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Original Article

Reliability and Analysis of Changes in Bite Marks at Different Time Intervals and Temperature Ranges

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Abstract

The purpose of this study is to assess time-dependent changes in the morphology of bite marks and to investigate the utility of matching bite marks on both perishable and non-perishable objects with the passage of time at different temperatures.

The study was conducted at Maharana Pratap College of Dentistry and Research Centre, Gwalior, India. Twenty volunteers were asked to bite 6 perishable and non-perishable items. Perishable items were apple, banana and Burfi, (a milk-based popular sweet confectionary) while non-perishable items included wax, clay, and rubber. Photographs were taken with a digital camera at 0-hours and 24-hours after biting these objects at temperature ranges of 24 ºC to 28 ºC and 36 ºC to 40 ºC, respectively. Life-size photographs of these bitten objects were printed on transparent overlays and compared to hand drawn transparencies prepared from suspect dentition using an X-ray viewer. The comparison of all the 960 transparencies was done by two researchers, independently.

All objects gave a positive identification of the biter on matching just after biting. After 24-hours, all items also showed positive matching except banana and apples.

This proposed method is simple, reliable and less technique sensitive. It narrows down the subjectivity of interpretation. It highlights that due to decomposition changes occur in perishable food items and more so in apples and bananas, making bite marks less reliable evidence.

Keywords: Forensic Science, Bite Marks, Perishable Items and Non-perishable Items, Life Size Photograph, X-ray Viewer.

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موثوقية وتحليل التغيرات في علامات العض على فترات

A bite mark is a pattern that is created by dentition in any substance. Forensic dentistry is the assessment and examination of the evidence left by teeth [1]. Nowadays, forensic dentistry is considered as a necessary part of forensic science. In violent situations, teeth are often used as a weapon in life and death struggles both by assailants and victims. In crimes, bite marks may be found in assaults of sexual or non-sexual nature, murders, cases of physical and sexual abuse and homosexual attacks [2]. In addition, bite marks are left on various types of food items like chewing gum, chocolate, vegetables, fruits and other edibles. In addition, solid food items are more effective in retaining the morphology of bite marks [3]. In some rare cases, bite marks are also found on paper and Styrofoam crockery items, cigarette-butts, car steering wheels and other similar objects [4-5].

Human identification from bite marks is possible due to the presence of unique features in dentition that can be accurately recorded in the injury on skin or on an object [5]. Bite marks are influenced by the pressure of the bite, the anatomy of the body part involved or the shape of the object. These factors determine which teeth were involved in the bite mark and what part of the dental surface marked the skin or the object [6]. Although the mechanism of bite marks is not found to be specifically defined, the pattern of the biting injury caused by the bite is usually affected by the time length and force of the bite. Also, a combination of other physiologic and mechanical factors determines the morphology of bite marks [5].

There are several procedures for comparing bite marks with a suspect's dentition which include measuring and analyzing the size, position, and shape of individual teeth. However, the most frequently used comparison methods involve the fabrication of overlays [7]. There are various approaches to produce overlays from a suspect's dentition. Among these are hand-tracing from wax impressions,

زمنية مختلفة، ومجالات مختلفة من درجات الحرارة

المستخلص

إن الغرض من هذه الدراسة هو تقييم التغيرات المتعلقة بالزمن في شكل علامات العض ولمعرفة الفائدة من مطابقة علامات العض على كل من الأشياء القابلة للتلف وغير القابلة للتلف مع مرور الوقت في درجات الحرارة المختلفة.

أجريت الدراسة في كلية Maharana Pratap لطب الأسنان ومركز أبحاث Gwalior في الهند. حيث طُلب من 20 متطوع عض 6 أشياء بشكل منفرد، وشملت هذه الأشياء مواد قابلة للتلف و أخرى غير القابلة للتلف، وكانت المواد القابلة للتلف هي التفاح والموز والبرفي (وهي قطع حلويات هندية أساسها الحليب)، في حين شملت المواد غير القابلة للتلف الشمع والطين والمطاط. إلتقطت صور للمواد بواسطة الكاميرا الرقمية عند العض مباشرة وبعد 24 ساعة من العض، وذلك بظروف مجالي درجات حرارة مختلفين؛ المجال الأول بين 28-24 درجة مئوية والمجال الثاني بين 40-36 درجة مئوية، على التوالي. طُبِعت الصورة الملتقطة بالحجم الطبيعي على شرائح شفافة وتم مقارنتها مع رسومات شفافة رسمت باليد اعتماداً على مشاهد الأشعة السينية لأسنان المشتبه، وأجريت المقارنة بين جميع الصور والرسومات الشفافة الـ 960 من قبل اثنين من الباحثين وبشكل منفصل.

أعطت جميع المواد مطابقة إيجابية في تحديد الهوية من خلال علامات العض بعد العض مباشرة. أما بعد 24 ساعة من عملية العض جميع المواد أظهرت مطابقة إيجابية باستثناء الموز والتفاح.

تعد هذه الطريقة المقترحة بسيطة وموثوق بها وأقل حساسية تقنية، وتضيق مجال الذاتية في التفسير (the subjectivity of interpretation)، وتسلط الدراسة الضوء على تأثير التحلل بما يحدثه من تغييرات في المواد الغذائية القابلة للتلف وبالأخص التفاح والموز ما يجعل علامات العض أدلة أقل موثوقية.

الكلمات المفتاحية: علوم الأدلة الجنائية، علامات العض، المواد القابلة للتلف، المواد غير القابلة للتلف، التصوير بالحجم الطبيعي، مشاهد الأشعة السينية.

dental study casts, the radiopaque wax impression method, hand-tracing from xerographic images and computer-based digital imaging techniques. Other techniques include life-sized printed photographs [8].

The comparison and analysis of bite marks is a complicated procedure. The first bite mark analysis was reported in 1874. Since then, various techniques for the comparison of dentition to bite marks left on the skin or other inanimate objects have been described [9]. Most of the studies in the literature are confined to bite marks examination immediately after the bite mark is created [10]. The authors of this paper propose this technique for the analysis of bite marks present on both perishable and non-perishable objects at two different times and temperature ranges. This paper describes a simple manual method of comparing and analyzing bite marks with a suspect's dentition by a superimposition technique using an x-ray viewer.

2. Materials and Methods

The research was carried out on 20 volunteers at Maharana Pratap College of Dentistry and Research Centre, Gwalior, India. For this study, the sample included an equal number of male and female volunteers, aged between 19-25 years. As the procedure was non-invasive, oral informed consent was obtained from the volunteers. The proposed technique is explained in six steps for a sample overview of the method applied in the present study.

The first step involved asking 20 volunteers to make bite marks on the following perishable and non-perishable items: apple, banana Burfi, wax, clay, and rubber.

The selection of perishable items was based on their size and consistency. Medium to large size apples and bananas were chosen. The bananas were firm in consistency. The apples were free of any decay and marks on their surfaces. Burfi (a milk-based popular sweet confectionary) with substantial length and width was preferred so that canine to canine marks could be obtained. In non-perishable items, bite registration wax sheet (10 x 6 x 0.5 cm) was folded with a piece of gauze between the folds for obtaining optimum width. Clay was molded approximately into the shape of a rectangular block measuring 7 cm x 3 cm. White colored Natraj rubber measuring 6 cm x 1 cm was selected.

Volunteers were asked to bite all items with firm pressure except banana, which was bitten using a small amount of force. They were instructed to bite deeply into the surfaces with a sufficient number of teeth from both arches. Also, each of the 6 items was bitten by all the 20 volunteers. This experiment was done once at an environmental temperature range of 24 ºC to 28 ºC and then repeated in a different season of the year at an environmental temperature range of 36 ºC to 40 ºC. At both the temperature ranges, steps 2 to 6 were followed.

The second step consisted of taking photographs of the bite marks made on each of the 6 items, both perishable and non-perishable, by all 20 volunteers immediately after biting. ABFO (American Board of Forensic Odontology) scale no. 2 was placed at right angles beside all the items, and photographs were taken with the digital camera with and without flash. (Photographs of both upper and lower teeth were taken separately from each volunteer for all the 6 items). In the third step, photographs of all the above-bitten items were taken 24 hours after biting.

The fourth step involved printing life-size photographs of all 6 bitten items on transparent sheets, according to the method described by Gorea and Jasuja [11]. (Life size photographs of both upper and lower teeth of each volunteer were printed separately for in all each volunteer in all 6 items).

The fifth step involved making hand drawn transparencies from the dental casts of all the 20 volunteers. In order to prepare the casts of study, dental impressions were prepared using alginate impression material, and the cast was

poured using dental stone. Handling of all materials was done according to the manufacturer's instructions. Care was taken to make sure that the soft tissue extensions of the impression in the master cats were carefully trimmed.

In the sixth and final step, comparison of life-size photographs of items printed on the transparent overlay to hand-drawn transparencies of a volunteer's dentition was done using an x-ray viewer by superimposition technique as shown in figure-1 and figure-2.

2.1. Superimposition Technique

For this proposed technique, two overlays were prepared. The first overlay was a hand drawn transparency pre-

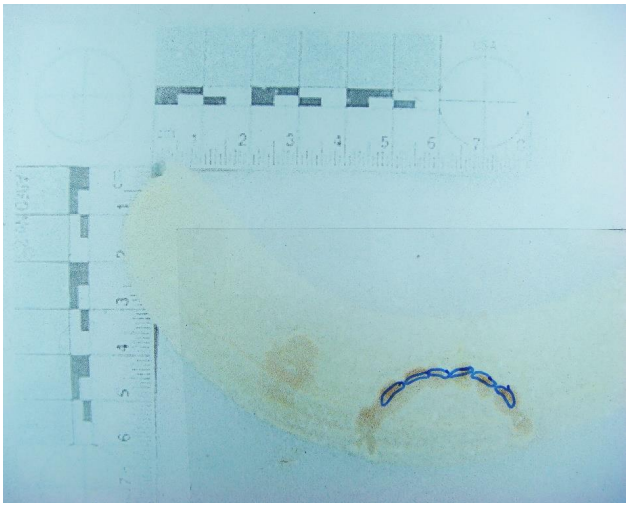

Figure 1- *Superimposition of hand drawn transparency on the life-sized photograph printed on the transparency showing bite marks on banana.*

pared from a dental study cast using a fine-tipped felt pen. The hollow part volume of an overlay is supposed to be life-sized because it is generated with the help of the actual cast of the teeth [12]. The second overlay was prepared by taking a printout of the life-size image of the bitten surface on a transparent sheet. Both these transparencies prepared above were then superimposed over each other on an x-ray viewer box for enhanced comparison and matching.

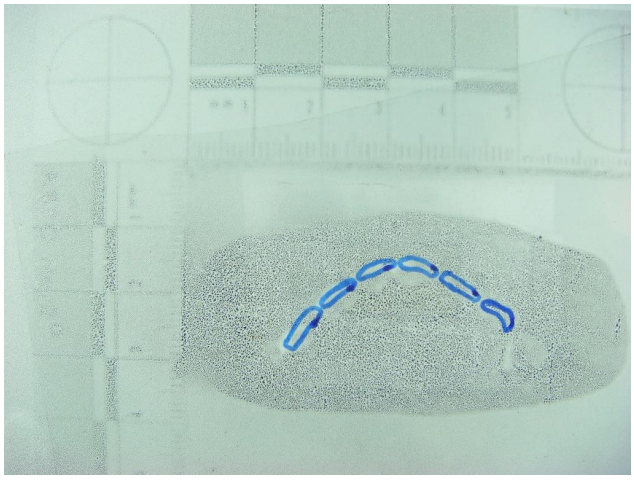

Figure 1- *Superimposition of hand drawn transparency on the life-sized photograph printed on the transparency showing bite marks on banana.*

2.2. Matching Strategies

In our experimental study, 20 volunteers bit 6 items each at two different environmental conditions at two different timings, and two researchers (R1 and R2) gave their opinion independently for the same samples. Matching of a hand drawn transparency and a life-size photograph printed on transparent overlay by using a superimposition technique was done by both the researchers by using the following strategies:

- At 24 ºC to 28 ºC, immediately after biting superimposition was done for 120 transparent overlays of upper teeth and 120 transparent overlays of lower teeth.
- At 24 ºC to 28 ºC, 24 hours after biting superimposition was done for 120 transparent overlays of upper teeth and 120 transparent overlays of lower teeth.
- At 36 ºC to 40 ºC, immediately after biting and 24 hours after biting, 240 transparent overlays of upper teeth, and 240 transparent overlays of lower teeth were superimposed and matched correspondingly.

2.3. Matching Criteria

For a particular volunteer, superimposed overlays were

considered to be matched if either upper jaw teeth matched or lower jaw teeth matched or both upper and lower jaw teeth matched the bite marks. In this way a total of 960 overlays were compared by each researcher.

Matching was done as per the guidelines given by BAFO (British Association of Forensic Odontology), based on individual teeth status, unique features and orientation of teeth. Also, while analyzing arch center point, size and shape were considered. Further, detailed examination of incisal edges of upper and lower central and lateral incisors and detailed examination of cusps of upper and lower canines and first premolars if present was also done. [13]

3. Results

For perishable items, at both the temperature ranges, immediately after biting both researchers could match a maximum number of bite marks on Burfi followed by banana and then apple, as shown in Table-1.

According to Table-1 and 2, findings of both researchers were similar (100% matching) on superimposition produced immediately and 24 hours after biting all the non-perishable items (wax, clay, and rubber) at both the temperature ranges.

After 24 hours of biting of perishable items, both researchers at the mentioned temperature ranges could not match any bite mark on apple and banana. However, both researchers could match an equal number of bite marks on Burfi at mentioned temperature ranges as shown in Table-2.

Although identification of bite marks on Burfi was higher at a temperature range of 36 °C to 40 °C (19 sam-

Table 1- *Comparison and matching of bite marks showing medically certain cases by two researchers immediately and 24 hours after biting at two different temperature ranges.*

Temperature Range/ Test bite media	Researcher 1 (R1)		Researcher 2 (R2)	
	Immediately after biting	24 hours after biting	Immediately after biting	24 hours after biting
24 °C - 28 °C Perishable Items				
Apple	5 (25%)	0	4 (20%)	0
Banana	9 (45%)	0	7 (35%)	0
Burfi	17 (85%)	17 (85%)	17 (85%)	17 (85%)
Non-Perishable Items				
Wax	20 (100%)	20 (100%)	20 (100%)	20 (100%)
Clay	20 (100%)	20 (100%)	20 (100%)	20 (100%)
Rubber	20 (100%)	20 (100%)	20 (100%)	20 (100%)
36 °C - 40 °C Perishable Items				
Apple	4 (20%)	0	3 (15%)	0
Banana	8 (40%)	0	6 (30%)	0
Burfi	19 (95%)	19 (95%)	19 (95%)	19 (95%)
Non-Perishable Items				
Wax	20 (100%)	20 (100%)	20 (100%)	20 (100%)
Clay	20 (100%)	20 (100%)	20 (100%)	20 (100%)
Rubber	20 (100%)	20 (100%)	20 (100%)	20 (100%)

ples) as compared to that at 24 °C to 28 °C (17 samples), the difference was not statistically significant (Fisher exact $p = 0.605$), as shown in Table-1 and 2.

Between group comparisons at 24 °C to 28 °C, it was found that bite marks on apple and banana matched significantly lower compared to other perishable (Burfi) and non-perishable (wax, clay, rubber) items ($p < 0.001$). Although positive matching of bite marks present in Burfi was comparatively less than non-perishable items, the difference was not statistically significant ($p = 0.231$), as shown in Table-3.

Furthermore, group comparisons at 36 °C to 40 °C showed that bite marks present on apple and banana showed a significantly low degree of matching as compared to other perishable (Burfi) and non-perishable (wax, clay, rubber) items ($p < 0.001$). Burfi showed the same number of matched bite marks compared to non-perishable items thus showing no difference from non-perishable items ($p = 1$), as shown in Table-4.

Subsequently, on a within-group comparison of two temperature ranges, no difference in bite mark matching ability was observed for apple, banana, wax, clay and rubber ($p = 1$). Although Burfi showed a higher matching at 36 °C to 40 °C as compared to 24 °C to 28 °C, the difference was not statistically significant ($p = 0.605$), as shown in Table-4.

Next, the study analyzed the total agreement of two researchers at given conditions and found, that immediately after biting at 24 °C to 28 °C and 36 °C to 40 °C for all the items, a strong ($\varkappa > 0.6$) to perfect ($\varkappa = 1$) agreement was observed. Similarly, for analyzing bite marks after 24 hours at given temperature ranges, the total agreement of two researchers for all the items was a perfect match ($\varkappa = 1$).

4. Discussion

At the crime scene, bite marks can be found on the body or any other unfinished food like cheese, on any other inanimate objects like pencil, duct tapes, fruits or discarded chewing gums. [14]. The purpose of our study was to analyze the usefulness of a superimposition technique for bite mark identification in both perishable and non-perishable items immediately after bite marks were made and after a time lapse of one day (24 hours) at different environmental conditions. This approach helped us in evaluating the effect of time lapse and temperature variations on bite mark evidence present at a crime scene.

Among the examined perishable food items, Burfi recorded the individual characteristics of the dentitions very well. The biter could be identified in 85% of samples by the two researchers immediately after biting and after 24 hours of biting at a temperature range of 24 ºC to 28 ºC. While at 36 ºC to 40 ºC, 95% of Burfi samples could be identified

Table 2- *Comparison between group of perishable and non-perishable items at 24 °C - 28 °C.*

	Apple	Banana	Burfi	Wax	Clay	Rubber
Apple	-	-	< 0.001	< 0.001	< 0.001	< 0.001
Banana		-	< 0.001	< 0.001	< 0.001	< 0.001
Burfi			-	0.231	0.231	0.231
Wax				-	1	1
Clay					-	1
Rubber						1

* *Significance of difference by Fisher's exact test p-value*

positively immediately and after 24 hours of biting by both the researchers (Table-1 and 2). These results show that these temperature ranges do not have any effect on Burfi. This disparity in bite marks identification was attributed to the nature of the bite mark made by the volunteer. Our results also suggest that Burfi can be a reliable source for bite mark identification if found at a crime scene under any circumstances, as shown in Table-4.

The bite marks on another two perishable items showed a lesser degree of matching immediately after biting at the given temperature ranges as assessed by both researchers. Our results showed that bite marks on apple could be matched 25% by researcher 1 and 20% by researcher 2 at 24 °C to 28 °C, and 20% R1 and 15% R2 at 36 °C to 40 °C (Table-1). Matching of bite marks on a banana at 24°C to 28 °C was 45% by R1 and 35% by R2, and at 36 °C to 40 °C it was 40% by R1 and 30% by R2 (Table-1). The probable reason could be the consistency of these items that disrupt the bite marks in question. Foodstuffs are subjected to considerable shrinkage and distortion, which in turn distorts the bite marks on test media. Apples and banana will lose a great deal of water contents so photography should be done within a short time [15].

The results of our study show that bite marks could not be interpreted on perishable items like apple and banana after 24 hours. The influence of the time lapse on the food depends on the kind of food examined [16]. It also suggests that the possibility of obtaining identifiable bite marks depends upon the time duration of the biting time and steps taken to preserve the object [17]. Apples and bananas contain enzymes like Tyrosinase and Polyphenol oxidase that respond to iron-containing phenols and oxygen. However, the oxidation reactions mostly form a sort of rust on the surface of the fruit. That is the reason for the browning of the apple and banana seen after a few hours of biting [18]. The rate of decomposition of apples and bananas is different as they contain different amounts of water. These fruits contain more water compared to Burfi which makes them more susceptible to a faster rate of decomposition. The temperature ranges studied were optimum temperatures for bacterial growth, which also speeds up decomposition.

Furthermore, when analyzing bite marks on non-perishable items 100% matching was seen by both the researchers immediately after biting and 24 hours after biting at the two temperature ranges. Our results are in concordance with a previous study done by Gorea et al. (2005), in which they showed that wax and clay are good test bite media [19]. If the photographs were printed on the paper success rate was 92.02% on the clay [10], whereas by this method 100% identification was possible on the clay. This study has further shown that these media can be successfully used for bite mark analysis using a superimposition

Table 3- *Comparison between groups of perishable and non-perishable items at 36 °C - 40 °C.*

	Apple	Banana	Burfi	Wax	Clay	Rubber
Apple	-	-	< 0.001	< 0.001	< 0.001	< 0.001
Banana		-	< 0.001	< 0.001	< 0.001	< 0.001
Burfi			-	1	1	1
Wax				-	1	1
Clay					-	1
Rubber						1

* *Significance of difference by Fisher's exact test p-value*

Table 4- *Within-group comparison of perishable and nonperishable items at 24 °C to 28 °C.*

	Apple	Banana	Burfi	Wax	Clay	Rubber
***p*-value**	1.000	1.000	0.605	1.000	1.000	1.000

* *Fisher's exact test p-value*

technique, even after a time lapse of 24 hours at variable temperature ranges.

Cases have been reported in which bite marks on foodstuffs have been analyzed, but there has been little experimental or empirical work directed toward understanding biting mechanics in food. Loizzo et al. have described a method for creating a permanent model of bite marks on perishable substances; however, unfortunately, no analysis was done to assess the accuracy or reliability of this method [20]. Our results suggest that overlay superimposition of a life-size image on an x-ray viewer demonstrates a positive concordance between the bite mark and the suspect's dentition. In the present study, the authors propose a new method using the manual technique for comparison of overlays on an x-ray viewer for better observation, which is easy and reproducible. This procedure is less technique sensitive and more economical. Because of these advantages, this method can be used by any forensic odontologist in criminal cases where several suspects have been selected for initial screening for exclusion purposes and can be further referred to a specialist for using sophisticated technical methods like Adobe photoshop for better inclusion purposes.

This research highlights the fact that at different temperatures and at different time spans objects showing bite marks can be studied even with less technique sensitive methods and manual procedures. Moreover, the authors would like to highlight to dentists and forensic odontologists that even at variable temperatures and time intervals bite marks on perishable or non-perishable items can not only be recovered but can also be matched successfully if proper procedures are followed.

It is recommended that for better enhancement, whitener or nail polish (white or any other light color) may be applied while taking photographs of the bitten area on transparency sheet of non-perishable items.

5. Conclusion

Our results have shown that the superimposition technique is not only economical but can also be easily performed and gives reliable results. In the author's opinion, bite marks present on non-perishable objects and perishable food items can be matched with medical certainty immediately after biting. On perishable items, however, an opinion of "medical certainty" should be given cautiously in bite mark cases after a time lapse of 24 hours depending upon the type of food and its proneness to decomposition. However, this does not apply to non-perishable items as non-perishable items do not decompose within such a short interval.

Conflict of interest

Authors declare no conflict of interest.

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