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A comparative study of overlay generation methods in bite mark analysis

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Abstract

Aim: To evaluate the best method of overlay generation out of the three methods, i.e., manual, photocopying, and computer assisted method. **Materials and Methods:** Impressions of maxillary and mandibular arches of 25 individuals participating in the study were made and dental study models were prepared. Overlay production was done by manual, photocopying, and computer assisted methods. Finally, the overlays obtained by each method were compared. **Results:** Kruskal Wallis ANOVA H test was used for the comparison of manual, photocopying, and computer assisted overlay generation methods. H value being highest in case of computer assisted overlays, thus, making it the best method of overlay generation out of the three methods. **Conclusion:** We conclude that the method of computer assisted overlay generation is the best among the three methods used in our study.

Key words: Bite mark, computer assisted method, manual method, overlay, photocopying method

Introduction

Bite marks may be found at the scene of a crime and their analysis has been used for many years as an aid in forensic investigation. Bite marks can occur on the skin of a victim or on other objects, including foods such as cheese, chocolate, apples, or chewing gums. Solid food has an advantage in such cases.[1,2] Bite marks tend to have a double horseshoe pattern showing the six central teeth of the upper jaw and the corresponding six teeth in the lower jaw.

Bite marks made in food are usually well defined; but the bite marks made in flesh are usually less defined. Bite marks reveal features such as gaps between the teeth, ridges on the biting surfaces of the teeth, rough fillings, as well as missing, broken, chipped, or distorted teeth. In fact, human teeth patterns are individual and careful expert analysis of a bite is able to relate the mark to a suspect.[3-5]

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It must be again emphasized that the bite marks obtained on food items tend to be more accurate and reproducible than on skin of a person and many studies have proved the fact. There are many different ways of analysis of bite marks on food substances like impression making and hand tracing from dental study casts, photography method, photocopying, and computer assisted methods of overlay generation.[6]

In this study, an attempt is made to compare the bite mark overlays generated by three methods, i.e., manual, photocopying, and computer assisted methods of overlay generation to find the most reliable method out of the three methods used.

Materials and Methods

Impressions of maxillary and mandibular arches of 25 individuals participating in the study were made and dental

study models prepared in dental stone. Overlay production was done by manual, photocopying, and computer assisted method of overlay generation.

In manual method a sheet of transparency film and a fine tipped pen were used to mark the perimeter of the biting surface. The transparent sheet was directly placed over the biting edges of the dental model [Figure 1]. Then with the help of a black fine tipped marker the biting edges were traced. Both the maxillary and mandibular models were traced individually in horse shoe shape pattern [Figure 2] to simulate a human bite.[6]

In the photocopying method an accurate image of the dental model was made by placing the biting edges of the dental model over the glass plate of the photocopying machine [Figure 3]. The dental models were again placed to simulate human bite. This image [Figure 4] was then placed upside down on a radiograph view box and the tooth edge outlines were traced [Figure 5]. These outlines were then photocopied on a transparent sheet [Figure 6].[7]

In the computer assisted method first the study models were scanned with the biting edges of the dental model over the glass plate of the scanner [Figure 7]. The images [Figure 8] were transferred to a laptop. The images were opened in photoshop software version 7.0 already installed in the laptop. Then a gradual selection of biting edges of the teeth was done using magic wand selection tool [Figure 9] resident in the photoshop software version 7.0. The outlines of the biting edges were reproduced [Figures 10 and 11]. The images obtained were printed on transparent sheet [Figure 12].[6,8,9] Thus, three overlays were made for one set of dental model and in total 75 overlays were made. The three overlays corresponding to a set of dental model was placed directly over the biting edges one by one for matching and assigned one out of the four values (0-3) with "0" assigned to no matching and "3" assigned to excellent matching [Tables 1 and 2].[10,11]

Results

Kruskal Wallis ANOVA H test was used for the comparison

Figure 1: Biting edges being traced

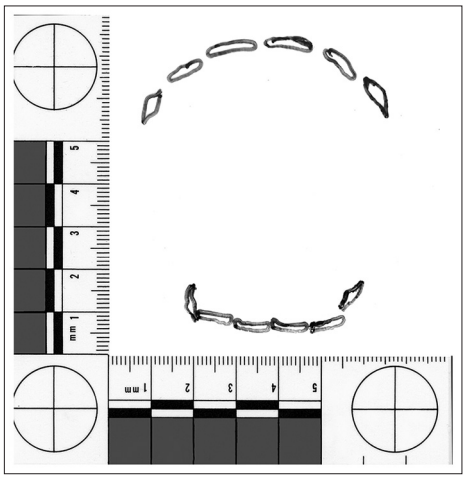

Figure 2: Manual overlay

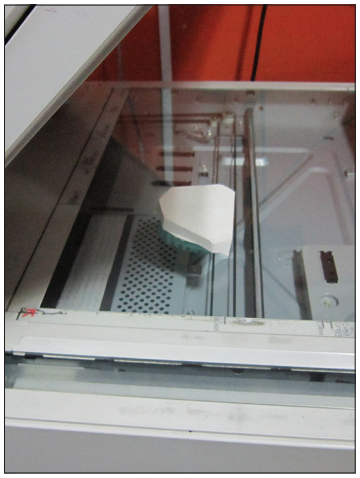

Figure 3: Dental model being photocopied

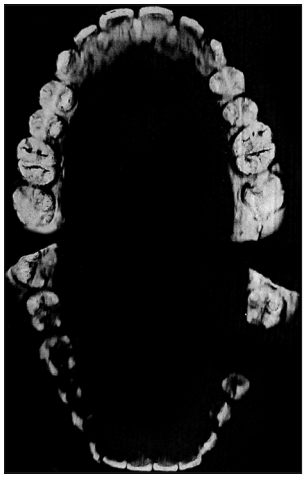

Figure 4: Photocopied dental model

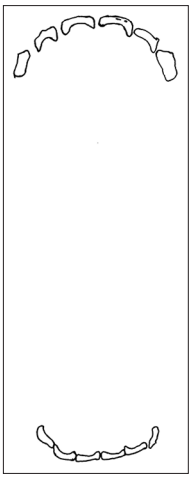

Figure 5: Traced biting edges

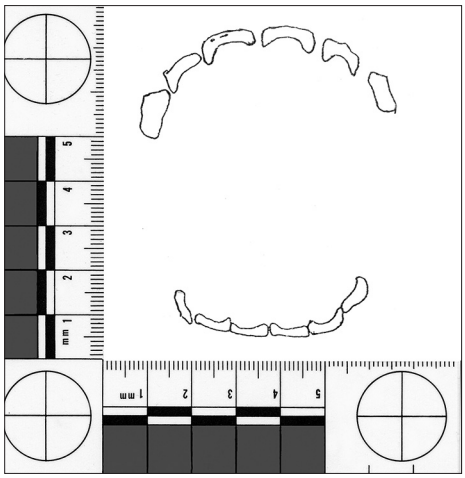

Figure 6: Photocopied overlay

Figure 7: Dental model being scanned

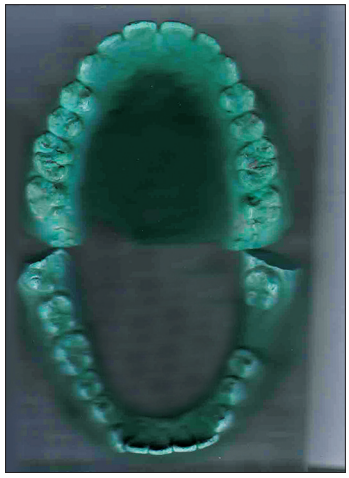

Figure 8: Scanned dental Model

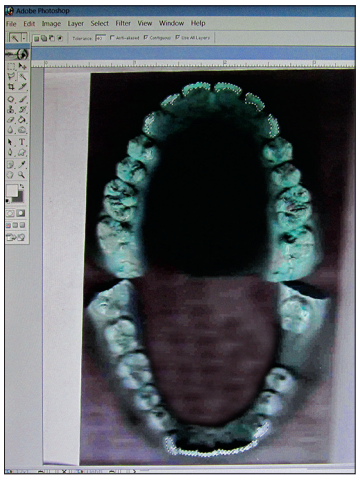

Figure 9: Biting edges selected by magical wand selection tool

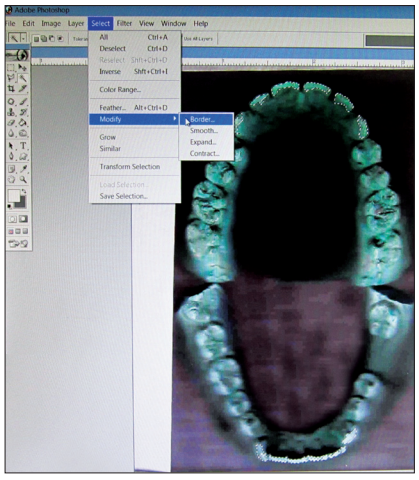

Figure 10: Borders of biting edges being reproduced

of manual, photocopying, and computer assisted overlay production methods. H value for manual *vs.* photocopying overlay the generation method was 5.74 ($P < 0.05$ – Significant at 5% level) [Table 3]; for manual vs. computer overlay the generation method was 19.17 ($P < 0.01$ – Significant at 1% level) [Table 4] and for photocopying *vs.* computer overlay

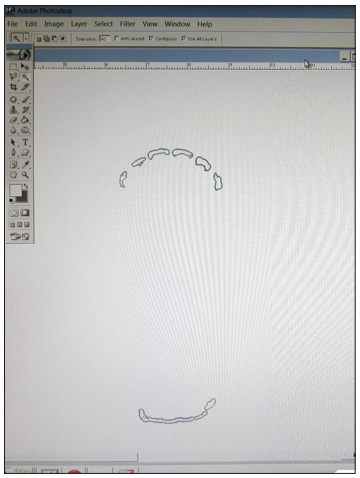

Figure 11: Reproduced borders

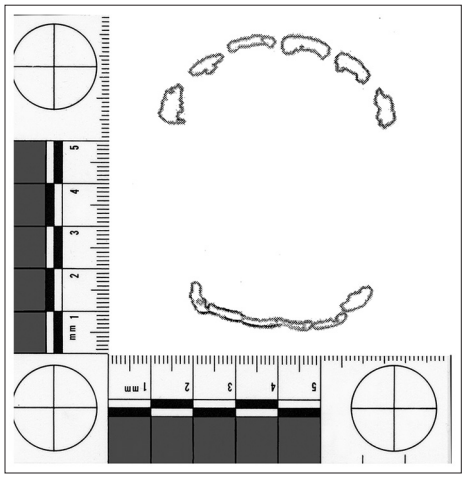

Figure 12: Computer assisted overlay

Table 1: Numeric values for matching

No matching	0
Slight matching	1
Moderate matching	2
Excellent matching	3

Table 2: Observations

Patient serial no.	Matching		
	Manual method	Photocopying method	Computer generated method
1	2	2	3
2	1	2	3
3	1	2	3
4	2	2	2
5	1	1	2
6	1	2	2
7	2	2	3
8	1	1	1
9	2	2	3
10	1	2	2
11	2	2	3
12	2	2	3
13	1	2	2
14	2	2	2
15	2	3	3
16	2	3	3
17	2	2	2
18	1	1	2
19	2	2	2
20	2	2	3
21	1	2	2
22	2	3	3
23	2	2	2
24	2	2	3
25	2	2	3

the generation method was 22.97 ($P < 0.01$ – Significant at 1% level) [Table 5].

Table 3: Manual vs. photocopying

Manual	Photocopying				Total
	No	Slight	Moderate	Excellent	
No	0	0	0	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Slight	0	3	6	0	9
	(0.0)	(33.3)	(66.7)	(0.0)	(100.0)
Moderate	0	0	13	3	16
	(0.0)	(0.0)	(81.3)	(18.8)	(100.0)
Excellent	0	0	0	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Total	0	3	19	3	25
	(0.0)	(12.0)	(76.0)	(12.0)	(100.0)

Kruskal Wallis ANOVA H test, H value=5.74 ($P<0.05$-Significant at 5% level)

Table 4: Manual vs computer assisted

Manual	Computer assisted				Total
	No	Slight	Moderate	Excellent	
No	0	0	0	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Slight	0	1	6	2	9
	(0.0)	(11.1)	(66.7)	(22.2)	(100.0)
Moderate	0	0	5	11	16
	(0.0)	(0.0)	(31.3)	(68.8)	(100.0)
Excellent	0	0	0	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Total	0	1	11	13	25
	(0.0)	(4.0)	(44.0)	(52.0)	(100.0)

Kruskal Wallis ANOVA H test, H value=19.17 ($P<0.01$-Significant at 1% level)

Discussion

The principle of bite mark analysis is based on the premise that no two people have similar teeth, and hence the bite marks made are also dissimilar. Historically, the manual method was the only method known for generating overlays and was used first in about 1966. Dailey (1991) presented a quick, inexpensive, and accurate technique for generating

Table 5: Photocopying vs. computer assisted

Photocopying	Computer assisted				Total
	No	Slight	Moderate	Excellent	
No	0	0	0	0	0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Slight	0	1	2	0	3
	(0.0)	(33.3)	(66.7)	(0.0)	(100.0)
Moderate	0	0	9	10	19
	(0.0)	(0.0)	(47.4)	(52.6)	(100.0)
Excellent	0	0	0	3	3
	(0.0)	(0.0)	(0.0)	(100.0)	(100.0)
Total	0	1	11	13	25
	(0.0)	(4.0)	(44.0)	(52.0)	(100.0)

Kruskal Wallis ANOVA H test, H value=22.97 ($P<0.01$-Significant at 1% level)

transparent overlays, using office photocopy machines, for use in bite mark case analysis. He discussed the critical step in the fabrication process involves determination of the accuracy of the product produced by the photocopy machine.[7] Naru and Dykes (1996) introduced the computer assisted overlay generation method to forensic odontology. They advocated a method of selection of tooth edges from the image by a technique known as "edge detection." The selected edges were then printed onto transparent sheets as overlays.[6] The present study was undertaken to find the best method out of these three methods, i.e., manual, photocopying, and computer assisted method for overlay generation.

One of the limitations of the overlays is that they are two dimensional representatives of three dimensional bite marks. Sweet *et al*. (1998) in their study compared five different methods of overlay generation. The computer-based production method was determined to be the most accurate of those studied. It produced accurate representations of the biting edges of the teeth in an objective manner.[12] Kouble *et al*. (2004) in their study to compare direct and indirect methods available for human bite mark analysis found that the photocopier-generated overlays were significantly more accurate at matching the correct bite mark to the correct models.[10] Anne *et al*. (2005) conducted a study to compare the reliability of two methods used to produce computer-generated bite mark overlays with Adobe Photoshop®. One method was, by using magical wand selection tool, while the other method is by inverting the glowing edges. It was concluded that both techniques were reliable methods to produce bite mark overlays in assessing tooth position.[13] Wu *et al*. (2005) conducted an experimental study on human bite marks digital analysis and its accuracy. Their result showed that the human bite marks digital analysis was a more accurate approach to human bite marks identification.[14] Herb Blitzer *et al*. (2009) presented their experiments describing the development of a semi-automated method to compare 3D dental models taken from candidate humans and bite mark impression images left in the scene of the crime. Starvianos *et al*. (2011) conducted a study to evaluate the accuracy of two methods for the bite mark analysis in foodstuff. The results of their study showed that the computer-based method of bite mark analysis was as accurate as the docking procedure. Maloth *et al*. (2011) in their study to determine the most accurate bite mark overlay fabrication technique by studying two physical characteristics, i.e., area and rotation of biting edges of anterior teeth, they concluded that forensic odontologists should discontinue the use of hand traced overlays in bite mark comparison as there is lot of scope for manipulation and observer bias.[15]

A recently developed new software package, "Dental Print" (2004, University of Granada, Department of Forensic Medicine and Forensic Odontology, Granada, Spain) generates comparison overlays from 3D images of the suspect's dental cast. This software allows users to accurately and objectively select the biting edges of interest from the suspect's teeth when compared to 2D images. The procedure for generating comparison overlays is entirely automatic and it is impossible for third parties to manipulate or alter the 3D images. This dental print software is an important step forward in Forensic Sciences for bite mark analysis.[16-18]

In our study, the computer assisted overlay generated matched excellently with study models in 13 cases. In comparison, only three overlays generated by photocopying method matched excellently with the study models. None of the overlay generated in a manual method matched excellently with the study models. Thus, the results of our study show that photocopying method is better than manual method, but computer assisted method is more reliable than both manual method and photocopying method.

Conclusion

Although many newer and sophisticated methods of bite mark comparison have evolved, comparison by overlay generation remains one of the best and easiest methods. Within various overlay generation methods, computer assisted overlay generation method enjoys widest acceptance because of its objectivity, ease of production, and being inexpensive along with being well researched. So it can be concluded that computer assisted overlay generation method is the best method of overlay generation.

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