentition. Discrepancies between the bite mark and the suspect's dentition are noted in three categories of "gross features." These are presence of each tooth in the suspect and consistent size, and consistent shape of arches. In addition, "tooth position" (in labiolingual position, in rotational position, and in terms of spacing between tooth margins) and "interdental features" (e.g., mesiodistal and labiolingual lengths of each tooth, distinctive curvatures of any teeth) are compared between the bite mark and the individual teeth in the suspect. This format leaves a category for other features. With this scoresheet, the odontologist may score eight or ten characteristics for each tooth in the suspect's dentition (ABFO, 1986:386).

Despite some research showing great reliability (Rawson et al., 1986), much criticism has been levelled at the ABFO method for its scorecard style approach. Some experts have questioned the reliability of some of its criteria, such as the measurements of the bite mark (Ebert, 1988). Other researchers could not reproduce the high reliability reported by Rawson et al. (1986) when different techniques of evidence preservation were used (Rothwell, 1995).

The ABFO system of data collection, ponderous and detailed, is the only major standardization of bite mark analysis. Despite the ABFO's valiant 1986 effort and several interim revisions, the method is the subject of controversy to this day.

Therefore, this study was the first step toward the development of a more sparse, easy, and standardized format that will be more understandable and less controversial than that of the ABFO. This paper presents the results of an analysis of dental characteristics commonly found in solved forensic cases involving human bite marks. Such an analysis is uncommon in the forensic literature, which emphasizes case studies and technical reports rather than attempts at generalization or standardization. Hopefully, the information will contribute to forensic and clinical guidelines and protocols that will give investigations, evidence preservation, and training of forensic and clinical staff increased uniformity, thoroughness, efficiency, and speed, especially for busy, over-burdened jurisdictions.

METHODS AND MATERIALS

A retrospective review of bite mark cases was made in the forensic literature. Cases were accepted if the report included a photograph, a diagram, or a thorough verbal description of the bite mark. All cases from any state or country and from any time period were included in this study if they fit the above criteria. The surveyed literature was limited to books and journals in the various libraries of the Arizona State University.

The photographs, sketches, and verbal descriptions of the bite marks were scrutinized in order to determine the visually obvious characteristics of the dentition, such as malposition, diastema, missing teeth, dental wear, and arch shape. When a book or journal had a photograph or an overlay of an appropriate bite mark, a description of the bite mark traits was sought in the accompanying written text. The photograph and description of the bite mark were then compared.

In some cases (Cases #2, #3, #6, #9, and #14), I added traits that were visible in an illustration, not noted in the text. I accepted the author's identification of the bite mark traits. I did not add more information than I could find by looking at the illustration of the bite mark. For each bite mark, a list of traits was compiled. Table 1 contains a list of these traits in the 18 bite mark cases reviewed.

The same kind of data was not available for all of the cases. Although the reports on all 18 cases included photographs of bite marks, none of these photographs showed the same amount of detail. Some of the reports also contained diagrams of some sort. The reports on cases #11 and #12 had diagrams made from overlays on the bite marks. The accounts of cases #13 and #14 showed tooth imprints that had been dusted and lifted from the bite mark. The description of case #18 included a simple schematic diagram of the teeth in the upper arch to show a diastema. Some written description accompanied each report of a bite mark case. These descriptions varied from a short caption to a four- to five-page long textual account. In other words, this study was done using data collected and presented in many different ways. This use of non-standardized information brought about a loss of detail in some cases and potentially contributed to sources of error for this study.

Counts and percentages were done based on the number of different traits and their occurrences. A trait was defined as an unusual characteristic in a given tooth in the dentition. For example, a fracture of the upper right lateral incisor and a fracture of the upper left lateral incisor were considered as two different traits. Diastemata between the lower central incisors and between the upper central incisors were considered different traits, also. These various traits, specific down to the level of the individual tooth/teeth affected, were sometimes grouped into larger categories, such as fractures, diastemata, etc., for the purpose of discussion and generalization. A number of different traits (e.g., lingual displacement and fracture or rotation plus buccal displacement) can occur in a single tooth. In this situation, the traits were counted as multiple traits (e.g., a rotated and buccally displaced canine showed two traits: rotation and buccal displacement).

Traits, such as the presence of dental treatment (e.g., bridges, filings, crowns) and missing teeth, were considered as localized traits. Other kinds of traits, such as wear and overall size, that similarly affected four or more teeth of all types (e.g., affected molars and incisors or premolars and canines) were considered as a single generalized trait and counted as one trait. Those traits that involved only one type of tooth (e.g., pitting of the canines, pegging of the lateral incisors) were tabulated as a number of localized traits (e.g., pitting of the upper left canine, pitting of the lower left canine), even if four teeth were involved. The rationale behind the decision to use these criteria was that one or the other(s) of these individual traits could be used to distinguish dentitions. Traits were defined as non-overlapping categories.

Occurrences of the characteristics and the number of different traits were counted and used to generate percentages. Some data have been given as the percentage of the total number of traits; some, as the percentage of the total number of cases; and some, as the percentage of occurrences. Complete tooth-by-tooth scoring of all traits was not possible for most of the cases, because the typical bite mark involved only the anterior dentition. Also, some of the textual

descriptions were less detailed than others. Some information was not given by the author and not visible to my perusal of the photographs and texts. In this review, systematic scoring of all cases was not the goal. Instead, the study concentrated on readily visible traits in illustrations and written descriptions.

RESULTS

General Trends

According to my observations, the 18 bite marks found in the literature review show 68 distinctive traits, involving either a single tooth or multiple teeth. The number of occurrences of these 68 traits totalled 82 for the entire sample. The average number of traits per case was 4.5 with a range of two to seven traits per case. Seven generalized traits occurred in five (27.8%) of the cases. All of these five cases also had localized traits. Table 1 has a list of the cases, diagnostic traits of the teeth indicated by the bite mark, and locations of the bite marks.

Anatomical Location of Bite Marks

In this study, the anatomical location of the bite mark was given in only 15 of the 18 cases. Upper extremities had the most bite marks of the study (five cases or 33.3% of the 15 cases), followed by the face (four cases or 26.6% of the 15 cases), breast (three cases or 20.0% of the 15 cases), and the back (two cases or 13.3% of the 15 cases). One case each involved the chest, scalp and head area, lower extremities, neck, and abdomen. Two cases involved multiple locations.

Maxillo-dental Features Reflected in Bite Marks

Arches

The bite was made by upper teeth alone in eight cases (44.4% of the total number cases). Lower teeth alone were involved in only two cases (11.1% of the total number of cases). Evidence of involvement of teeth of both arches was present in the remaining eight cases (44.4% of the total number of cases).

Arch shape was reported in only four cases (22.2% out of the 18 cases). The maxillary arch shape was used in two cases; mandibular arch shape, in only one; and the shapes of both arch shapes in one case. The maxillary arch was described as V-shaped by the authors (Karazulas, 1984; Bernstein, 1985) of the original references in two cases. However, other than these details, no other information was given about the specifics of arch shape. In case #9, the original authors (Jakobsen and Kaiser-Nelson, 1981) mentioned maxillary and mandibular arch shapes a factor in the investigation. I observed that the arches in this case were V-shaped also.

Malposition

The most commonly occurring trait was malposition. This category, divided into seven subgroups, affected ten cases (55.5% of the cases) in this review. The seven sub-groups within the malposition category are: angulation or tipping (the teeth were placed at some angle to the normal vertical orientation, such as tipped buccally or lingually), displacement (tooth was positioned outside of the usual arc of the dental arcade, such as buccal or lingual to the arch), overlapping (with or without angulation), rotation, angulation between teeth (adjacent teeth were appropriately aligned in the dental arch but did not meet one another at an angle, such as winging of the incisors), and mild misalignment (very minor displacement from a perfect arch but without significant displacement or angulation of either type), and mesial drift.

The average of malposition in the ten cases was 2.1 malpositions per case with a range of one to four occurrences per case. These 21 characteristics accounted for 25.6% of the 82 trait occurrences in this review.

Forty percent of the malposition traits were lingual or buccal displacements of teeth. Four rotation traits occurred in three cases. These three cases accounted for 16.7% of the total number of cases in the study, and the number of rotation traits, 7.3% of the total number of different traits in the study. Angulation and overlapping occurred in three cases each (each trait 16.7% of the cases). Mesial drift occurred in a single case. Only one case (#3) involved three categories of malposition (overlapping, displacement, and angulation). Some cases had two or more types of malposition each. In many cases, more than one type of malposition involved one tooth. For example, a tooth was buccally displaced and also overlapped its neighbor (case #3) or was displaced and rotated (case #15).

Diastemata

Diastemata accounted for ten different traits or 14.7% of the traits identified in this study (Table 1). Diastemata made up 20 of the 82 trait occurrences (24.4%) and occurred in seven out of the 18 cases (38.8%). The average number of diastemata per case was 2.8 and the range, one to five diastemata per case. Of the seven diastema cases, three (42.8%) had a single diastema. Three cases involved four diastemata, and one case, five. The most commonly occurring diastema was that between the upper central incisors. This trait occurred five times and accounted for 25.0% of all diastema occurrences. Yet lack of a diastema was a critical trait in case #18. This case was not included in the tally of diastema cases.

Table 1. Characteristics of the dentitions responsible for the bite marks and the locations of the bite marks in this review.

Case #	Diagnostic characteristics of the teeth as indicated by the bite mark	Arch	# Teeth Involved	Generalized Traits	Missing Teeth	Bite Location	Reference
1	Diastema between upper central incisors	upper	2			Breast	Harvey (1976)
	Diastema between lower central incisors	lower	2				
	Diastema between lower right central and right lateral incisors	lower	2				
	Diastema between lower right lateral incisor and canine	lower	2				
2	Diastema between lower central incisors	lower	2			Scalp, forehead, arm	Harvey (1976)
	Diastema between lower left central and left lateral incisors	lower	2				
		lower	2				
	Diastema between lower right lateral incisor and canine	lower	2				
	Diastema between lower left lateral incisor and canine	lower	2				
	Unusual shape and location of the apex of the lower right canine	lower	1				
	Unusual shape and location of the apex of the lower left canine	lower	1				
	Fracture of lower left central incisor		1				
3	Malposition: angulation between lower right central and lateral incisors	lower	2			Not given	Vale (1983)
	Malposition: buccal displacement of lower right central incisor	lower	1				
	Malposition: overlapping of lower right central and right lateral incisors	lower	2				
4	Pitting on upper right canine	upper	1			Breast	Harvey (1976)
	Pitting on upper left canine	upper	1				
	Pitting on lower right canine	lower	1				
	Pitting on lower left canine	lower	1				
	Fracture of upper left central incisor	upper	1				
	Fracture of upper left lateral incisor	upper	1				
5	Flat edge wear on upper and lower teeth due to grinding	upper, lower	?	yes		Cheek	Harvey (1976)
	Wide diastema between upper central incisors	upper	2				
6	Missing upper right lateral incisor	upper	1		1	Back	Whittaker and MacDonald (1989)
	Missing upper right canine	upper	1		1		
	Malposition: angulation between upper left lateral incisor and left canine	upper	2				
	Deep sagittal sulcus between buccal and lingual cusps of upper left second premolar	upper	1				
	Malposition: labial displacement of lower right central incisor	lower	1				
	Malposition: labial displacement of lower left canine	lower	1				
7	Mandibular arch shape	lower	4			Wrist	Whittaker and MacDonald (1989)
	Malposition: angulation between upper central incisors	upper	2				
8	Large size of upper central incisor	upper	1			Breast	Whittaker and MacDonald (1989)
	Malposition: buccal rotation of upper right central incisor	upper	1				
	Unusual curved shape of incisal edge of upper right central incisor	upper	1				
	Unusual shape of lower right lateral incisor due to metal-backed crown	lower	1				
	Malposition: slight rotation of lower right canine	lower	1				
9	Arch shape (V-shaped according to observation in this study	upper lower				Back	Jakobsen and Kaiser-Nielson (1981)
	Greatly increased wear on all incisors and canines	upper, lower	12	Yes			
	Large lingual cusp on upper right first premolar	upper	1				
	Large lingual cusp on upper left first premolar	upper	1				
	Malposition: lingual displacement of lower right central incisor	lower	1				
	Malposition: buccal displacement of lower right lateral incisor	lower	1				

TABLE 1. Continued.

Case #	Diagnostic characteristics of the teeth as indicated by the bite mark	Arch	#Teeth Involved	Generalized Traits	Missing Teeth	Bite Location	Reference
10	Peg-shaped upper right lateral incisor	upper	1			Chest,	Irons, et al.
	Peg-shaped upper left lateral incisor	upper	1			knee	(1983)
	Diastema between upper central incisors	upper	2				
	Diastema between upper right central and lateral incisors	upper	2				
	Diastema between upper left central and lateral incisors	upper	2				
	Diastema between upper right lateral incisor and canine	upper	2				
	Diastema between upper left lateral incisor and canine	upper	2				
11	Missing upper right lateral incisor	upper	1		1	Arm	West et al.
	Malposition: mesial drift of upper right canine	upper	1				(1990)
12	Diastema between upper right central and lateral incisors	upper	2			Cheek	West et al. (1990)
	Diastema between upper left central and lateral incisors	upper	2				
	Diastema between upper right lateral incisor and canine	upper	2				
	Diastema between upper left lateral incisor and canine	upper	2				
	Shape of teeth		all	Yes			
13	Shapes of biting edges of all upper teeth	upper	all	Yes		Not	Rao and
	Shapes and sizes of upper premolar and molar cusps	upper	10	Yes		given	Souviron
	Diastema between upper central incisors	upper	2				(1984)
14	Malposition: anterior overlapping of upper left central over upper right central incisor	upper	2			Not given	Rao and Souviron (1984)
	Malposition: buccal prourusion of upper left central incisor	upper	1				
	Shapes and sizes of incisal edges of all upper incisors and canines	upper	6	Yes			
	Shapes and sizes of upper molar cusps	upper	6	Yes			
	Missing upper right second premolar	upper	1		1		
	Missing upper left second premolar	upper	1		1		
15	Malposition: rotation of upper right lateral incisor	upper	1			Nose	Vale et al.
	Malposition: rotation of upper left lateral incisor	upper	1				(1976)
	Malposition: lingual displacement of upper right lateral incisor	upper	1				
	Malposition: lingual displacement of upper left lateral incisor	upper	1				
	Diastema between upper central incisors	upper	2				
16	Missing upper left lateral incisor	upper	1		1	Forearm	Bernstein
	Fracture of upper right lateral incisor	upper	1				(1985)
	Fracture of upper left canine	upper	1				
	Fracture of upper left premolar	upper	1				
	Sharp edge of lower right lateral incisor	lower	1				
	Sharp edge of lower right canine	lower	1				
17	Unusual V-shaped maxillary arch	upper	6			Abdomen	Bernstein
	Malposition: rotation of upper left central incisor	upper	1				(1985)
	Malposition: rotation of upper left lateral incisor	upper	1				
	Large sharp upper right canine	upper	1				
18	V-shaped maxillary arch	upper	6			Arm	Karazulas
	Malposition: overlapping of upper central incisors	upper	2				(1984)
	Lack of diastema between upper central incisors	upper	2				

Generalized means that four or more teeth were involved. "Dusting technique" was applied in cases 13 and 14.

Diastema and malposition appeared together in only one case (5.5%) in the review. One or both types of traits (diastema and malposition) occurred in 16 out of the 18 cases (88.9%). Only two cases (#4 and #16) lacked diastema or malposition. These two cases had twelve other trait occurrences, an average of six per case, above the overall case average of 4.5 occurrences in this study.

Of the 16 cases which involved diastema, malposition, or both traits, 14 cases also included one or more additional traits (range of one to three other traits). Yet, as mentioned above, the two traits occurred together in only two cases.

Other Localized Traits

Six fracture traits were noted in this study and accounted for 8.8% of the traits. These dental fractures were reported in only three cases (16.6%). Five traits (7.3%) involved various missing teeth in four cases (22.2%) in the review. One trait, a missing upper right lateral incisor occurred in two cases (#6 and #11).

Both fractures and missing teeth occurred in premolars as well as in the anterior dentition. The involvement of the premolars seems to be a distinction from malposition and diastemae. In two of the three fracture cases, more than one fracture occurred in each dentition. In half of the cases (two cases) with missing teeth, more than one tooth was missing from the dentition

Dental therapeutics such as crowns, fillings, and prostheses occurred in only one (5.5%) case. This finding did not fit my expectation, given the prevalence of major dental work in much of the population. However, dental prosthetics may reflect demographic, economic, and cultural factors.

Additional localized traits in this review included peg-shaped teeth (two traits involving upper lateral incisors) and canine pitting (four traits, one trait involving each of the four canines in one dentition). Each of the traits occurred in only one case.

Tooth and Arch Size and Shape

Consideration of overall tooth and arch size and shape is part of every forensic bite mark case. In three (16.6%) of the cases reviewed, the authors specified the general size and/or shape of teeth as factors in their analyses. General considerations of both size and shape were involved in two (11.1%) cases, while consideration of general shape alone was important in a single (5.5%) case. Specific size criteria were not given by the authors in these cases. If an author mentioned shape or size, the feature was included in this study, but details were not clarified beyond those given.

Size or shape of an individual tooth were important traits in three (16.6%) cases. Case #2 had an unusual shape and location of the curved crown apex of a canine. Case #8 involved a very large upper lateral incisor. Case #17 demonstrated the large size of an unusually sharp upper canine.

Occlusal Surface Abnormalities

Abnormalities of the occlusal surface were noted in six (33.3%) of the cases. These traits included wear, sharp edges of biting surfaces, and unusual cusp shapes. Features of the molar or premolar cusps were demonstrated in four (22.2%) of the cases, including the two very detailed cases in which the fingerprint dusting technique was used. These four cases represent 22.2% of the 18 cases but account for 57.0% of the occlusal surface findings.

Wear was an important character in two cases. Grinding wear affected the upper and lower teeth in case #5. All incisors and canines in case #9 were more worn than the rest of the dentition.

The dusting technique used in cases #13 and #14 gave a great deal of information about the biting surfaces of the anterior teeth and the molar and premolar cusps. The large amount of overall detail made possible by this technique put these two cases well above the level of information obtainable in the other 16 cases in this study. Due to the vast amount of relatively minute observations that could be made on the cusp surfaces and biting edges in these two cases, I could not enumerate specific traits. I included these very detailed cases under general traits (i.e.,overall size and shape of teeth).

In contrast to cases #13 and #14, four other cases displayed occlusal abnormalities in individual teeth. Case #6 had a very deep sagittal sulcus on an upper second premolar. Case #9 had very large lingual cusps on both upper second premolars. Case #8 had an unusual, curved shape to the incisal edge of an upper incisor. Case #16 had especially sharp edges on the lower right lateral incisor and canine.

DISCUSSION

Standardization of Bite Mark Analysis

The previous sections have presented a compilation of simple, easily identifiable dental traits that were reported in successfully prosecuted investigations involving bite marks. The goal of this study was the application of the patterns of trait occurrence to a protocol of bite mark analysis in order that frequency information could become the basis for a relatively simple and systematic approach of dental traits associated with bite marks.

Review of these 18 bite mark cases supports a non-numerical approach to the early stages of forensic bite mark analysis, because all of these cases had characteristics that were easily recognized by a newcomer to the subject and no measurements were reported. Though no actual measurements were taken, some cases did involve size of certain

dental structures. Two cases involved the large sizes of one tooth relative to its antimere (cases #8 and #17) and one case utilized the large size of the premolar lingual cusps. The detailed cases #13 and #14 showed information about the size of all of the teeth. In the four cases that involved the dental arches, shape rather than size was the pivotal factor. The results of this review seem to indicate that dental measurements may not be necessary in every analysis and should be reserved for cases that are not amenable to simple interpretative methods.

When discussing standardization of forensic bite mark impressions, one must consider the ABFO's effort to be a foundation and a landmark. The ABFO protocol is complicated, but has a major advantage: a high degree of reliability. Hundreds of forensic odontologists used the ABFO format to evaluate a series of experimental bite mark impressions, photographs, and models from solved cases. One study (Rawson et al., 1986) showed a high degree of inter-observer concordance among experts, as well as various degrees of matches between bite marks and biters' dentitions. Rawson et al. (1986) indicated a high degree of reliability of the ABFO scoring technique when looking at the range of scores, 90% confidence values, and mean scores from many interpreters.

Unfortunately, other researchers could not reproduce the high confidence level of this thorough, systematic study. Rothwell's (1995) review summarized some studies that showed high rates of inaccuracy by multiple odontologists who participated in controlled studies of bite marks in various media. Rawson's (1986) study did not really address the reliability of these guidelines under the variable conditions of everyday forensic procedures.

A number of the variables in the ABFO protocol, such as tooth absence, arch shape, incisal edge abnormalities, rotation, and displacement, are represented in this review. The ABFO guidelines demand many measurements of tooth size but are not nearly as precise about other traits. This review fleshes out the category of "other distinctive features" much more thoroughly than the ABFO scoring form.

Interpretation of bite marks according to some uniform routine protocol seems useful in terms of collecting, comparing, and presenting data. However, many factors in the biting event itself may make standardization difficult. Many researchers voice concerns about the skin's ability to distort bite marks through movement, stretching, or bunching. Movement of extremities may change the shape of bite marks due to skin position variations of up to several centimeters along Langer's Lines (normal lines in the skin due to subcutaneous tissue and skin surface tension) (Harvey, 1976). Facial or neck bites may be affected by the victim's jaw movement (case #12) (West et al., 1990). Also, shape, size, and clarity may change according to the struggling movements of the victim or the biter's mandibular movement during the infliction of the injury (Furness, 1981; Sperber, 1990). The mechanisms of both suction and tongue thrust can change the skin position and tension so much that bite marks can vary considerably, even to the point of showing lingual tooth surface markings and tongue impressions (Beckstead et al., 1979; Sperber, 1990). The effects of biting through clothing are poorly studied.

Individuality of the Dentition

This paper presents a simple analytic approach and arrives at some very basic information on trait frequencies in successfully identified bite mark cases. Yet, the overall dentition is not necessarily simple, and many dental traits did not occur in this study. Possibly, simple analyses lack so much specificity that features of multiple dentitions could be consistent with a basic series of traits, such as those discussed in this study. This concern leads to the subject of the individuality of the dentition.

The uniqueness of the individual dentition is assumed in the legal cases. Rawson et al. (1984) examined this issue to determine the validity of this very basic assumption. These workers estimated the probability of exact matches in the degree of rotation among the upper and lower anterior teeth of 397 individuals. A match was consideration of involvement of the same rotations in six out of the twelve anterior teeth. One of the assumptions was that all types of rotation were equally likely to occur. Given that dental traits are heritable, this might not be a valid assumption within certain populations, such as a number of family members who might be suspects in a given bite mark case. Yet, Rawson and his group (1984) found no statistically significant indicators of sex or race in their distribution of tooth positions. They calculated that the probability of even five teeth having exactly matched rotations was so high that the ratio involved a denominator larger than the population of the world (Rawson et al. 1984).

Another study (Sognnaes et al., 1982) of dental uniqueness involved computerized comparisons of standardized bite marks made by five pairs of monozygotic (MZ) twins. Assuming that MZ twins are likely to have the highest possible genetic similarity, their bite marks should be the most similar of any possible pair of people. However, computerized comparisons involving rotation showed that even identical twins were dentally distinctive.

The results of these two studies (Sognnaes et al., 1982; Rawson et al., 1984) lead to the observation that individual dentitions are distinctive enough to be identified by a simple series of common traits and by the general considerations of tooth size and shape. Both of the studies also reported one of the two most common traits found in this review, malposition, as their sole criteria. Addition of data for diastema should add power to the analysis.

Sources of Error

One major source of potential error in this analysis was small sample size. Certainly, this small sample limited the use of statistical methods. Additionally, the small sample size might not be representative of successfully concluded forensic cases.

Distortions of bite mark photographs in books, journals, or photocopies were other sources of potential error. The variable degrees of photographic and written information in each of the 18 cases also could have had an impact on the accuracy of the results of the study. This lack of standardization of original data made my study an uncontrolled one, and possibly subject to greater error than a study using standardized criteria.

Experts systematically use multiple points of correspondence in any bite mark to exactly match shapes, sizes, and locations of teeth. This complicated process was outside of the realm of this paper and the skills of this reviewer.

The sample used in this study was not random because only solved and published cases found in the Arizona State University libraries were used. The sample was also not standardized with respect to forensic technique. The eighteen case reports reflect differences in sensitivity and specificity due to the wide variety of techniques used in evidence collection, photography, casting, overlay, and tracing.

CONCLUSIONS

The results of this study suggest that a relatively simple protocol of dental trait analysis may be successfully used in the preliminary phases of the majority of forensic bite mark cases. This protocol is simply the comparison of the bite mark and the suspect's dentition in terms of the basic traits that occurred in this study. The review demonstrated the importance of dental malposition and diastema pattern as useful traits for bite mark interpretation. These characters occurred in relatively high frequencies and could easily be identified. The ABFO scoresheet lists these two traits under their "tooth position" category, which included traits of rotation, labial or lingual displacement, and diastemae ("spacing between the adjacent marking edges") (ABFO, 1986:386). The scoresheet condenses other kinds of malposition noted in this study (e.g., angulation and overlapping) into the category of "rotational position" and puts the malposition trait of tipping into "vertical position of tooth/occlusal plane matches" (ABFO, 1986:386).

Other traits that occurred in low frequency in this study, such as arch shape, fractures, dental work, pitting, and wear might also be critical, either singly or in combination, in any given case.

This series of dental traits may also be considered an addition to the ABFO outline as an enhanced scorecard of "other distinctive features."

This protocol of comparison of simple dental traits in the bite mark with those in the dentition of a suspect may eliminate the need for dental measurements, if dentitions do not match the bite mark. This method seems most suitable for ruling suspects out of an investigation. If a suspect's dentition is compatible with features of a bite mark according to this basic protocol, a thorough analysis, such as the full ABFO scoresheet and work up should be done.

The conclusions of this study do not advocate changing the current ABFO scoring technique at this time. Research of larger samples than the one analyzed here may lead to modification and streamlining of analytic techniques after large-scale studies have been done. Future work should: 1) consist of studies of large bite mark samples, 2) be obtained and preserved using standardized techniques, 3) compared with cases in which the bite marks were and were not useful in eliminating or implicating suspects, and 4) interpreted by the same, experienced forensic odontologists.

LITERATURE CITED

American Board of Forensic Odontology, Inc. (1986) Guidelines for Bite Mark Analysis. J. Amer. Dent. Assn. *112(3)*: 383-386.

Beckstead JW, Rawson RD, and Giles WS (1979) Review of bite mark evidence. J. Amer. Dent. Assn. *99*:69-74.

Bernstein ML (1985) Two bite mark cases with inadequate scale references. J Forensic Sci. *30 (3)*:959-964.

Ebert JI (1988) Discussion of 'The Bite Mark Standard Reference Scale-ABFO #2'. J Forensic Sci. *33(2)*:301-304.

Furness J (1981) A general review of bite-mark evidence. Amer. J. Foren. Med. Path. *2(1)*:49-52.

Harvey W (1976) Dental Identification and Forensic Odontology. London: Henry Kimpton Publishers.

Irons F, Steuterman MC, and Brinkhous W (1983) Two bite marks on assailant: primary link to homicide conviction. Amer. J. Foren. Med. Path. *4(2)*:177-180.

Jakobsen JR, and Keiser-Nielsen S (1981) Bite mark lesions in human skin. Forensic Science International *18(1)*:41-55.

Karazulas P (1984) Presentation of bite mark evidence resulting in the acquittal of a man after serving seven years in prison for murder. J. Forensic Sci. *29(1)*:355-358.

Rao VJ, and Souviron RR (1984) Dusting and lifting the bite print: A new technique. J. Forensic Sci. *29(1)*:326-330.

Rawson RD, Koot A, Martin C, Jackson J, Novosel S, Richardson A, and Bender T (1984) Incidence of bite marks in a selected juvenile population: A preliminary report. J. Forensic Sci. *29(2)*:254-259.

Rawson RD, Ommen RK, Kinard G, Johnson, and Yfantis A (1984) Statistical evidence for the individuality of the human dentition. J. Forensic Sci. *29(1)*:245-253.

Rawson RD, Vale GL, Sperber ND, Hershaft EE, and Yfantis A (1986) Reliability of the scoring system of the ABFO for human bite marks. J. Forensic Sci. *31(4)*:1235-1260.

Rothwell BR (1995) Bite marks in forensic dentistry: A review of legal, scientific issues. J. Amer. Dent. Assn. *126(2)*:223-231.

Sognnaes RF, Rawson RD, Gratt BM, and Hyugen NBT (1982) Computer comparison of bite mark patterns in identical twins, J. Amer. Dent. Assn. *105*:449-451.
Sperber N (1990) Lingual markings of anterior teeth as seen in human bite marks. J. Forensic Sci. *35(4)*: 838-844.
Vale GL, Sognnaes RF, Felando GN, and Noguchi TT (1976) Unusual 3 dimensional bite mark evidence in a homicide case. J. Forensic Sci. *21(3)*:642-652.
Vale GL, and Noguchi TT (1984) Anatomical distribution of human bite marks in a series of 67 cases. J. Forensic Sci. *28(1)*:61-69.
Weigler S (1992) Bite mark evidence: forensic odontology and the law. Health Matrix *2(2)*:303-323.
West MH, Barsley RE, Frair J, and Seal MD (1990) The use of human skin in the fabrication of a bite mark template: two case reports. J. Forensic Sci. *35(6)*:1477-1485.
Whittaker DK, and MacDonald DG (1989) A Colour Atlas of Forensic Dentistry. London: Wolfe Medical Publications, LTD.

AN UNUSUAL TALON CUSP

TRIONA MC NAMARA
Regional Orthodontic Department, St. James's Hospital, Dublin 8, Ireland

A 13 year-old male Caucasian presented for routine orthodontic treatment. He had a Class II division 1 malocclusion with significant crowding in both mandibular and maxillary labial anterior segments of the dentition. He had no significant medical history. Marked tubercles of Carabelli were noted on the maxillary first permanent molars. The mandibular right second molar was infra-occlusal and a facial talon cusp was noted on the permanent left mandibular central incisor (Fig.1).

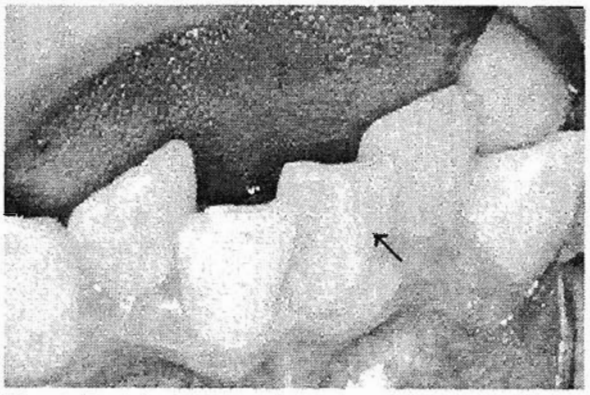

Fig. 1. 'Facial' talon cusp on a permanent mandibular left central incisor (arrow).

As the facial talon cusp of the mandibular incisor would prevent a proper reduction in overjet and ultimately interfere with the occlusion, the orthodontic treatment plan decided upon was extraction of this tooth, in addition to extraction of three of the first premolars. Uneventful fixed orthodontic appliance therapy is now underway.

The facial location of this talon cusp is unusual. The affected incisor tooth is currently being investigated to assess the extent of its pulp chamber.

The aetiology of talon cusps is unknown. However, the feature is thought to be a combination of genetic and environmental factors (Davies and Brook, 1992).

In the cases that I have found in the literature, talon cusps occurred most commonly on permanent incisors, 90% in the maxilla, with the maxillary lateral incisor the most commonly affected (Rismah, 1991). They have been reported primarily in the secondary dentition, though recent cases involving the primary maxillary incisors have been reported (Chen, 1986; Meon, 1990a,b; Rusmah, 1991). Males were more commonly affected than females, with racial variation reflected by a predominance of the feature in the Chinese population (Davies and Brook, 1992). The facial talon cusps usually occurred in single cases (Pledger, 1989; Meon, 1990a; Acs, 1992) or a few individuals (Meon, 1990b; Harris and Owsley, 1991). Talon cusps have been reported as an isolated finding (Chen, 1986) or in association with other dental anomalies such as shovel-shaped incisors, peg-shaped lateral incisors, unerupted canines, three-rooted mandibular first molars, impacted mesiodens, and odontomes (Davies and Brook, 1986; Acs, 1992). Syndromes associated with talon cusps include Mohr syndrome, *incontinenta pigmenti achromians*, and Rubenstein-Taybi syndrome (Tsutsumi, 1991; Acs, 1992).

The example of the talon cusp shown in Fig. 1 differs from most of the examples in the literature. It occurs on the facial aspect of a mandibular permanent central incisor of a Caucasian, who lacks the anomalies and syndromes associated with published cases. Therefore, I am seeking comments from readers on the facial talon cusp shown in Fig. 1. Personal findings, bibliographic references on other cases of facial talon cusps, and information about the aetiology of this anomaly also would be greatly appreciated.

LITERATURE CITED

Acs G (1992) Shovel incisors, three-rooted molars, talon cusp and supernumery on one patient. Paediatr. Dent. *13*:236-237.
Chen RJ (1986) Talon cusp in primary dentition. Oral. Surg. Oral. Med. Oral. Path. *62*:67-72
Davies PJ, and Brook AH (1986) The presentation of the talon cusp: diagnosis, clinical features, associates, and possible aetiology. Brit. Dent. J. *160*:84-88.
Harris E, and Owsley DW (1991) The talon cusp: A review with three cases from North America. J. Tennessee Dent. Assoc. *71*:20-22.
Meon R (1990a) Talon cusp in primary dentition-case report. Sing. Dent. J. *15*:32-40.
Meon R (1990b) Talon cusp in two siblings. N. Z. Dent. J. *86*:42-44.
Pledger DM (1989) Talon cusp: Report of two cases. Brit. Dent. J. *167*:171-173.
Rusmah M (1991) Talon cusp in Malaysia. Aust. Dent. J. *36*:11-14.
Tsutsumi T (1991) Labial talon cusp in a child with *Incontinentia pigmenti achromans*: case report. Pediat. Dent. *13*:236-237.