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A Review on Comparison of Human Bite Marks in Forensic Images

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***Abstract*—** Human bite mark analysis is most demanding and complicated part of forensic dentistry, involving identification of assailant by comparing record of their dentition with record of bite mark left on a victim. Bite marks are unique to individual such as distance and angles between teeth, missing, and teeth fillings. This type of impression evidence can be left in the skin of a victim. Following the identification of an injury as a bite mark, the comparison of the pattern produced to a suspect's dentition is very vital. This article contains the current methods of comparison of human bite marks using different methods and technologies.

***Keywords*—** Bite marks, Forensic images, comparison overlays, Suspect identification, Bite mark analysis

I. INTRODUCTION

Bite mark comparison is the comparison of a human bitemark to a suspect's dentition using various methods such as dental models and overlays for the purpose of determining whether a suspect can be eliminated from a pool of possible perpetrators. This is not a part of a medico-legal autopsy, but rather a separate process is being done by members of the legal system as part of the prosecution of a suspect.

Much of the research in the field of forensic odontology has been done with respect evaluating and attempting to improve the methods of comparison. In general, the forensic odontologists compare exemplars of the teeth of the suspected biter(s) to bitemarks of victim following guidelines and accepted methods. Need of looking at every possible connection with how the patterned mark was made, or could have been made is become important now.

II. BITEMARKS COMPARISON TECHNIQUES

With the recent developments the need for accurate, reliable, reproducible and above all objective methods for bite mark analysis and comparison research is needed to explore the possibilities of image overlay techniques and to visualise more details in forensic bite mark images. There are few papers which describes about bitemark comparison techniques.

A. Bite mark analysis and comparison using image perception technology

Van der Velden et.al [1] used a bite mark image is opened with the image perception software, and a region of interest is then selected. After such selection, one can add colour to different greyscale areas of the image. The opacity of individual layers can be increased or decreased according to the requirements of the forensic odontologist.

The enhanced image can now be used to accommodate an overlay of the suspected biter's dentition. The opacity of the individual layers can be increased or decreased according to the requirements. Both hollow and compound overlays can be used, depending on the amount of incisal detail. The image perception technology gave better outcome earlier. Therefore improvement can be done on bite mark comparison and analysis using current technologies is necessary.

Advantage:
Enables the researcher to analyse the image more extensively and come to a more accurate conclusion regarding the source of the bite.

Disadvantage:
More attention needed to explore the possibilities of image perception technology and its possibilities to visualise more details in a bite mark image.

B. A new method to geometrically represent bite marks in human skin for comparison with the suspected dentition

Beatriz Ramos et.al [2] introduces BitePrint software represents the biting edges of dental casts as a set of geometric coefficients, offering a measurable, semi-automatic and less subjective analysis. This novel software minimizes the subjective component in human bite mark

analysis and might be applied in practical forensic cases involving human bite marks [3, 4].
Advantage: Making of new software that allows the semi-automatic identification of tooth marks.
Disadvantage: Limitations in the BitePrint Software.

C. Computer–based method of bite mark analysis: A benchmark in forensic dentistry?

Nandita Kottieth Pallam et.al [5] says that no single technique has been shown to be better than the others and very little research has been carried out to compare different methods. Thirty samples were collected with complete set of natural upper and lower anterior teeth after overlay was produced by using hand tracing technique, wax impression technique, radiographic wax impression technique, xeroradiographic technique and 2D computer layout for comparison.

This study evaluated the accuracy of direct comparisons between suspect's models and bite marks with indirect comparisons in the form of conventional traced overlays of suspects, it is found that the computer based method and the xerographic based method was found better than other commonly used overlay methods.

Advantage: Using various comparison techniques and ranking of each overlay method to computer-based method led to the appropriate resulting of xerographic method.
Disadvantage: More concentration required on xerographic method to improve the accuracy of result.

D. Bite Mark Analysis: Chasing the Bite!

Rakhee Modak et.al [6] confer study with classification of bite marks and analysis of bite using direct and indirect comparison techniques. Comparing and analyzing the bite mark with overlays of suspected biter's dentition is done using image perception software.

This study includes classification of bite marks using MacDonald's classification that deals with tooth pressure marks, tongue pressure marks, tooth scrape marks, complex marks and collection of bite marks that delas with demographics, location of the bite mark, shape of the bite mark, size and colour of the bite mark, type of injury and nature of the bite mark [7].
Advantage**:** It is discovered that bitemarks are a form of patterned injury.
Disadvantage**:** Additional supportive methods may lead to difficulties in bite mark analysis.

E. Comparative Study on Two Methods for Bite Mark Analysis

Nima A. Osman et.al [8] presents the computer assisted overly generation is as accurate as the manual docking technique for bite mark analysis on food materials. Considering three food materials the apple, the eggplant and the chocolate that reliable for bite mark analysis with no matching, slight matching, moderate matching and excellent matching by fixing significant test value that results in chocolate being the most accurate one in both methods. The obtained results are dependent on non-parametric tests. Kruskal-Wallis H test to detect the accuracy among several bite samples and Spearman's correlation test to compare between the docking and the computer assisted overlay generation technique.
Advantage: Bite mark analysis on food materials is a helpful task in finding the suspect.
Disadvantage: Study is restricted to very few food materials.

F. Human Bite Marks – A Computer-based Analysis Using Adobe Photoshop

Lalitha Chintala et.al [9] used overlays prepared with scanned casts of suspect then it is matched with bitemarks of the victim using superimposition technique. This study was done on identification and analysis of human bite marks by computer based superimposition technique [10].

This involves steps of scanning bite marks in image followed by construction of the overlay and non metric analysis of the bite mark and suspect dentition using adobe photoshop software. Since use of current advanced technologies in human bite mark analysis instead of traditional software.

Advantage: Computer based superimposition technique using adobe photoshop software is easy and cost-effective and gives reproducible results.
Disadvantage: Limitations in the adobe photoshop software lead to complexity in analysis and identification.

G. Bite marks: A potent tool in forensic dentistry: A review

Dr. Shazia Shafat Shah [11] presented bite mark analysis involves classification of bite marks that comprise of clinical classification, etiological classification, by degree of impression, agents producing marks, materials in which bite mark produced and definition of bite mark. In composition of bite marks it is discussed about class characteristics, and individual characteristics followed by classic appearance of bite marks and collection of evidence. In bite mark analysis comparison by direct and indirect methods conferred. Direct method using metric analysis and Indirect method using transparent overlays, photographic overlays and computer based overlays. Bites on perishable items, non-human substrates also deliberated. The importance of tool in bite marks needs a furthermore scope [12].

Advantages: Shows usefulness of direct and in direct methods in bite mark analysis.
Disadvantages: Less focus in the analysing methods.

H. Analysis and Identification of Bite Marks in Forensic Casework

Sandeep Kaur et.al [13] explore this study with Classification of Bite Marks that includes diffused bite marks as class1, pattern of injury as class2, part of body and applied pressure in those areas as class3, laceration of the tissues caused by the bite as class4. Characteristics of Bite Marks details about class characteristics and individual characteristics. Mechanism of Bite Marks associated with

tooth pressure marks caused by various factors and Bite Mark Analysis and Identification based on individuality of a dentition and pattern analysis of bite mark.

Advantages : Recognizing a patterned injury followed by pattern analysis detects correct offender.
Disadvantages : Complications arising in bite mark analysis by appearance and affecting factors.

I. Bite Mark Analysis

SK Padmakumar et.al [14] says images of one of the dental cast were imported into a commercially available software program. In the software, the biting surfaces of the maxillary incisor teeth were traced semi-automatically. Superimposition of the traced biting surfaces onto the bite mark on image revealed concordance in terms of general alignment of the four incisor tooth marks [15-17].

Advantage: Finding the shape and pattern of bite marks lead to correctness in finding the suspect.
Disadvantage : Comparison is focussed more on tooth marks only.

J. Comparison between five commonly used two-dimensional methods of human bite mark overlay production from the dental study casts

Saritha Maloth et.al [18] says finding the mean, standard deviation, and standard error of area for thirty samples in the bite mark based on different methods like Computer based method, Hand tracing from wax method, Radiopaque method, Xerographic method, Hand tracing from study casts method. Mahalanobis distances for each overlay method compared to computer-based method. Mahalanobis distance ranked in decreasing order of accuracy for area and rotation. Finally the best results obtained from Xerographic method.

Advantage: The limitations of each overlay production method identified in this study and best results obtained from xerographic method in bite mark comparison.
Disadvantage : Bite mark comparison is made on few methods only.

III. ANALYSIS TABLE

The following table gives the analysis of techniques and methods used in research papers on bite marks comparison in forensic images.

Sl.no	Paper Title	Technique	Addressed Problem
1.	Bite mark analysis and comparison using image perception technology [1]	Overlay Comparison	Dental study casts were scanned using the flatbed scanner. Hollow and compound overlays were produced from Dental study casts were scanned, Hollow and compound overlays were produced from these casts for comparison.
2.	A new method to geometrically represent bite marks in human skin for comparison with the suspected dentition [2]	Overlay Comparison	Two axes of each tooth mark are drawn and then compared.
3.	Computer–based method of bite mark analysis: A benchmark in forensic dentistry? [5]	Overlay comparison hand tracing from study casts method, hand tracing from wax impression method, radiopaque wax impression method, xerographic method	Indirect Comparisons made in the form of conventional traced overlays, and the xerographic technique was found to be the best among the other methods.
4.	Bite Mark Analysis: Chasing the Bite! [6]	Overlay comparison	Comparing and analyzing of coloured image of bite mark with overlays using imaging software.
5.	Comparative Study on Two Methods for Bite Mark Analysis [8]	manual docking technique, computer assisted overlay technique	The computer assisted overly generation is as accurate as the manual docking technique for bite mark analysis on food materials.
6.	Human Bite Marks – A Computer-based Analysis Using Adobe Photoshop [9]	Edge detection, Overlay comparison, Nonmetric analysis	Identification and analysis of human bite marks by computer-based superimposition technique using Adobe Photoshop software which gives reproducible results.

7.	Bite marks: A potent tool in forensic dentistry: A review [11]	Physical method, Overlay comparison.	Comparison of Direct and Indirect methods.
8.	Analysis and Identification of Bite Marks in Forensic Casework [13]	Overlay comparison.	Pattern analysis of the bite mark provides individual information.
9.	Bite Mark Analysis [14]	Overlay comparison, Pattern Analysis.	Finding the shape and pattern in bite mark analysis.
10.	Comparison between five commonly used two-dimensional methods of human bite mark overlay production from the dental study casts [18]	Overlay comparison	Comparing with various overlay generation methods, computer assisted overlay generation method is best among others.

IV. COMPLICATIONS IN BITE MARK COMPARISON TECHNIQUES

There are numerous methods used for bite mark comparison. This obscures every researcher to find a best suitable method for the bite mark analysis. Selecting a suitable method is not only based on scenario but also depend on various factors like correctness, performance and cost. This leads to difficulties in choosing a particular method for best results.

V. CONCLUSION

This study assessed the correctness of comparisons between suspect's bite marks with victim's bite marks using computerized overlay technique. Development of new image processing techniques give rise to a new direction of research in comparison of human bite marks.

Overall, this study is used to gain knowledge of best methods used for matching bite marks in forensic images and also state about the scope of development in this research area. This study presents an effective literature survey on bite mark comparisons in forensic images and overview of related techniques and methods.

These bite mark comparison techniques requires an extra focus in achieving more accuracy in results. Thus, there exists a gap in improving the accuracy of results in bite mark comparison. Using current image processing techniques it can be attained quickness and more accuracy results in bitemark comparison. Recent virtuous classifiers and more effective edge detection techniques make better and fast outcome in the results of bite mark comparison.

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