Original Research Paper

Comparative Study of Three Different Methods of Overlay Generation in Bite Mark Analysis

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Abstract

Bite mark is considered as a pattern produced by human or animal dentition in any substance capable of being marked by those means. Bite marks may be found at the crime scene and overlays generated from these bite marks are being used for comparison with the dentition of the suspect. This study was aimed to evaluate and compare three overlay generation techniques i.e. wax-impression, radiographic and computer assisted methods and validate the best method of overlay generation. Impressions of maxillo-mandibular arches were made and study models were prepared in dental stone. Overlays were generated by aforesaid three methods and overlays generated by each method were compared. Kruskal- Wallis ANOVA H test was used for comparison of the three methods and computer generated overlays were found to be the best as the H value was highest in this case. Computer assisted method of overlay generation proved to be the best method of overlay generation and should be widely used for bite mark analysis in future as it is free from subjectivity incorporated in other techniques.

Key Words: Bite marks, Overlays, Overlay Generation Techniques

Introduction:

Personal identification is important in criminology and Forensic Odontologists are key personnel for identifying a highly individual dentition which in turn could be used to convict or exculpate a suspect. [1, 2] Odontologic evidence is third to fingerprints and DNA analysis as most accurate means of identification. It was rightly said by Furness that "the criminal may lie through his teeth though teeth themselves cannot lie."

Actually in human identification anything different, such as variation from normality, becomes an important tool when trying to establish identity of suspect. [3]

Individuality of human dentition allows Forensic odontostomatologists to reach a strong opinion of association in cases of identification and bite mark analysis.

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It is especially useful in cases of heinous crimes such as sexual assault wherein bite marks are very commonly found on breasts and genitals in females and in cases of child abuse where multiple bite marks are seen. [4]

Normally main focus is on analyzing bite mark injuries on human bodies but bite marks on food may also play an important role in the forensic investigation of a crime especially because marks on food items tend to be more accurate and reproducible than skin. [5, 6]

Bite mark is considered as a pattern produced by human or animal dentition in any substance capable of being marked by those means. Bite mark analysis assumes that uniqueness of dentition can be accurately recorded on skin or an object.

They are assumed to be different even in identical twins. [7] Generally bite marks consist of superficial abrasion, subsurface hemorrhages or bruising of skin. Characteristic of human bite marks are superficial abrasion or subsurface hemorrhages looking like an arch.

They are caused by incisors, canines and premolars depending on amount of skin incised. If less amount of skin is incised, pattern is elliptical extending up to canines but pattern is oval when more skin is incised and premolar imprints are also found in such cases. Abrasions caused by canines are in shape of points.

If perpetrator has dentures additional specific marks can be expected. Such peculiarities can be responsible for specific

wounds and are additional markers for identification. Though the mechanism of bite mark is not clearly understood, the pattern of injury is invariably affected by force and length of time in bite in combination with other physiological and mechanical factors.

Biting is a dynamic procedure involving three moving systems maxilla, mandible and victims reaction. So the same dentition can produce bite marks that exhibit variations in appearance. [8] Depending on part of body and constitution of skin bite mark can be distorted-primary distortion is caused by dynamics of bite and secondary distortion may be time, posture or photography related.

Bite mark investigation involves physical comparison of unknown mark found on skin or objects to known exemplars of suspect's teeth followed by metric analysis of suspect's teeth. Comparison protocols include measurement and analysis of pattern, size and shape of teeth against similar characteristics observed in an injury on skin or a mark on an object. [9]

The tooth exemplar independent of method used to produce it is called an overlay when biting surface data is transferred to a clear transparent sheet; this is then compared with injury on skin or a patterned mark.

Overlays can be hollow when only perimeter of biting edges is recorded to produce facsimile images and inner aspect of tooth image is left transparent while the compound overlays provide images of individual features such as chipping, erosion or wear facets also.

A compound overlay provides 3D topography of teeth surfaces when a partial bite mark exists and identification is otherwise difficult and in such cases identification comparison can be based on individual features of a single tooth. [10]

Dental study model is the most accurate for collecting evidence for human bite mark identification. [11] In this study, an attempt was being made to evaluate and compare three overlay generation techniques i.e. wax-impression, radiographic and computer assisted method and validate best method of overlay generation from dental models.

Materials and Methods:

This study was a single centre clinical and radiographic prospective study which included healthy volunteers with complete set of natural upper and lower anterior teeth. Subjects with impaired mouth opening, compromised periodontal status, developmental tooth anomalies, and loss of anterior tooth structure, orthodontic appliances and intra oral prosthesis were excluded from the study.

Impressions were made for maxillary and mandibular arches for all volunteers who agreed to participate in the study. Impressions were then rinsed thoroughly. Study models were made from these impressions using dental stone and were serially numbered. For each model so prepared, overlays were generated by three methods namely wax impression method, radiographic method and computer generated method. Thus a total of 75 overlays were generated.

1. Wax Impression Method:

Upper and lower dental models were pressed into a sheet of modelling wax (Hindustan modelling wax No.2) to obtain impression of biting edges of six upper and lower anterior teeth by applying manual pressure. Care was taken not to perforate wax sheet. Wax impression of biting edges of anterior teeth was obtained on wax sheet.

A transparent sheet was placed over the obtained wax impression and periphery of each shallow depression was hand traced with a black fine tipped marker pen to obtain hollow volume overlay for both arches to simulate a human bite.

ABFO scale No.2 was placed on left side of obtained wax impression overlay as laterality marker and sides were marked with a marker pen. (Fig. 1, 2)

2. Radiographic Method:

Wax impression was obtained as described earlier and the depressions were coated with a radioopaque dye (iohexol) with a thin hairbrush and allowed to dry. (Fig. 3)

Now the wax sheet was placed on an occlusal film size No.4 (57* 76mm).A radiographic image of wax impression was obtained using 60 kvp, 10 ma and central ray directed perpendicular to wax sheet.

Bite marks present as white teeth marks in a dark background when film is processed. These white marks were traced on a transparent sheet to obtain radiographic overlay.ABFO scale No. 2 was placed on radiographic overlay so obtained as laterality marker and sides were marked with a marker. (Fig. 3, 4)

3. Computer Assisted Method:

Dental study model was placed on a scanner with incisal edges touching the glass plate of the scanner. An ABFO No.2 scale was placed on left side of cast as laterality marker and the model was scanned.

The scanned image so obtained was imported into Adobe-photoshop software version 10.0. Biting edges were selected using magic

and tool and selection was smoothed. Again a new layer was created to obtain a hollow volume overlay.The image so obtained was printed on a transparent sheet to have computer assisted overlay (Fig. 5, 6). [12]

Now for each dental study model three overlays were there. Each overlay was placed over the biting surface of dental model one by one for assessing the degree of match and each time a value between0 to 3 was assigned depending on degree of match (Table 1). [13, 14] This method of comparison is called indirect comparison method and the method of analysis is non-metric analysis.

Results:

Spearman Rank Correlation results were suggestive for intra-observer reliability between observation 1 and 2 of first observer and inter observer reliability between observation 1 and 2 of first observer and second observer. Kruskal Wallis ANOVA test was used to compare matching between the three methods of overlay production.

There was no significant difference in matching overlays by wax impression and radio opaque methods ($p>0.05$) but both these methods varied significantly from the computer assisted method ($p<0.05$). (Table 2)

There was no significant difference in matching cases between wax and radio-opaque methods as H-value is 0.40.

There was a significant difference in matching cases between wax impression and computer generated methods as H-value was 28.68. Numbers of moderate and excellent matching cases were higher in computer generated method compared to that of wax imprint method. There was a significant difference in matching cases between radio opaque and computer generated methods as H-value was 25.48.

Numbers of moderate and excellent matching cases were higher in computer generated method compared to that of radio opaque method. Hence, computer generated method was found to be a better method relative to radiographic method. There was a significant difference in matching cases among different methods ($p<0.05$).

Number of moderate and excellent matching cases were higher in computer generated method (44%) compared to that of other two methods. Hence, computer generated method was found to be best method. (Table 3)

Discussion:

A bite mark may be defined as a mark having occurred as a result of either a physical alteration in a medium caused by the contact of teeth, or a representative pattern left in an object or tissue by the dental structures of an animal or human. Bite marks analysis is based on the premise that ‘no two mouths are alike’.

Bite marks are thus, considered as valuable alternative to fingerprinting and DNA identification in forensic examinations. The human bite mark is capable of withstanding the extreme conditions of the environment and is a ready source of information that can be identified even in the deceased individual.

In the present study we attempted to assess the reliability of three commonly used methods of overlay generation for analysis of bite marks. In our study H-value was 0.4 when we compared wax-impression and radiographic methods which suggests no significant difference in results between these two methods.

This probably could be attributed to the fact that dental models were pressed on wax sheet arbitrarily without any standardisation of force for various models which could have led to variations in area of indentations created on wax sheet. As regards to wax impression method our study also correlated with a previous study by Saritha Maloth et al [10] where they have recommended that it should be discontinued as there is lot of scope for manipulation and observer bias.

Sweet and Bowers also concluded in their study that subjective process of hand tracing should not be used. [15, 16] Similar result for wax impression method was also obtained in study by Khatri et al. [17]

Further the same wax impression was used for radiographic method also which probably affected the radiographic overlays too.

Some magnification or distortion could have incurred while taking radiographs. None of the overlays generated by radiographic method also matched accurately.

This finding of our study was not in accordance with prior study by Sweet et al [15, 16] where they found that area of tooth was best measured by radiographic method.

One reason for this variation in result could be that Sweet et al directly scanned the radiographs with bite indentations which probably reduced the subjectivity instead of tracing the periphery of indentation on radiographs on transparent sheet as we did in our study. H-value was significant when either of these methods were compared to computer assisted method i.e. there was significant difference in results.

In our study we have found maximum number of excellent matching overlays in computer assisted method i.e. 44% while in another 44% there was moderate matching.

Reason for this could be the fact that dental models were directly scanned and later biting edges were selected by inbuilt tools in software which minimised subjectivity and manipulation bias and allowed for more accurate reproduction of biting edges compared to the previous two methods.

Thus the result of our study showed that computer assisted method was the best method of overlay generation. This is in accordance with previous studies by Sweet et al, Maloth et al and Khatri et al. [10, 15-17] Mc Namee et al also suggested in their study that both direct and indirect computer assisted methods using Adobe photoshop software were reliable for overlay generation. [18]

An even better way of generating computer assisted overlays could be the use of Dental Print software that generates different comparison overlays from 3D dental cast images depending on pressure of the bite or distortion caused by victim biter reaction; this procedure is entirely automatic and thus avoids observer bias and it is impossible for third parties to manipulate the image. [19]

Conclusion:

Bite mark analysis is an important aspect of forensic dentistry that is invaluable in solving crimes and in identification of persons involved in criminal activities. The human bite mark is capable of withstanding the extreme conditions of the environment and is a ready source of information that can be identified even in the deceased individual.

The uniqueness of human dentition and analytical techniques usually allow an exact identification of perpetrator. But the better way of interpretation should be the statement that there is a possibility to exclude the suspect or a high probability that the suspect is the cause of bite mark.

The science of bite mark identification is quite new and potentially valuable. Bite marks if analysed properly not only can prove the participation of a particular person or persons in crime but also help in exoneration of the innocent. It is strongly recommended to discontinue hand tracing methods which depend on subjective input by Odontologists and use computer assisted methods which have comparatively higher reliability and accuracy.

The field of bite mark science is continuing to develop, and so is the need for those who are trained and experienced in the identification with regard to the cases relating to the bite marks. [20]

With respect to possible failures of DNA identification, Forensic stomatological investigations should be considered routinely in all cases of bite injuries. Experience of examiners has an influence on results but still the method has a high level of reliability.

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Fig. 1: Wax Impression of Biting Edges

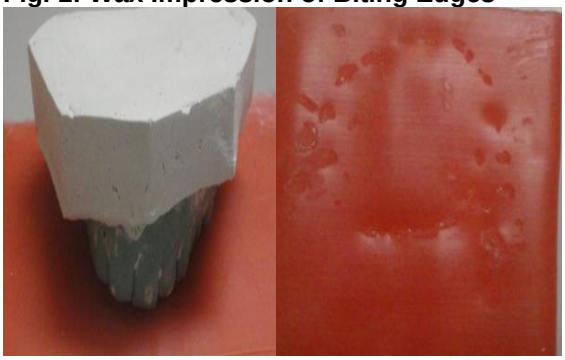

Fig. 2: Biting Edges Tracing and Wax Imprint Overlay

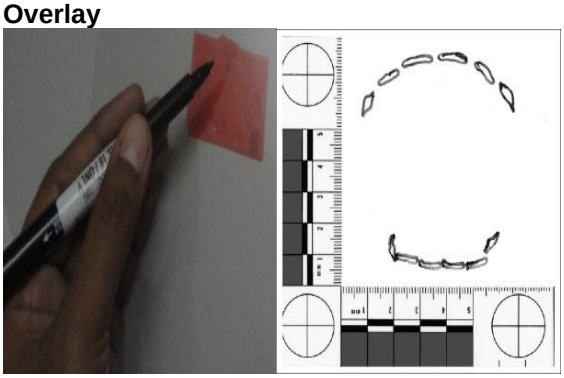

Fig. 3: Radiograph of Wax impression after coating with Dye

Table 1: Numeric Values for Matching

Numeric	Match
0	No match
1	Slight match
2	Moderate match
3	Excellent match

Fig. 4: Processed Bite Mark Radiograph & Overlay

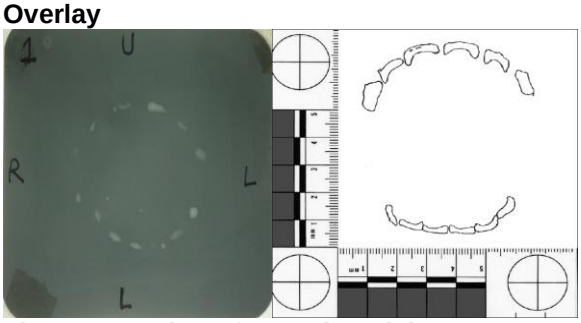

Fig. 5: Scanning of Dental Model

Fig. 6: Traced Biting Edges and Computer Assisted Overlay

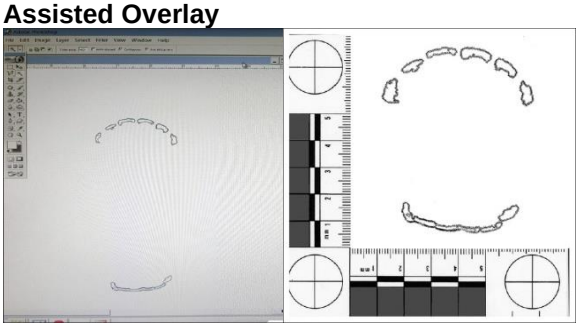

Table 2: Kruskal–Wallis ANOVA Test Comparing the Three Methods

	H-Value	P-Value
Wax impression and radio opaque method	0.4	0.52
Wax impression and computer method	28.68	0.0000
Computer assisted and radio opaque method	25.48	0.0000

Table 3
Kruskal–Wallis ANOVA Test Comparing Matching Cases by Methods

Method	Matching				Total	Kruskal Wallis ANOVA Test Statistic		
	No	Slight	Moderate	Excellent		Sum of Ranks	H Value	P Value
Wax Imprint	7(28.0)	15(60.0)	3(12.0)	0(0.0)	25(100.0)	656.5	37.35	0.0000
Radio Opaque Method	6(24.0)	14(56.0)	5(20.0)	0(0.0)	25(100.0)	730.0		
Computer Generated	0(0.0)	3(12.0)	11(44.0)	11(44.0)	25(100.0)	1463.5		
Total	13(17.3)	32(42.7)	19(25.3)	11(14.7)	75(100.0)			