ORIGINAL ARTICLE

Accuracy of bite mark analysis from food substances: A comparative study

M. Jonathan Daniel,
Ambiga Pazhani
Department of Oral Medicine and Radiology, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Government of Puducherry Institution, Puducherry, India

Address for correspondence:
Dr. Ambiga Pazhani, Department of Oral Medicine and Radiology, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Government of Puducherry Institution, Indira Nagar, Gorimedu, Puducherry - 605 006, India
Email: dr.ambiga@gmail.com

Abstract

Aims and Objectives: The aims and objectives of the study were to compare the accuracy of bite mark analysis from three different food substances-apple, cheese and chocolate using two techniques-the manual docking procedure and computer assisted overlay generation technique and to compare the accuracy of the two techniques for bite mark analysis on food substances. **Materials and Methods:** The individuals who participated in the study were made to bite on three food substances-apple, cheese, and chocolate. Dentate individuals were included in the study. Edentulous individuals and individuals having a missing anterior tooth were excluded from the study. The dental casts of the individual were applied to the positive cast of the bitten food substance to determine docking or matching. Then, computer generated overlays were compared with bite mark pattern on the foodstuff. **Results:** The results were tabulated and the comparison of bite mark analysis on the three different food substances was analyzed by Kruskall-Wallis ANOVA test and the comparison of the two techniques was analyzed by Spearman's Rho correlation coefficient. **Conclusion:** On comparing the bite marks analysis from the three food substances-apple, cheese and chocolate, the accuracy was found to be greater for chocolate and cheese than apple.

Key words: Bite marks, computer generated overlays, hand docking

Introduction

Bite marks left on foodstuff at the scene of crime offer a three-dimensional impression of the suspect's dentition and the bite mark analysis can give useful clues about the perpetuator who caused it, leading to the implication or exclusion of the individual under investigation.[1] The forensic value of bite marks on foodstuffs depends on the nature of the substrate[2] and the ability of the perishable food substance to dehydrate and deform at room temperature, the precision of impression of the suspect's dentition on the foodstuff and the time elapse in collecting and preserving the bite mark evidence. Furthermore life size photographs of the bite mark taken with good quality and angulation is of extreme importance to the forensic odontologist for bite mark analysis and for identifying the victim. As photography is the safest means of obtaining a permanent record of the bite mark[2] on perishable food substances such as apple, cheese, and chocolate, it must be of the highest standard for its forensic significance to be maximized. The process of comparing bite marks on a food substance with an individual's dentition includes analysis of size, shape, and spatial orientation of the individual tooth.[1]

As bitten food substances are commonly left away at the scene of crime, an attempt was made to study the accuracy of bite mark analysis on three different food substances-apple, cheese and chocolate. The fact that human dentition is unique[1] for each individual plays an important role in this study.

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The aims and objectives of the study were to compare the accuracy of bite mark analysis from three different food substances-apple, cheese, and chocolate using two techniques-the manual docking procedure and computer assisted overlay generation technique and to compare the accuracy of the two methods-the docking analysis and the computer assisted overlay generation technique for bite mark analysis on food substances.

Materials and Methods

Twenty-five individuals who participated in the study were made to bite on three food substances-apple, cheese and chocolate. The bitten food substance was then stored in a refrigerator in a sealed plastic bag[1] within an hour. Then, the impression of the bite mark on apple, cheese and chocolate was made using light body addition silicone (Affins) by gently injecting from a center point to periphery[1,3,4] using the plastic gun. It was then picked up with a heavy body silicone (Affins) and poured with die stone (Samit) to obtain the positive replica of the bitten surface[1,3,4] on apple [Figure 1], cheese [Figure 2] and chocolate [Figure 3]. The dental impressions were then made for the individuals using alginate impression material (Velplast) and dental casts were obtained.[4]

In the manual docking (direct) analysis, the dental casts of each individual were docked to the die stone cast (positive replica) of the bite mark on apple, cheese [Figure 4] and chocolate [Figure 4] to check for matching of incisal edges of the anterior teeth with the bite mark pattern on the foodstuff. While doing the docking analysis for cheese and chocolate with mandibular casts, the positive replicas were reversed to check for matching. The scoring was then assigned as "0" for not matching, "1" for slight (consistent)[5] matching, "2" for moderate (probable) matching and "3" for excellent (distinctive)[5] matching respectively. The highest score was assigned to the correct match as per modified version of the American Board of Forensic Odontology (ABFO) scoring system for bite marks.[6]

Finally by the computer assisted overlay generation (indirect) technique, overlays of anterior dentition were obtained from life size photographs of dental casts using "magic wand" wizard tool in Adobe Photoshop CS4 software [Figure 5].[7,8] Then, the overlays were superimposed over the bite mark pattern in the life size photographs of the food stuff and placed in a preferred position until satisfactory matching could be established [Figure 5]. The scoring was then assigned as "0" for not matching, "1" for slight (consistent)[5] matching, "2" for moderate (probable) matching and "3" for excellent (distinctive)[5] matching respectively. The highest score was assigned to the correct match as per modified version of the ABFO scoring system for bite marks.[6]

Results

The results were tabulated and the accuracy of bite mark analysis on the three food substances was analyzed by Kuskall-wallis ANOVA test. By manual docking analysis, excellent matching was observed in 24% of cases for apple, 56% of cases for cheese and 72% of cases for chocolate [Table 1]. By computer assisted overlay generation technique, the excellent matching percentages of bite mark analysis were 32, 60, and 76, respectively for apple, cheese and chocolate [Table 2]. The comparison of hand docking and computer assisted overlay generation technique was done by Spearman's correlation and the Rho coefficient was found to be 0.896 for apple, 0.945 for cheese and 0.951 for chocolate [Table 3].

Discussion

A bite mark has been defined as "a pattern produced by human or animal dentitions and associated structures

Figure 1: Showing the methodology to obtain positive replica of bitten surface on apple

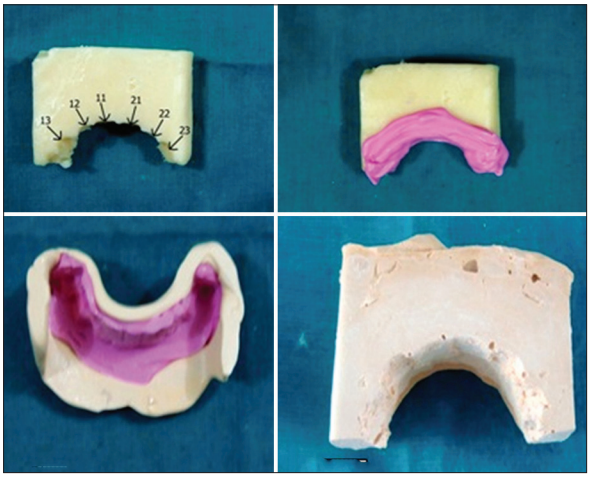

Figure 2: Showing the methodology to obtain positive replica of bitten surface on cheese

Figure 3: Showing the methodology to obtain positive replica of bitten surface on chocolate

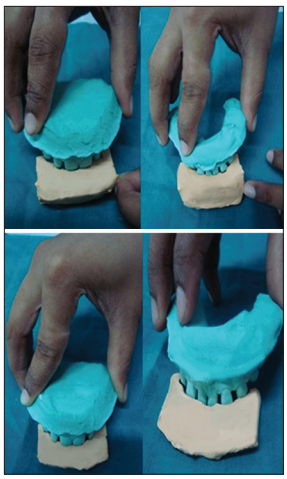

Figure 4: Showing manual docking analysis done on the die stone cast of bite mark on cheese and chocolate using maxillary and mandibular casts

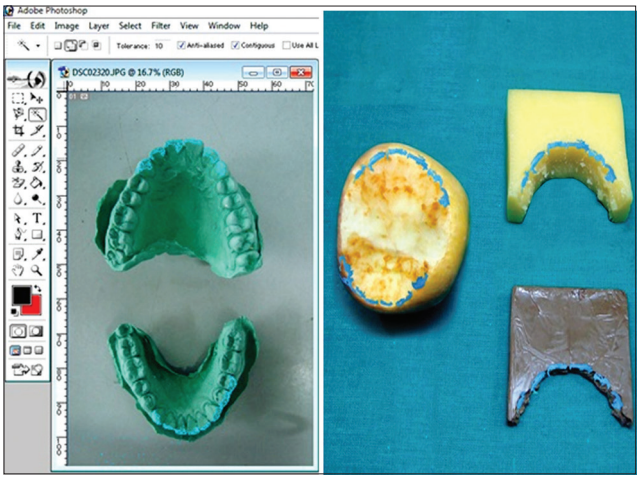

Figure 5: Showing selection of incisal edges using the "magic wand"wizard tool in Adobe Photoshop software from the photograph of dental cast and the superimposition of computer generated overlays over the photograph of bite mark on apple, cheese and chocolate done to check for matching

in any substance capable of being marked by these means" (Clark 1992). Bitemarks left away on a foodstuff offer a three-dimensional impression,[9] which is superior to the two-dimensional impression often left away on the skin. A study conducted by MacFarlane *et al*. supported the concept of dental uniqueness.[10] The physical characteristics of bite mark which contributes to uniqueness include the shape of the dental arch, distance between canines,

Table 1: Comparison of accuracy of bite mark analysis for apple, cheese and chocolate by manual docking method using Kruskall-Wallis ANOVA test

Foodstuff	Frequency	Percentage	*P*
Apple			
Not matching	4	16.0	0.002
Slight matching	10	40.0	
Moderate matching	5	20.0	
Excellent matching	6	24.0	
Total	25	100.0	
Cheese			
Not matching	2	8.0	
Slight matching	3	12.0	
Moderate matching	6	24.0	
Excellent matching	14	56.0	
Total	25	100.0	
Chocolate			
Not matching	2	8.0	
Slight matching	2	8.0	
Moderate matching	3	12.0	
Excellent matching	18	72.0	
Total	25	100.0	

ANAVA: Analysis of variance

Table 2: Comparison of accuracy of bite mark analysis for apple, cheese and chocolate by computer assisted overlay generation technique using Kruskall-Wallis ANOVA test

Food stuff	Frequency	Percentage	*P*
Apple			
Not matching	2	8.0	0.017
Slight matching	5	20.0	
Moderate matching	10	40.0	
Excellent matching	8	32.0	
Total	25	100.0	
Cheese			
Not matching	2	8.0	
Slight matching	2	8.0	
Moderate matching	6	24.0	
Excellent matching	15	60.0	
Total	25	100.0	
Chocolate			
Not matching	2	8.0	
Slight matching	1	4.0	
Moderate matching	3	12.0	
Excellent matching	19	76.0	
Total	25	100.0	

ANOVA: Analysis of variance

Table 3: Spearman's correlation between the 2 techniques-manual docking analysis and computer assisted overlay generation technique for the three food stuffs-apple, cheese and chocolate

Foodstuff	Manual docking analysis versus computer assisted overlay generation technique	
Apple	Spearman's Rho correlation coefficient	0.896
	Significance (2-tailed)	0.000
Cheese	Spearman's Rho correlation coefficient	0.946
	Significance (2-tailed)	0.000
Chocolate	Spearman's Rho correlation coefficient	0.951
	Significance (2-tailed)	0.000

presence of a tooth out of alignment, spacing between teeth, rotation of teeth, missing teeth, the curves of biting edges and wear patterns.[1,3] Hence, the premise of bite mark analysis is that human dentition is unique and that this asserted uniqueness[11] is replicated on the bitten substrate in sufficient detail to enable a match[12] to the individual under suspicion.

The factors which influenced the accuracy of bite mark analysis in our study were physical nature of the foodstuff, the biting force with which bite mark was done, time elapse in the preservation of foodstuffs, proper impression technique, proper generation of dental casts and positive replica of bitten surface of the foodstuff and the quality and angulation of the bite mark photographs. In our study, bite mark impressions were made with addition silicone as this impression material has excellent dimensional stability[13-16] and accurately duplicates the bite mark pattern on the foodstuff.

On comparing the bite mark analysis on the three food stuffs by the two techniques-hand docking method and computer assisted overlay generation technique; the Spearman's Rho correlation coefficient was found to be 0.951 for chocolate, 0.946 for cheese and 0.896 for apple [Table 3]. When meticulous steps were taken for preservation and handling of foodstuff after the bite mark was done by the individual, the accuracy of bite mark analysis was found to be slightly greater on chocolate than cheese and poor on apple in our study. The poor accuracy of bite mark on apple was because of its firm substrate and its dehydration and decomposition at room temperature and the good accuracy on chocolate and cheese could be because of fine bite registration due to homogeneity of the substrate of the two foodstuffs. On observing the bite mark pattern on chocolate and cheese, both chocolate and cheese showed a fine registration of incisal edges of maxillary and mandibular anterior teeth, but the bitten edges on cheese showed some irregularities and cracks and this could be the reason for a slightly greater accuracy of bite mark on chocolate than cheese in our study. In a comparative study conducted by Bernitz *et al.* on accuracy of bite marks on cheese, butter and cooked potato, it was found that the examiners correctly identified all the true matches of bite marks on the three foodstuffs with their respective study models.[17] Rai *et al.* conducted a comparative study on bite mark analysis on cheese and clay and found that for bite marks on clay, the match by docking analysis and overlay method was positive in 95% of cases, while for bite marks on cheese, it was positive in 81% of cases.[9]

In our study, on comparing the hand docking method and computer assisted overlay generation technique, hand docking method showed an excellent matching in 24% of cases for apple, while for cheese in 56% of cases and for chocolate in 72% of cases [Table 1]. Computer assisted overlay generation technique showed an excellent matching in 32% of cases for apple, while for cheese in 60% of cases and for chocolate in 76% cases [Table 2]. The hand docking (direct) method was found to be an objective technique, but the technique was difficult and cumbersome. Generation of good dental casts and a proper positive replica of bite mark on foodstuff played a critical role in this study for bite mark analysis by hand docking method. The positive replica of bitten surface was not accurate when excessive pressure was applied on the bite mark pattern on the foodstuff during impression making.

The computer assisted overlay generation (indirect) technique was relatively easier and less time consuming than hand docking method. However, the computer generated overlay technique was found to be a subjective analysis, so it was found to be more accurate when the analysis was done on bite marks caused by a dentition displaying some unique features like rotation, spacing, crowding, etc., Sweet and Bowers compared computer generated overlay method with other overlay generation techniques and concluded that computer generated overlay technique is the most accurate and the gold standard technique for bite mark analysis.[8] In our study, the computer assisted overlay technique had a greater accuracy, when bite mark analysis was done on life size photographs of dental casts and the bite mark pattern on the three foodstuffs and on photographs with good quality and angulation and in cases of dentition showing some unique features. The results of our study were consistent with the study conducted by Stavrianos *et al.,* who concluded that computer assisted overlay generation technique for bite mark analysis was as accurate as hand docking method in cases of bite mark on apple and may be useful in a variety of substrates.[1] Rai *et al*. compared the direct (docking analysis) and indirect method (overlay method) of bite mark analysis on cheese and clay and concluded that when the comparison by indirect method remains inconclusive, the direct comparison method tends to match.[9] McKenna *et al.* reported a case of bite marks on chocolates, which were recovered from the scene of theft in a chocolate factory and it was found that both direct and photomicrographic comparisons between the casts of chocolate and of the

suspect's dentition revealed correspondence between their unique characteristics and this led to the conviction of chocolate thieves.[18] Aboshi *et al*. have reported a case of fire in a Snackbar in Mount Gambier, South Australia in which the suspect was identified by comparing computer generated images of biting surfaces of the victim's cast with that of bite marks on cakes obtained from the crime scene.[19]

The drawbacks of our study were there was no matching of the dentition with bite mark pattern when there were an excessive delay in the preservation of the bitten food stuff, poor cast generation and in cases of poor quality and angulation of photographs of bite mark on foodstuffs and of dental casts.

Conclusion

On the basis of the results of our study, among the three perishable food substances apple, cheese and chocolate, bite marks on chocolates and cheese may serve as valuable, reliable and accurate evidences for identifying a victim because of the fine bite registration on these two foodstuffs than apple. Computer assisted overlay generation method may serve as a reliable, easier, less expensive, and less time consuming technique for bite mark analysis, but further research is needed to develop sophisticated software with greater specificity for bite mark analysis to avoid wrong implication of crime due to subjective errors.

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