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Bite Marks Analysis in Forensic Odontology

Sujatha S Reddy[*]
N Rakesh[**]
Atul Kaushik[***]

ABSTRACT

Background: Bite marks may be one of the physical and biological evidences left by criminals at the site of criminal act. Bite mark identification is based on the individuality of a dentition, which is used to match a bite mark to a suspected perpetrator., **Aims & objectives:** To formulate an integrated technique for analyzing the bite marks by devising an experimental case study using new and accepted techniques., **Methodology:** Dental stone casts and VPS impressions of bite marks on wax wafers were made for thirty volunteers having complete set of natural upper and lower anterior teeth. Pattern association followed by metric analysis of selected dental features in the dental stone casts and VPS impressions was done., **Results:** A high sensitivity 0f 100% and positive predictive accuracy of 66.6 % implies a fairly high degree of accuracy for this method of bite marks analysis., **Conclusion:** This paper describes an objective analysis technique which could be used when confronted with a bite mark case and can be adapted for each individual case. The relevant frequency of specific dental features within specified populations is, however, required.

Keywords: Forensic odontology, bite mark identification, pattern association, hollow volume overlays, metric analysis.

INTRODUCTION

The increased number of murder, rape and child abuse cases reported worldwide has led to an increase in the number of bite marks cases been reported. The individuality of human dentition frequently allows the forensic odonto-stomatologist to arrive at a strong opinion of association, in case of identification and bite mark analysis. An objective analysis which can withstand vigorous cross-examination is essential if perpetrators are to be matched with the bite marks found at crime scenes. Suspects can be physically linked to or exonerated from crime scenes through deoxy ribo nucleic acid (DNA) samples and bite marks [1]. The validity of DNA evidence is, however, regularly challenged, and the role of bite marks as substantive evidence is thus of great importance.

The most important step in bite mark analysis is to recognize a patterned injury as a human bite mark [2,3] followed by pattern association and metric analysis of the bite mark [4]. Detailed initial examination of the bite marks is important to ascertain whether the bite is of human or animal origin. The general impression, shape and size must confirm to the nature of human bite mark. Pattern association analysis of bite 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. Hollow volume overlays and computer-generated metric comparisons are regarded as the most objective method of bite mark analysis [5,6]. The conclusion of the forensic analysis should never exceed the degree or likelihood ratio of guilt which can be

Author's Affiliations: *Professor Department of Oral Medicine, Diagnosis and Radiology, **Senior lecturer M S Ramaiah Dental College & Hospital, ***PG Student MSRIT Post, New BEL Road, Bangalore-560054, Karnataka (India).

Reprints Requests: Dr. Sujatha S Reddy, Professor, Dept of Oral Medicine, Diagnosis and Radiology,M S Ramaiah Dental College & Hospital, MSRIT Post, New BEL Road, Bangalore-560054, Karnataka (India). E-mail id: s_sujathajanardhan@yahoo.com, dratulkaushik@gmail.com, Ph: +91-09448974887, +91-09448507494, 080-23602079, Fax: 080-23601825.

expressed through a range of conclusions which 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) D supports identification and exclusion of identity [4]. The need for an objective bite mark analysis system is recognized, although the problems of variability of presentation of injuries may render this ideally difficult to accomplish. 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 different stages using an experimental case study. Thirty volunteers, 18 male and 12 female, with complete set of natural upper and lower anterior teeth between the age group of 15 and 30 years, were included in the study after obtaining their informed consent (Table 1). Subjects with orthodontic appliances, intraoral prosthesis, impaired mouth opening, periodontal and gingival abnormalities, developmental tooth anomalies and severe wasting diseases were excluded from the study.

The first step in this analysis involved simulation of human bite marks by producing volunteer's dental stone models and bite marks on wax wafers. The next step was pattern association between the bite marks on wax wafers and upper and lower dentition of volunteers. The final step was a metric analysis of selected dental features in the bite marks.

Table 1: Subjects included in the study

	No. of Subjects	Mean age (Years)
Male	18	25 ± 6
Female	12	23 ± 8

Table 2: Descriptive Statistics for stone casts and VPS impressions

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
MCSA*	30	.037	.095	.06093	.002827	.015485
MISA†	30	.034	.086	.05720	.002692	.014747
MCPM‡	30	2.934	5.646	4.37623	.136663	.748534
MIPM§	30	2.926	5.642	4.34677	.135067	.739791
DCSA((	30	.029	.073	.04607	.002077	.011374
DISA¶	30	.026	.068	.04243	.001991	.010903
DCPM**	30	2.634	4.886	3.73210	.109690	.600796
DIPM††	30	2.628	4.881	3.72803	.110449	.604956

* – maxillary cast surface area

† - maxillary impression surface area

‡ - maxillary cast perimeter

§ - maxillary impression perimeter

((- mandibular cast surface area

¶ – mandibular impression surface area

** – mandibular cast perimeter

†† –mandibular impression perimeter*

SIMULATING HUMAN BITE MARKS

Positive replica of the upper and lower anterior teeth of all thirty volunteers were prepared by taking alginate impressions and pouring dental stone into them, thus producing stone models. Wax wafers were used to record the bite of anterior teeth in these individuals similar to the technique used by Rawson et al. Pink dental modeling wax No. 2, measuring 90 mm x 160 mm and 1.5mm thick but were first folded double and again folded around a cardboard measuring 55 mm x 115 mm and 0.15 mm thick, giving a total thickness of 6.15 mm. On the remaining cardboard, a label was applied and glued for recording the unique number, age, gender, Angle's classification, midline deviation, cross bites if present, rotations and any other additional information [7]. The bites were taken between 11:00 AM and 2:00 PM, when the ambient temperature was higher during the summer months, as the wax was warmer and therefore easier to work with. After the volunteers had bitten into the wax, tooth marks were inspected for quality and clarity. When necessary, bites were repeated.

PATTERN ASSOCIATION ANALYSIS

Upper and lower anterior bite marks present in the wax wafers were compared to the teeth in stone casts by the examination of each individual tooth for fractures and grooves on the incisal edges as well as position relative to the surrounding teeth, diastema, missing teeth, rotated teeth and alignment of teeth which help in 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. On the basis of pattern association analysis, a number of bite marks and volunteers stone dental casts could be differentiated from the others.

HOLLOW VOLUME GENERATION AND METRIC ANALYSIS

Impressions were again made for each volunteer for the maxillary and mandibular anterior bite marks on the wax wafers using vinyl polysiloxane (VPS) impression material (Reprosil, Dentsply, Caulk) with light body consistency. Incisal edges of teeth from the stone models as well as VPS impressions were highlighted using permanent marker, for clarity during bite mark analysis. These highlighted incisal edges of all the stone models and VPS impressions were scanned with an ABFO scale No-2, using a flat bed scanner (Astra 3600) and stored with proper labeling for identification. The purpose of using ABFO scale No-2 was to rule out any geometrical distortion while scanning (Figure 1a and 1b).

Figure 1 - Scanned image of dental stone cast (a) and VPS impression of bite mark (b) with ABFO scale no – 2 using flat bed scanner.

Figure 2 - Hollow volume overlay of the incisal edges of dental stone cast shown in Figure 1a (a) and VPS impression shown in Figure 1b (b).

Overlays of these scanned highlighted incisal edges of the anterior teeth from stone model and VPS impressions were made using computer image-processing software, the Adobe Photoshop 9 ''magic wand'' tool [9] (Figure 2a and 2b). Metric analysis was done using features available in the "Image J" software, an image processing computer program available from the National Institutes of Health[10]. Values obtained from stone models were considered as reference values and compared to values from VPS impression (Table 2).

The volunteers were numbered from 1 to 30 and the scores obtained after metric analysis were assigned to them. A comparison was made between the values obtained from stone casts and VPS impressions respectively. Those subjects in whom these values were closely matching were designated as "*Metric match*" and others in whom these values were not closely matching were designated as "*Metric non match*".

Validity parameters such as sensitivity, specificity, positive predictive value and negative predictive value were computed. The mean differences in the parameters measured by the different techniques were compared using independent T -test with 95% confidence interval (CI).

Figure 1: Scanned image of dental stone cast (a) and VPS impression of bite mark (b) with ABFO scale no – 2 using flat bed scanner.

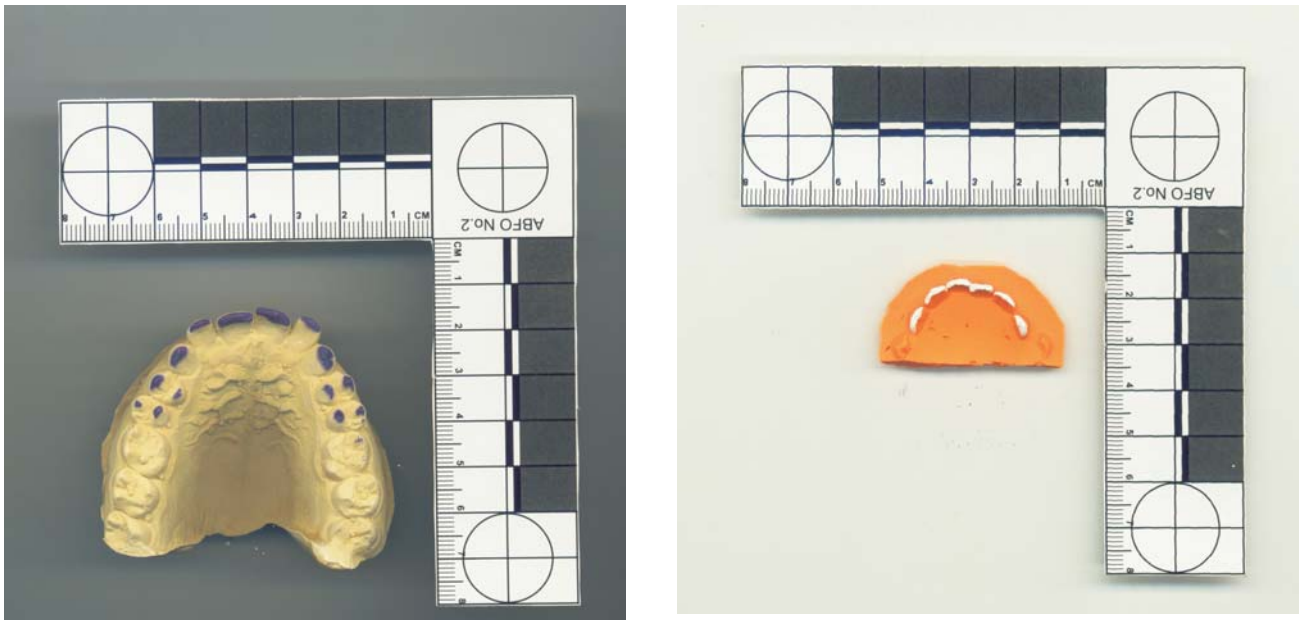
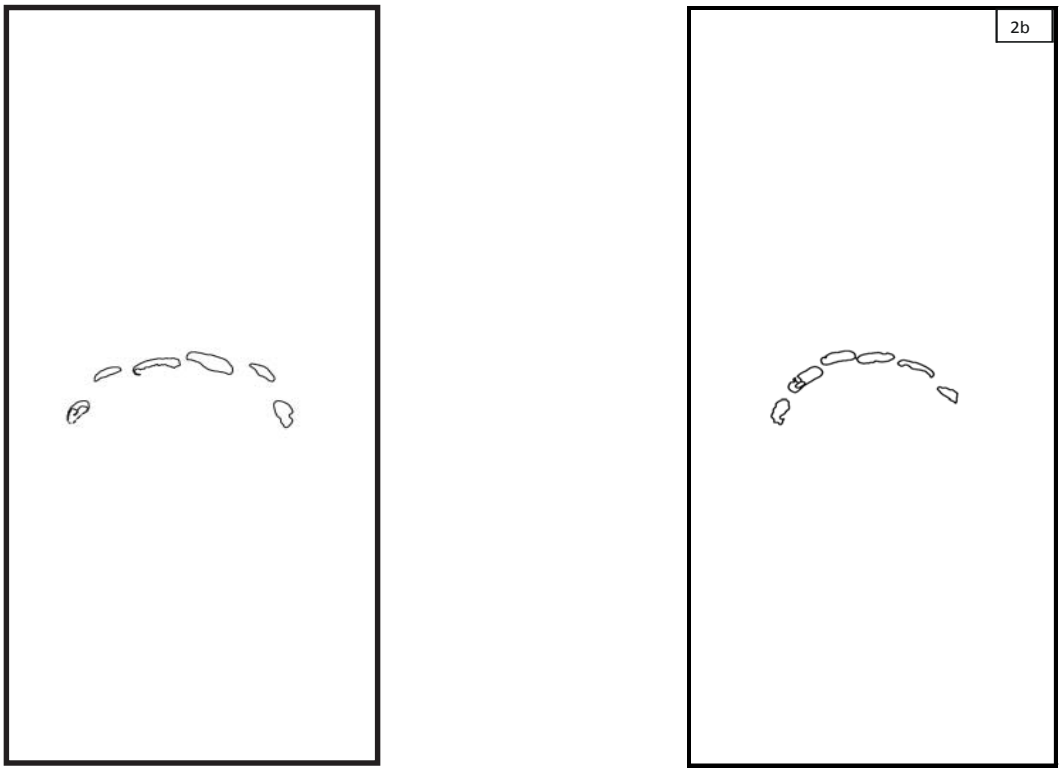


Figure 2: Hollow volume overlay of the incisal edges of dental stone cast shown in Figure 1a (a) and VPS impression shown in Figure 1b (b).



RESULTS

The sensitivity and specificity was obtained using "*table of two*", keeping X-axis as *visual observation* and Y-axis as *metric + visual observation*. The sensitivity obtained was 100% and the specificity was 25%. A sensitivity of 100% means that the test recognizes all actual positives, which are the persons who truly made the bite marks. A low specificity of 25 % means that the test may have more "false positive" results. Positive predictive accuracy was found to be 66.6 %, which implies a fairly high degree of accuracy for this method in bite marks analysis.

DISCUSSION

The above technique clearly demonstrates that bite marks can be scientifically analyzed for crime investigation. Once it has been established that the mark is in fact a human bite mark, a multi-dimensional pattern-associated analysis of every feature present in the mark is required. It has been shown that a small degree of warping and shrinkage will not affect the pattern-associated analysis of the bite mark. It 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[4]. The expert will never know the exact position of victim during the biting process, but the relationship of dental features in a mark will remain constant, making bite mark analysis possible. The results of pattern association of dental features in our experimental case study showed multiple concordant features. All twelve teeth were present in both the bite marks on wax wafers and volunteers dentition. Many cases could be differentiated from others on the basis of unique features like diastema, rotated teeth and teeth out of dental arch while matching the patterns. The pattern association of dental features in this study clearly demonstrated degree of concordance between the bite marks and volunteer's dentition.

Metric analysis is a method of establishing approximate numerical values which can be used in weighing the features according to the relevant population statistics. 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. A conclusion of ''absolute certainty'' should never be given, but of ''possible degree of certainty D possible identification'' would be more appropriate in bite mark cases [4]. Pretty and Sweet has used the term "highest level of forensic significance" which in effect does not imply "absolute certainty" [12]. According to the case study done by Bernitz et al[4], data from metric analysis of selected dental features when compared with relevant population group, showed features ranging from common to very uncommon. But the metric analysis values of selected dental features of suspect's dentition and victim's bite marks were very closely matching, signifying the importance of metric analysis. In our study also, the high sensitivity of 100 % indicates that this method can be used with high success rates for screening of the suspects and a low specifity of 25 % indicate that possible identification of the victims can be done only after taking other evidences into consideration to avoid the false positive results.

CONCLUSION

There has been a degree of skepticism regarding the validity of bite mark analysis by expert witnesses. The dramatic increase in bite marks cases being heard by the 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 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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ABBREVIATIONS USED

Deoxy ribo nucleic acid - DNA

Vinyl polysiloxane – VPS

Confidence interval – CI

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