TECHNICAL NOTE

An Integrated Technique for the Analysis of Skin Bite Marks

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ABSTRACT

Abstract:The high number of murder, rape, and child abuse cases in South Africa has led to increased numbers of bite mark cases being heard in high courts. Objective analysis to match perpetrators to bite marks at crime scenes must be able to withstand vigorous cross-examination to be of value in conviction of perpetrators. An analysis technique is described in four stages, namely determination of the mark to be a human bite mark, pattern association analysis, metric analysis and comparison with the population data, and illustrated by a real case study. New and accepted techniques are combined to determine the likelihood ratio of guilt expressed as one of a range of conclusions described in the paper. Each stage of the analysis adds to the confirmation (or rejection) of concordance between the dental features present on the victim and the dentition of the suspect. The results illustrate identification to a high degree of certainty.

KEYWORDS
forensic science • forensic odontology • bite marks • court cases

The high number of murder, rape, and child abuse cases in South Africa has led to an increase in the number of bite mark cases seen at the forensic section of the Department of Oral Pathology and Oral Biology, School of Dentistry, University of Pretoria, South Africa. An objective analysis which can withstand vigorous cross-examination in high courts is essential if perpetrators are to be matched with the bite marks found at crime scenes. The comparison of bite marks with the dentitions of possible perpetrators must be regarded as a scientific analysis in which a degree of concordance is demonstrated or rejected, and not as a procedure in which

criminal, as he should only analyze the relevant evidence presented to him, give a scientific evaluation, and leave the verdict to the judiciary.

Metric analysis, pattern association, and a combination of the two methods have been used in the past to analyze bite marks with varying degrees of success (2–4). Acetate overlays and computer-generated comparisons are regarded as the most objective method of bite mark analysis (5–7). Individual cases in which highly scientific methods such as tissue micro-replication followed by scanning electron microscopy for determination of concordance between a suspect's dentition and a victim's epidermal lesions have also been described (8). The need for an objective bite mark analysis system is recognized, although the problems of variability of presentation of the injuries may render this ideally difficult to accomplish (9). It must be emphasized that tooth marks are not necessarily bite marks and can be caused by various forms of trauma in which the teeth of the suspect or victim are imprinted onto the skin. To establish the identity of the perpetrator in a bite mark case, the probability of another individual showing the identical print must be beyond any reasonable doubt. In the absence of a large number of features present in a bite mark, a single but heavily weighed feature could be of equal discriminatory potential to several common features in linking a suspect with a bite mark (10). Several researchers have tried to calculate the minimum requirements for establishing identity with tooth marks. Forensic odontologists often rely on personal experience when weighing features, a practice which can be questioned and challenged in court of law. The conclusion of the forensic analysis as presented in court should never exceed the degree or likelihood ratio of guilt which can be expressed through a range of conclusions. These include:

- absolute certainty (should never be used in skin bite mark cases).
- high degree of certainty pertaining to identification or with all probability.
- possible identification (cannot exclude)/supports identification.
- exclusion of identity.

Dental experts giving evidence in bite mark-related cases need to determine which of the above conclusions are appropriate to their specific case. An analysis technique which can aid in the scientific determination of these likelihood ratios is described in this paper.

Materials and Methods

The proposed technique is described in four stages using a real case study. The first step in this analysis involved the identification/determination of the mark as a human bite mark. This was followed by a pattern association between the mark present on the ventral abdomen of the victim and the upper and lower dentition of the suspect. The next step was a metric analysis of selected dental features present in the bite mark. Finally, the data obtained from the metric analysis were compared to the relevant population data relating to the specific features, in an attempt to weigh the features as common, uncommon, or very uncommon (11). Accordingly, an event which occurred five times or less, out of 100 possible events, but more than once was regarded as an uncommon event, and an event which occurred one time or less, out of 100 events, was a very uncommon event. Events occurring more than five times out of a 100 were thus regarded as common. The relevant frequencies of 16 selected dental features were determined from a sample of 300 volunteers in the geographic area in which the suspect lived (12). For continuous variables, 1, 5, 95, and 99 percentiles were determined, which corresponded with Allan's (11) classification of common, uncommon, and very uncommon events.

Stage 1. Determination/Identification of the Mark as a Human Bite Mark

This initial examination is important as certain marks can present as arch forms easily mistaken for human tooth marks (13,14). The converse is also possible where the initial impression is that of an injury caused by an inanimate object. The general impression, shape, and size (GISS) must conform to that of a human bite mark. Individual recognizable tooth marks must be present within the dental arches if any degree of identification is to be made.

Stage 2. Pattern Association Analysis

Pattern association analysis of bite marks/tooth marks can be defined as a three dimensional analysis and comparison of the dental arch forms, arch relationships, and individual tooth features within the described dental arches (3). The tooth marks present in the upper and lower arches were compared, followed by the examination of each individual tooth present in the bite mark as well as each tooth's position relative to the surrounding teeth. Obvious features which included diastemas, missing teeth, rotated teeth, and teeth out of the dental arch help with orientation while matching the patterns. It is important to note that minimal tissue distortion will not affect the pattern-associated comparison of features in the bite mark (15).

Stage 3. Metric Analysis

The next step was the metric analysis of selected dental features present in the bite mark. This metric analysis was carried out to weigh the features against the population data (16). Modern computer software programs allowed for the easy calibration of the image and the accurate analysis of the individual features. This case study included measuring the intercanine distance and tooth rotation values. These measurements were compared with the measurements for the corresponding features on the suspect's models.

Stage 4. Comparison with Population Data

The fourth step of the analysis was to compare the metric analysis of the selected dental features with data relating to the relevant population sector to which the suspect belongs. Each of the selected features were evaluated and classified as common, uncommon, or very uncommon (11,16).

Results

Determination/Identification of the Mark as a Human Bite Mark

The first impression of the mark in Fig. 1 was that of a square inanimate object, e.g., a square bed post. On closer examination, individual tooth marks were visible (Fig. 2). The square shape of the bite mark was unusual but a clear upper and lower arch could be distinguished. The bite mark was oriented by prominent bruising caused by the slightly longer canines in the maxillary

rectangular marks between the diamond-shaped canines in the maxillary arch, representing the four anterior incisors. The maxillary intercanine distance of c. 31 mm was within normal limits for a human dentition. The GISS or class characteristics were therefore consistent with that of a human bite mark.

FIG. 1—Suspected "bite mark" on ventral abdomen of the victim.

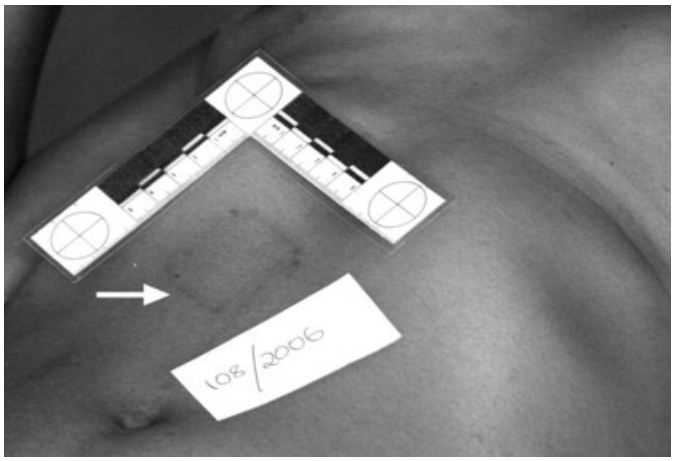
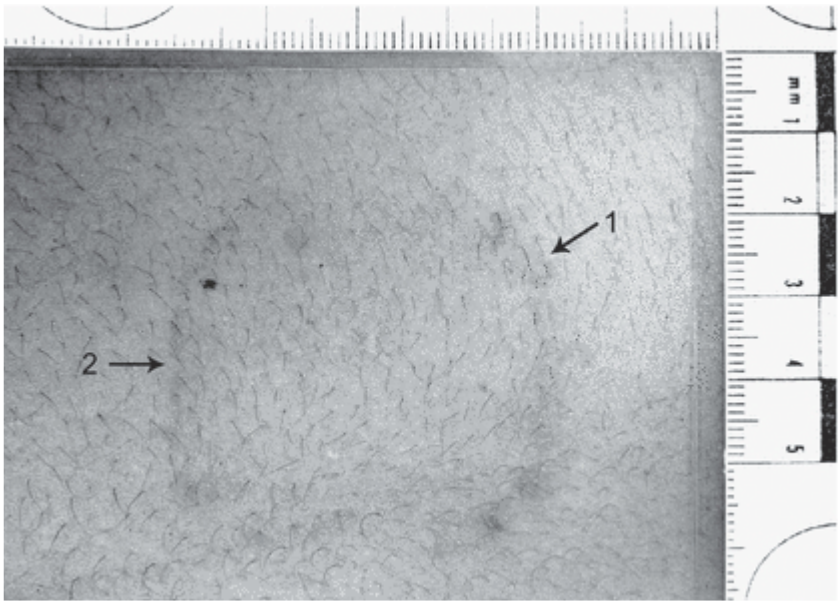


FIG. 2—Close-up view showing mandibular and maxillary arches and clearly recognizable dental features.



Pattern Association Analysis

The results of the pattern association showed the following concordant features. Both the

maxillary and mandibular arches were remarkably square in shape. All twelve teeth were present in both the bite mark and the suspect's dentition (Figs. 3 and 4). The upper left lateral incisor in both bite mark and the dentition of the suspect showed a similar negative distal rotation (16). The V caused by the positive mesial rotations of the lower central incisors was clearly visible on the mandibular section of the bite mark and showed concordance with the mesial rotations of the suspect's lower central incisors. When an acetate overlay depicting the incisal surfaces of the suspect's twelve anterior teeth was matched with the tooth marks, a positive pattern association was observed (Fig. 5).

FIG. 3—Maxillary arch of a suspect showing rotated left lateral incisor.

FIG. 4—Mandibular arch of a suspect showing inwardly rotated central incisors.

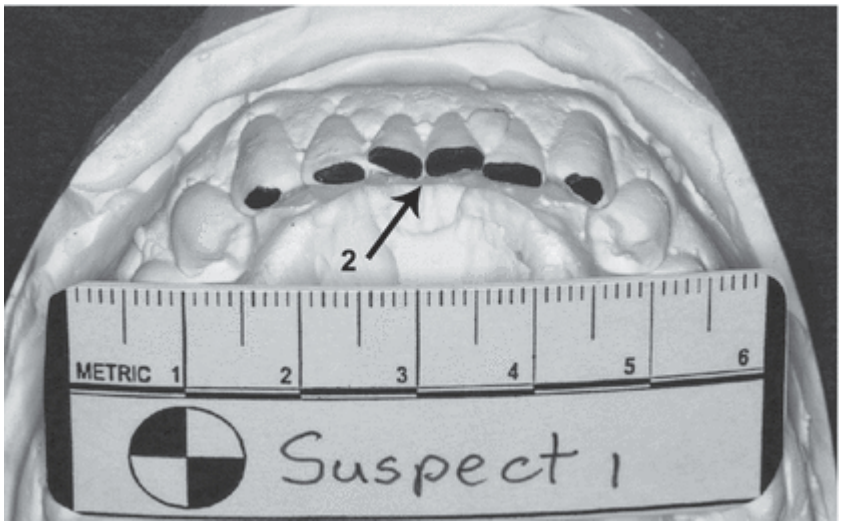
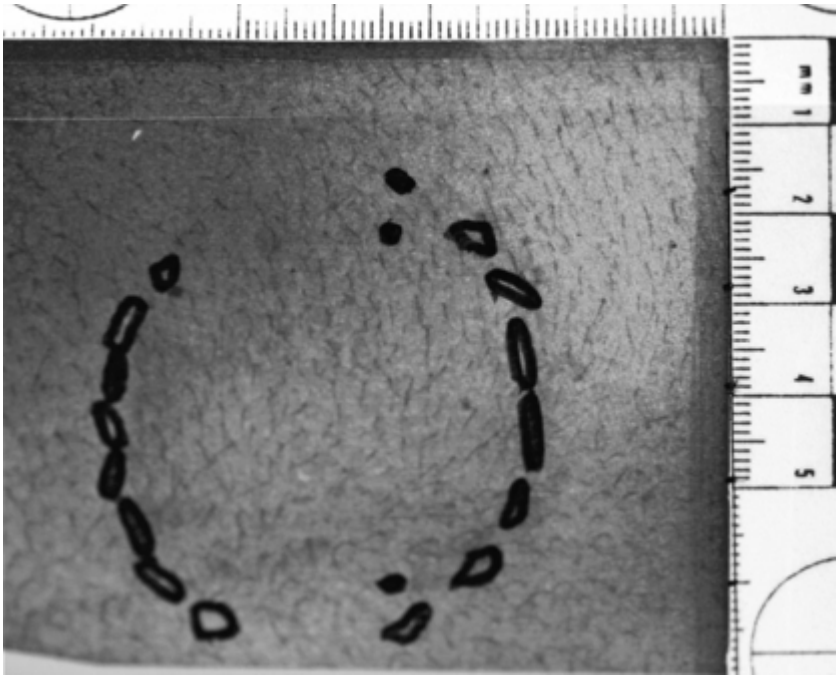


FIG. 5—Acetate overlay demonstrating high degree of association.



Metric Analysis

The results of the metric analysis of selected features are illustrated in Table 1.

TABLE 1—The results of the metric analysis of selected dental feature.

Metric Analysis of:	Measurement Bite Mark	Measurement Suspect
Rotation angle 22	–30 degrees	–32 degrees
Rotation angle 41	+20 degrees	+22 degrees
Rotation angle 31	+21 degrees	+22 degrees
Intercanine distance 13–23 mm	31 mm	32 mm

Comparison with Population Data

The data from the metric analysis of the selected features were compared to the available population data from Gauteng province in which the crime was perpetrated and are illustrated in Tables 2–4. A square-shaped arch is uncommon in the relevant population (Table 5).

TABLE 2—Common, uncommon, and very uncommon values for intercanine distance observed in the maxillary arches in Gauteng volunteers (n = 300) (12).

Upper Teeth	Very Uncommon Values	Uncommon Values	Common Values	Uncommon Values	Very Uncommon Values
Intercanine distance in mm (mean 34.5 mm, SD 2.2 mm)	<28.7	28.7 to <30.9	≥30.9 to <38.1*	≥38.1 to ≤39.6	>39.6

*The values 31 mm (victim) and 32 mm (suspect) are common in the relevant population.

TABLE 3—Common, uncommon, and very uncommon tooth rotation values for left lateral maxillary incisors in Gauteng volunteer (n = 300) (12).

Upper Teeth	Very Uncommon Negative Rotation (Values in Degrees)	Uncommon Negative Rotation (Values in Degrees)	Common Rotation (Values in Degrees)	Uncommon Positive Rotation (Values in Degrees)	Very Uncommon Positive Rotation (Values in Degrees)
Left lateral incisor (mean −6.2 degrees; SD 14.0)	<−24*	−24 to < −15	≥−15 to <16	≥ 16 to ≤29	>29

*The value of −30 degrees (victim) and −32 (suspect) degrees is very uncommon in the relevant population

TABLE 4—Common, uncommon, and very uncommon values of tooth rotations observed in the mandibular central teeth in Gauteng volunteers (n = 300) (12).

Lower Teeth	Very Uncommon Negative	Uncommon Negative Rotation	Common Rotation (Values in	Uncommon Positive Rotation	Very Uncommon Positive

	Rotation (Values in Degrees)	(Values in Degrees)	in Degrees)	(Values in Degrees)	Rotation (Values in Degrees)
Right lower central (41) (mean 1.4 degrees; SD 8.5)	<–25	–25 to <–17	≥–17 to <12	≥12 to ≤20	>20*
Left lower central (31) (mean 1.3 degrees; SD 5.6)	<–26	–26to < –16	≥–16 to <12	≥12 to ≤18	>18*

*The value of +20 degrees (victim) and +22 degrees (suspect) on the right lower central (41) is very uncommon in the relevant population. The value of +21 degrees (victim) and +22 degrees (suspect) on the left lower central (31) is very uncommon in the relevant population.

TABLE 5—Arch shapes as a percentage of the Gauteng volunteers examined (n = 300) (12).

Arch Shape	Square Shape	Parabolic Shape	V Shape
Maxillary arch	4.92%	91.8%	3.28%

Discussion

The protocol followed in this case study is a scientific analysis of the facts which when presented in court will be defendable under ruthless cross-examination. The above technique clearly demonstrates that tooth marks in skin can be scientifically analyzed for presentation in court cases. The step-by-step approach builds on the available data to a point where a degree of certainty can be established between the mark present on the victim and the dentition of the suspect.

Once it has been established that the mark is in fact a bite mark, a multi-dimensional pattern-associated analysis of every feature present in the mark is required. Bernitz has shown that a small degree of warping and shrinkage will not affect the pattern-associated analysis of the bite mark (15). The expert will never know the exact position of the victim during the biting process, but the relationship of the dental features in a bite mark will remain constant, making bite mark analysis possible (17). The expert is required to demonstrate that the tooth marks present on the victim's body and the suspect's dentition show similar dental features present in the same position, in relation to the same teeth, in the same shaped arches and have similar size ratios.

In this case study, the mark initially looked square having symmetrically placed darker areas of bruise at the corners. It was not the classical appearance of a bite mark and could have been overlooked, or just documented as a traumatic wound on the ventral abdomen. The importance of step one in the analysis protocol is thus highlighted.

The pattern association of dental features in this case clearly demonstrated the degree of concordance present between the tooth marks and the suspect's dentition. The photographic images were enlarged so that the features could be clearly visualized. The fact that all the teeth were present in both exhibits showed similar tooth rotations, arch forms, intercanine distances without any unexplained discrepancies, points to a degree of similarity at stage two.

Metric analysis is a method of establishing an approximate numerical value which can be used in weighing the features according to the relevant population statistics. Here again, small discrepancies in the numerical values will not affect the weighing process, as they are classified into three groups according to Allen (11) and not seen as individual numerical values as demonstrated in this case. It is important to realize that when comparing the measurements of the suspect's dentition with the tooth marks present on the skin of the victim, an exact match will seldom be found (15). The population data used in this case study illustrate the technique but are not representative of the said province as only 300 bites were analyzed. A sample size of 300 is that number of volunteers deemed statistically adequate for the design of a model, namely "A Model to Determine the Individual Discrimination Potential of Numerically Analyzed Dental Features in the Anterior Twelve Teeth" which was the subject of a Ph.D. (12). The volunteer profile was based on, and reflected the results of the South African population census of 1996. The weighing of each of three concordant rotation values as very uncommon within the relevant population coupled with an uncommon weighing of the concordant arch form clearly demonstrated a "high degree of certainty/all probability" pertaining to identification of the bite mark as originating from the dentition of the suspect. No absolute statistical value to the likelihood of guilt should be given by a forensic odontologist as he may not be in a position to defend the statement under cross examination. If all the features present in this bite mark were analyzed as common, a conclusion of "possible degree of certainty/possible identification" would have been more appropriate. Obvious discrepancies would have indicated a mismatch.

It is the author's opinion that a conclusion of "absolute certainty" never be given in skin bite mark cases. The expert witness would find such a statement to be virtually undefendable on cross examination. Pretty and Sweet (18) use the term "highest level of forensic significance" which in effect does not imply "absolute certainty." Several other degrees of guilt have been expressed in the literature but are not applicable to skin bite marks (10). Bite marks present on inanimate objects can however be matched with absolute certainty.

This case study has demonstrated a positive concordance between the bite mark and the suspect's dentition. The expert can state with a "high degree of certainty" that the bite mark present on the central abdomen of the victim was inflicted by the suspect.

Conclusion

There has been a degree of skepticism regarding the validity of skin bite mark analysis by expert witnesses. The dramatic increase in skin bite marks cases being heard by the South African courts has necessitated research into this aspect of forensic dentistry. This paper described an objective analysis technique which could be used when confronted with a bite mark case. It has been applied with success in several cases involving tooth marks, and can be adapted for each individual case. The relevant frequencies of specific dental features within specified populations is, however, required.

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