

# Envelopment technique and topographic overlays in bite mark analysis

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## Abstract

**Aims and Objectives:** The aims and objectives of our study were to compare four sequential overlays generated using the envelopment technique and to evaluate inter- and intraoperator reliability of the overlays obtained by the envelopment technique. **Materials and Methods:** Dental stone models were prepared from impressions made from healthy individuals; photographs were taken and computer-assisted overlays were generated. The models were then enveloped in a different-color dental stone. After this, four sequential cuts were made at a thickness of 1mm each. Each sectional cut was photographed and overlays were generated. Thus, 125 overlays were generated and compared. **Results:** The scoring was done based on matching accuracy and the data were analyzed. The Kruskal-Wallis one-way analysis of variance (ANOVA) test was used to compare four sequential overlays and Spearman's rank correlation tests were used to evaluate the inter- and intraoperator reliability of the overlays obtained by the envelopment technique. **Conclusion:** Through our study, we conclude that the third and fourth cuts were the best among the four cuts and inter- and intraoperator reliability were found to be statistically significant at 5% level that is 95% confidence interval ( $P < 0.05$ ).

**Key words:** Bite marks, computer-assisted overlays, direct cast technique, envelopment technique, forensic dentistry, hollow volume overlays, topographic overlays


## Introduction

Bite mark analysis plays a crucial role in identifying the suspects and the onus lies on the forensic odontologist, since he is the one trained in such analysis. Bite marks are the representative patterns left in an object or tissue by the dental structures of an animal or human.<sup>[1]</sup> The science of bite mark identification is quite new and potentially valuable. Bite marks, if analyzed properly, can not only prove the participation of a particular person (s) in crime but also help in the exoneration of the innocent.<sup>[2]</sup> The important

point is to identify the marks of individual tooth and to detail the distinctive features. Corresponding features are then sought in the teeth of the accused.<sup>[3]</sup>

Bite marks can be compared by either direct or indirect methods. The former involves superimposition of the cast directly on the photograph of the bite mark, while the latter uses overlays generated from the casts. However, the choice of technique is based largely on the operator's preference.<sup>[4]</sup> Numerous techniques are used in the reproduction of the bite marks to generate overlays, including hand tracing, photography, photocopying, scanning, and generating computer-assisted overlays.<sup>[5]</sup>

With the recent technological advancement, computers play an important role by making the forensic experts' work simpler and faster with computer-assisted overlay generation methods. Researchers have suggested that the method of overlay generation is purely the preference of the operator. Certain studies recommend discontinuing the use of hand-drawn overlay generation method

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because it is subjective.<sup>[6]</sup> Many other studies have compared the various methods of overlay generation and are in favor of computer-generated overlays as the best method.<sup>[7-11]</sup> However, the subjectivity of this method remains a challenge. So through our study, we attempted to eliminate the subjectivity in computer-generated overlays.

The aims and objectives of our study were to compare four sequential overlays generated by envelopment technique and to evaluate inter- and intraoperator reliability of the overlays obtained by the envelopment technique.

## Materials and Methods

Healthy individuals above 15 years of age (as the eruption of all the anterior teeth in both the arches would have been complete by the age of 15 unless any tooth is impacted or congenitally missing) were randomly selected. Then impressions were made with irreversible hydrocolloid or alginate (New Algitex dust-free regular set alginate, Dental Products of India, Mumbai) and the casts poured using green-color dental stone (Goldstone, Asian Chemicals, Gujarat). Then, 125 computer-assisted hollow-volume overlays were generated using the “magic wand” selection tool in Adobe Photoshop (Version 10.0, Adobe Systems). These computer-assisted overlays were generated through two techniques: The direct-cast technique and the envelopment technique. Completely edentulous individuals, periodontally compromised individuals, individuals with restricted mouth openings, and individuals with temporomandibular joint (TMJ) disorders were excluded from the study.

### Direct-cast technique

The casts were photographed using a Canon Powershot G12 PC1564, 10 mega pixel digital camera (Canon Technologies, Japan). The photographs were taken at an angle of 90 degrees in accordance with the American Board of Forensic Odontology (ABFO) guidelines.<sup>[1]</sup> These data were fed to the computer and overlays were generated. Thus, one set of 25 overlays was generated and saved [Figure 1].

### Envelopment technique

The maxillary and mandibular casts were then trimmed up till the first premolars and the base of the cast was trimmed flat (this cast segment comprising the anterior

teeth was our area of interest as in the majority of cases we see the bite marks of anterior teeth). In a bite mark, the front teeth (which include the central incisors, lateral incisors, and the cuspids) are the primary biting teeth according to tooth class characteristics. This cast segment was inversed and placed on a teeth setting glass plate such that the incisal edges of the teeth and the cusp tips touching the glass plate formed a plane.<sup>[12]</sup> Boxing of the glass plate was done with wax sheeting and then the casts were positioned in the same plane as previously mentioned [Figure 2]. After that, a contrasting-color dental stone was poured until the entire cast was embedded in the glass plate receptacle; the contrasting-color dental stone preferred for this study was yellow-color dental stone (Dutt stone, dutt industries, Mumbai). The receptacle was gently tapped to aid in the removal of air bubbles incorporated during the cast envelopment procedure. Then it was left undisturbed until the envelopment completely set. The enveloped casts were removed from the receptacle using manual pressure and the cast base was trimmed using a fine model trimmer to maintain parallelism to the side that was in contact with the glass plate. Four sequential cuts were made on the enveloped casts, which were trimmed at a depth interval of 1mm each. The casts were photographed after each sequential cut and then the overlays were generated [Figure 3]. Thus, 100 overlays were generated from the enveloped casts (25 casts × 4 cuts = 100 overlays). The overlays thus obtained were superimposed on the corresponding overlays generated previously before enveloping the casts and they were checked for matching accuracy (a total of 125 overlays were generated: 25 direct-cast technique and 100 envelopment technique). Based on the matching accuracy of the overlays, a score was assigned as follows: 0-no matching, 1-mild matching, 2-moderate matching and 3-excellent matching.

## Results

The Kruskal-Wallis one-way analysis of variance (ANOVA) test was used to compare the accuracy of sequential cuts and Spearman’s rank correlation tests were used to determine inter- and intraoperator reliability. It was found that there was no statistically significant difference between the third and fourth cuts [Table 1]. The *h*-value was significant at 1% level that is 99% confidence interval was present ( $P < 0.01$ ) implying that there was greater accuracy for the third and

**Table 1: Kruskal-Wallis ANOVA test comparing the four sections**

Cut	Matching				Total	Kruskal-Wallis test statistics		
	<i>n</i>	Mild	Moderate	Excellent		Sum of ranks	<i>h</i>	<i>P</i>
1 <sup>st</sup>	20 (80.0)	4 (16.0)	1 (4.0)	0 (0.0)	25 (100.0)	515.0		
2 <sup>nd</sup>	9 (36.0)	10 (40.0)	5 (20.0)	1 (4.0)	25 (100.0)	905.0	66.36	0.0000
3 <sup>rd</sup>	0 (0.0)	5 (20.0)	4 (16.0)	16 (64.0)	25 (100.0)	1791.0		
4 <sup>th</sup>	0 (0.0)	0 (0.0)	11 (44.0)	14 (56.0)	25 (100.0)	1839.0		
Total	29 (29.0)	19 (19.0)	21 (21.0)	31 (31.0)	100 (100.0)			

*h*-value is significant at 1% level. It is found that the third and fourth sections are the best. ANOVA: Analysis of variance

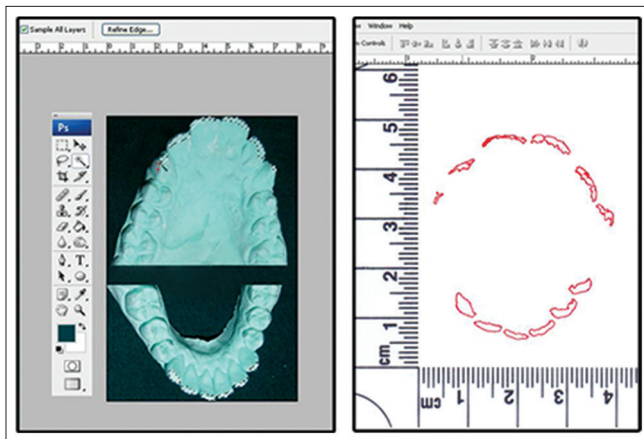
fourth cuts, making them better than the first and second cuts. The overlays from the third cut had the maximum number of excellent matching cases that is 64%, making it better than the fourth cut, which had 56%. Inter- and

intraoperator reliability were found to be statistically significant at 5% level that is 95% confidence interval ( $P < 0.05$ ), [Tables 2 and 3] suggesting it to be an objective technique.

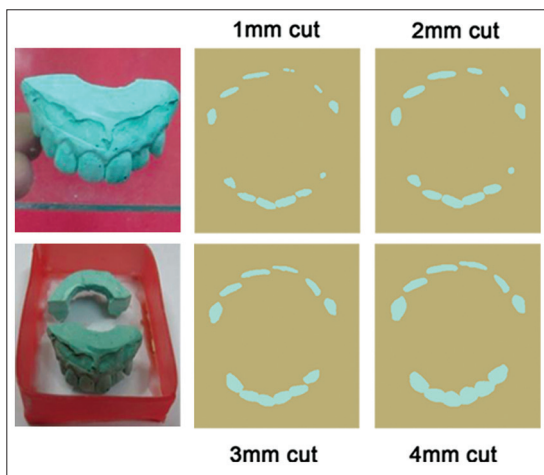
### Discussion

Human dentition is unique for each individual and so is the bite mark produced, and for this reason it can be considered as an alternative to fingerprints and DNA identification in forensics. Individuals with dental traits<sup>[1]</sup> like crowding, spacing, midline diastema, proclined or retroclined teeth, mesially or distally drifted teeth, and fractured teeth were included in the study as these cause peculiar patterns in the bite marks produced. A forensic odontologist's work can have great impact on the lives of individuals and their families. Therefore, the subjectivity in bite mark analysis must be eliminated by developing an accurately and objectively produced overlay. Overlays prepared by various methods are the reproduction of bite marks traced from static dental models, but in reality the bite marks produced on victims are the results of a dynamic process and may differ with the pressure applied by the biter, and for this reason they may not match with overlays generated from static dental stone models.

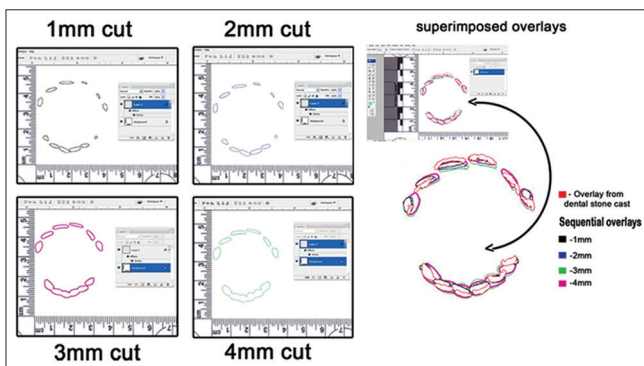
In the direct-cast technique, the routinely used overlay generation technique by computer-assisted methods, multiple selections and adjustments of the tolerance level was required to obtain the desired incisal outlines from the cast, which involves subjectivity. This difficulty was overcome in the envelopment technique because of the clearly defined borders of the incisal edges in a distinct green color against the background yellow color. Maloth *et al.* (2011) studied five commonly used methods of overlay generation and concluded that forensic odontologists should discontinue the use of hand-traced overlays in bite mark comparison because of the possible manipulation errors and observer bias.<sup>[6]</sup> Sweet *et al.* (1998) compared five different methods of overlay generation and concluded that the computer-based method of overlay generation was the most accurate of the five methods studied.<sup>[7]</sup>



**Figure 1:** Direct-cast technique: The Computer-assisted overlay from the direct-cast technique



**Figure 2:** Envelopment technique: The pictures on the left column show boxing with wax sheet; the pictures on the middle and right columns show the sequentially cut enveloped casts at 1mm, 2mm, 3mm, and 4mm



**Figure 3:** The computer-assisted overlay from envelopment technique: Superimposition of overlays of sequential cut sections at depth intervals of 1mm simulating cut sections of computed tomography (CT) [black 1mm, blue 2mm, purple 3mm, green 4mm]

**Table 2: Spearman's rank correlation for intra-operator reliability**

Observation	n	Spearman rank correlation			LS
		r	t	P	
Observation 1 vs. observation 2	25	0.4806	2.63	0.0150	5%

Spearman's rank correlation (*r*) is significant at 5%, indicating that there is interoperator reliability. LS: Level of significance

**Table 3: Spearman's rank correlation for interoperator reliability**

Observation	n	Spearman rank correlation			LS
		r	t	P	
First observer vs. second observer	25	0.4924	2.71	0.0124	5%

Spearman's rank correlation (*r*) is significant at 5% level, indicating that there is interoperator reliability. LS: Level of significance

The computer-based method usually employs Adobe Photoshop software for overlay generation; even in using this software, operator subjectivity is introduced when selecting the exact area of a tooth to be highlighted with the “magic wand” tool.<sup>[13]</sup> Naru and Dykes (1996) stated that repeated adjustments of the brightness and contrast were required while selecting the incisal edges in developing computer-generated overlays and that the technique was subjective, as the choice of adjustment may differ with the visual interpretation of each operator.<sup>[8]</sup> In our study, we found overlays generated using the “magic wand” selection tool of Adobe Photoshop software to be easier to make, to involve less subjectivity, and to be less time-consuming when the incisal edges appear distinct and are contrasted to a light-colored background. The sequential photographs taken after trimming the casts at different depths gave us the reproduction of bite marks in a range that would have resulted from the varied biting pressure. The computer-assisted overlays generated by this technique appeared as excellent replicas of the actual bite mark. Thus, the envelopment technique will help the expert to judge the suspect’s bite easily and more accurately. Overlay generation from the envelopment technique was easier and less time-consuming as in most of the cases it required only single-stroke selections, and a single tolerance level could be maintained in contrast to the multiple strokes and frequent checking of the tolerance level needed in the direct-cast technique.

In our study, green- and yellow-color dental stones were used, which helped in the easy detection by the “magic wand” selection tool. A similar result has been stated by Kaise Nam *et al.* (2002) on comparing different dental stone colors (yellow, white, pink, green, and blue). Their results indicated that green and yellow stones allowed accurate scanning and that the “magic wand” selection tool provided reproducible tracings of incisal edges.<sup>[14]</sup> The serious nature of the crimes in which bites are found often dictates that the highest level of forensic standards should be applied; the need for individuals trained and experienced in the recognition, collection, and analysis of this type of evidence is increasing.<sup>[15]</sup>

The results of our study, showed that there was no statistically significant difference between the third and fourth cuts, making both the cuts better than the first and second cuts. However, the maximum number of excellent matching cases were recorded in the third cut sections and that for moderate matching cases were recorded for the fourth cut, suggesting the third cut section to be better than the fourth cut section. The Spearman correlation for inter- and intraoperator reliability was 5%, suggesting the elimination of subjectivity by the envelopment technique. Forensic practitioners should be quite careful in giving opinions regarding the origin of bite mark and

the identification of the criminal on the basis of bite mark evidence.<sup>[16]</sup> Bite marks may be the enemy of natural justice at times and may lead to an increasing number of years of life lost by innocent people wrongfully convicted of crimes.<sup>[17]</sup>

The uniqueness in the enveloped-cast technique is that the teeth 4mm below the occlusal plane such as in severe crowding, fractured teeth and retained deciduous teeth did not appear in the cut sections. This is in contrast to the direct-cast technique where the incisal outline of all the teeth may be traced as overlay, even those below the occlusal plane, which would not have contributed to the actual bite mark. Thus, topographic overlays generated by the envelopment technique gave us a clue to the depth, which is the forgotten third dimension in the conventional overlays. Experts must always remember the three-dimensional aspect of a bite mark, which is forgotten most of the time as overlays traced are two-dimensional representations of the three-dimensional bites. In our study, we also found that the cut sections of the models in the envelopment technique appeared as the cut sections of computed tomography (CT). The results of our study have shown the elimination of subjectivity in computer-assisted overlay generation by the envelopment technique. This is in agreement with the study done by Dailey JC (2002), who conducted a study on the topographic mapping of teeth for overlay production in bite mark analysis and concluded that subjectivity was eliminated by this method.<sup>[12]</sup>

The difficulties we encountered in our study were that the envelopment technique was a cumbersome procedure and was more time-consuming. The trimming of the cast was a crucial step, needing meticulous care to prevent trimming more than the desired depth.

## Conclusion

Bite mark analysis is a vital area within this highly specialized field of forensic science and constitutes the commonest form of dental evidence presented in the criminal court.<sup>[18]</sup> In analyzing bite marks, forensic odontologists must apply scientific methods to the analysis of a bite mark in a systematic manner to provide courts with testable evidence.<sup>[19]</sup> Through our study we found that the third and fourth cut sections were the best among the four cut sections, and that the subjectivity of the computer-assisted overlays was eliminated by the envelopment technique. So we recommend the use of the envelopment technique in computer-assisted overlay generation as the forensic odontologists’ subjective opinions should not jeopardize the life of an innocent, for the sorrow, stigma, and the consequences he/she and his/her family faces would be bountiful.

## References

1. American Board of Forensic Odontology (2013) Diplomates Reference Manual. Available from: [www.abfo.org/wp./ABFO-Reference-Manual-1-22-2013-revision.pdf](http://www.abfo.org/wp./ABFO-Reference-Manual-1-22-2013-revision.pdf). [Last accessed on 2013 Dec 15].
2. Kaur S, Krishan K, Chatterjee PM, Kanchan T. Analysis and identification of bite marks in forensic casework. *Oral Health Dent Manag* 2013;12:127-31.
3. DKWhittaker, DGMacDonald. *A Colour Atlas of Forensic Dentistry*. London: Wolfe Publishing Ltd; 1989. p. 120-3.
4. Kouble RF, Craig GT. A comparison between direct and indirect methods available for human bite mark analysis. *J Forensic Sci* 2004;49:111-8.
5. DorionRB. *BitemarkEvidence*, 1<sup>st</sup>ed. New York: Marcel Dekker; 2005.p. 423-451.
6. MalothS, Ganapathy KS. Comparison between five commonly used two-dimensional methods of human bite mark overlay production from dental study casts. *Indian J Dent Res* 2011;22:493.
7. Sweet D, Bowers CM. Accuracy of bite mark overlays: A comparison of five common methods to produce exemplars from a suspect's dentition. *J Forensic Sci* 1998;43:362-7.
8. NaruAS, DykesE. The use of a digital imaging technique to aid bite mark analysis. *Sci Justice* 1996;36:47-50.
9. McNamee AH, Sweet D, Pretty I. A comparative reliability analysis of computer-generated bite mark overlays. *J Forensic Sci* 2005;50:400-5.
10. Stavrianos C, Vasiliadis L, Emmanouil J, Papadopoulos C. *In vivo* evaluation of the accuracy of twomethods for the bite markanalysis in food stuff. *Res JMedSci* 2011;5:25-31.
11. Sweet D, Parhar M, Wood RE. Computer-based production of bite mark comparison overlays. *J Forensic Sci* 1998;43:1050-5.
12. DaileyJC. The topographic mapping of teeth for overlay production in bite mark analysis. *Proceedings of the American Academy of forensic Sciences*.Atlanta 2002:237.
13. MetcalfRD. Yet another method for marking incisal edges of teeth for bitemark analysis. *J Forensic Sci* 2008;53:426-9.
14. Kasie Nam, Edwin T. Parks, G. Eckert. Computerized incisal edge tracing using different dental stone colors. *Proceedings of the American Academy of Forensic Sciences*. Atlanta 2002:230-1.
15. Pretty IA. Forensic dentistry: 2. Bitemarksand bite injuries. *Dent Update* 2008;35:48-50, 53-4, 57-8.
16. Page M, Taylor J, Blenkin M. Reality bites--A ten-year retrospective analysis of bitemark casework in Australia. *Forensic SciInt* 2012;216:82-7.
17. Pretty IA, Sweet D. A paradigm shift in the analysis ofbitemarks. *Forensic SciInt* 2010;201:38-44.
18. Rai B, Anand SC, Madan M, Dhatarwal SK. Bite marks: A new identification technique. *IJFS* 2006;2 (1).
19. Rajshekar M, Kruger E, Tennant M. Bite-marks: Understanding the role of general practitioners in forensic identification. *JInt Oral Health* 2012;4:1-8.

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