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Analysis of human bitemarks on food stuffs by computer based superimposition technique

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Abstract
Aims: Identification of human bitemarks on different food stuffs and analyse them by computer based superimposition technique using Adobe photoshop software.
Methods and Material: 25 bitemarks on food stuffs were selected for the present study. These bitemarks were analysed with computer based superimposition technique using Adobe photoshop software.
Results: Among 25 cases 24 were matched and 1 bitemark was not matched.
Statistical analysis used: Chi – square test was performed and a significant value (p = 0.000 i.e. < 0.005) was achieved
Conclusion: Computer based superimposition technique using Adobe photoshop software is an accurate and cost effective method for bitemark analyasis.

Keywords: human bitemarks, adobe photoshop, overlay

Introduction

'Forensic odontology' has been defined by Federation Dentaire International as "that branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence, and with the proper evaluation and presentation of dental evidence [1]." The most complex and controversial challenge in forensic dentistry is the recognition, recovery and analysis of bitemarks. Human dentition is unique because no two individuals have identical dentition in regard to the size, shape and alignment. Bitemarks on the skin, food stuffs or on any other material considered as a type of physical evidence and it has an evidentiary value in court of law. The aim of the present study was to identify and analyse human bitemarks on food stuffs by computer based superimposition technique using Adobe photoshop software.

Materials and methods

25 bitemarks were selected for the present study. Volunteer BDS students studying in Government Dental College & Hospital, Hyderabad participated in the study. Different food materials were given to the participants for making a bite. Food stuffs used in the study were cheese, chocolate, apple, mango, mango jelly. Bitemarks on food stuffs were collected and examined thoroughly. Bitemark analysis was carried out after taking permission from concerned authories.
Bitemark analysis was done in three steps 1. Identification of bitemark 2. Evidence collection 3. Analysis of bitemarks using adobe photoshop

Identification of bite-mark

25 bitemark cases were done on the food stuffs. Many cases with variable individual characteristics like mesiodense, crowding, attrition, spacing, and retained deciduous teeth were also selected for the study. Particulars were noted in a specially prepared proforma. Bitemarks on the apple, chocolate, mango appear clearer than in the mango jelly and cheese. This is may be due to the elastic nature of the mango jelly and melting nature of the cheese to room temperature.
Based on class features and individual features bite marks were identified on food stuffs like mango, mango jelly, apple, chocolate.

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Evidence collection
Both the bitemarks on food materials and the participants were examined and evidence from each is gathered for comparative study and evaluation.
a) The bitemarks were visually examined and following details were documented.

- Type of injury
- Contour, texture, and elasticity of the bite site
- Physical appearance (colour, size), orientation and location
- Differences between upper and lower arches, and between individual teeth.

Photography of the bitemarks
Bitemarks present on the food materials were documented by photographs with the use of ABFO no. 2 scale (American board of forensic odontology) and Sony Ciber shot camera with 12.1 megapixel and 5 optical zoom. [Figure 1] Photographs of bitemarks were taken using following instructions.

- The presence of scale is oriented on the same plane as the bitemark or evidence sample.
- The orientation of the camera back (film plane) to the scale is parallel.

Fig 1: bitemark on apple

Evidence collection from the participants
A standard case history was taken from all the participants. Informed consent was obtained before any evidence recovery procedure. An intraoral and extraoral examination is completed. Following the detailed clinical examination, the following evidences were collected.

- Photographs of the teeth [Figure 2]
- Maxillary and mandibular impressions were made with alginate impression material, followed by cast pouring with dental stone. [Figure 3]
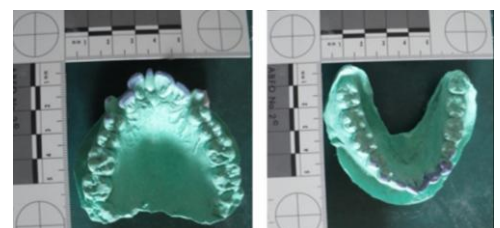

Fig 2: photograph of teeth

Fig 3: photograph of maxillary and mandibular casts

Analysis of bitemarks using adobe photoshop
Scanning the bitemark: photograph of the bitemark was scanned and resized to a life size photo using Adobe Photoshop software. The impressions of the subject's dentition were obtained, the casts were poured. Two coats of cold mould seal (separating media) was applied to the casts using a thin haired brush. After the separating media was dried, the casts were pressed with moderate pressure into stamp pad such that the plane of occlusion was parallel to the surface of the ink pad to select the incisal edges. Then the cast was scanned along with the ABFO No 2 scale placing beside. The scanned image was then transferred to adobe Photoshop. The Magic wand tool cursor was clicked on the blue coloured inked incisal edges of the teeth. The Magic wand tool selects an area of similar pixel tone. To add to the selected area of a tooth or to select additional teeth, the Shift key was held down while making the additional selections. Thus keeping the Shift key pressed, the blue coloured inked incisal edges of the rest of the teeth were also selected. In this way all of the incisal edges of the six teeth will be selected. After the selection is complete, they are smoothed.

Construction of the overlay
Since the overlay will be on a layered separate from the Background, a new layer was created. The selected edges were outlined by clicking Edit > Stroke > Stroke dialog box > Stroke width > 1, Location > Inside > OK > Ctrl + D

Nonmetric analysis of the bitemark and dentition
When the bitemark image and the overlay are completed, a nonmetric analysis was carried out. This analysis involves superimposing the overlay onto the bitemark and investigating points of concordance or discrepancy. A typical bitemark comparison image includes the bitemark image as the background layer, the maxillary arch overlay layer, a mandibular overlay layer. Each of these layers can be enhanced or moved individually. [Figure 4]
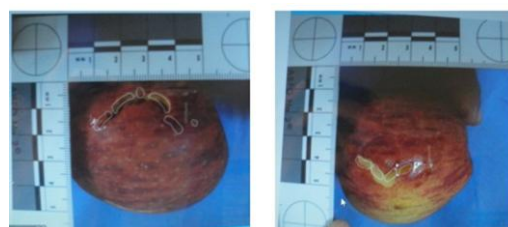

Fig 4: superimposition of overlay on to the bitemark

Results
Based on the gross, class and individual features (Table: 1) overlays of teeth of the subject was matched with the bitemark on the food stuffs in a computer based method using Adobe photoshop (Table 2).

Table 1

Bitemark features	
Gross features	Circular or elliptical pattern injury representing maxillary and mandibular arches as Lacerations, Punctures, Erythema and avulsions with central ecchymosis
Class features	Incisors- rectangles; canines- triangles with some variation; premolars- single or dual triangles, diamond with some variations; molars- rarely leave marks but when present refer the shape of making area.
individual features	Rotated tooth, fracture tooth, mesiodense, crowding, attrition, spacing, and retained deciduous teeth

Table 2

S. No	Bite mark location	Result
1	Chocolate	Matched
2	Chocolate	Matched
3	Chocolate	Matched
4	Chocolate	Matched
5	Chocolate	Matched
6	Chocolate	Matched
7	Chocolate	Matched
8	Cheese	Matched
9	Cheese	Matched
10	Cheese	Matched
11	Cheese	Not Matched
12	Cheese	Matched
13	Apple	Matched
14	Apple	Matched
15	Apple	Matched
16	Apple	Matched
17	Apple	Matched
18	Apple	Matched
19	Apple	Matched
20	Apple	Matched
21	Mango	Matched
22	Mango	Matched
23	Mango	Matched
24	Mango	Matched
25	Mango	Matched

In the present study among 25 Bitemarks on the food stuffs 24 bitemarks were matched. One bitemark present on the cheese didnot matched (table3). Chi – sqare test was performed and the test give a significant value (p = 0.000 i.e. < 0.005) for matched cases (table 4, picture 1)

Table 3: Bite mark analysis with percentage

	Frequency	Percent %
Matched	24	96.0
Un matched	1	4.0
Total	25	100.0

Table: 3 shows, 25 bitemarkson the food stuffs were included in the study among them 24 were matched giving a percent of 96% and 1 was not matched giving a percent of 4%.

Table 4: Chi-Square Test

	Results
Chi- Squre[a]	21.160
Df	1
Asymp.sig.	.000

Table: 4 Shows the particulars of Chi-square test. This test give a significant value (p = 0.000 i.e. < 0.005) for matched cases.
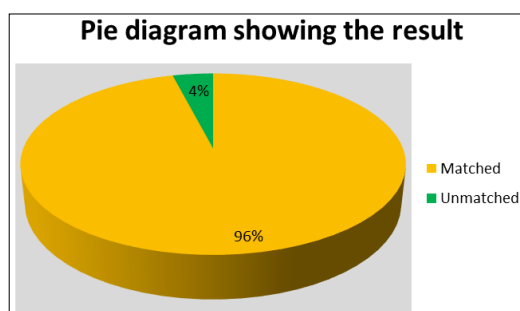
Pic 1: Bite mark Analysis – Pie diagram

96% cases were matched, indicated by yellow colour. 4% cases were not matched which is indicated by green colour.

Discussion
It has long been recognized that bitemarks are unique [2, 3] and can be attributed to specific individuals. A study in 1991 has established dental uniqueness beyond a reasonable doubt. Even the dentition of identical twins is not identical.
It has been estimated in about 2.5 billion people there may be two persons who produce identical bitemarks. This means that in India, with a population 1 billion, no two persons will have identical bitemarks [4].
Mac Donald defined bitemark as "a representative pattern left in an object or tissue by the dental structures, either alone or in combination with other oral structures of an animal or human" [5].
Bitemarks may be caused by humans or animals. They may be on tissue, food items or other objects. Many forensic odontologists classified bitemarks like. Cameron and Sims classification, Mac Donald's classification [6], Webster's classification [7].
Terms commonly used in bitemark analysis are [8];
1. Victim, is the recipient of the bitemark
2. Perpetrator, is the person who caused the bite mark

Webster's classification [9]
He classified bitemarks on food stuffs
- **Type 1:** The food item fractures readily with limited depth of tooth penetration. E.g.: Hard chocolate
- **Type 2:** Food item fractures with considerable penetration of teeth E.g.: Apple and other firm fruits
- **Type 3:** Complete or near complete penetration of the food item with slide marks. E.g.: Cheese

In 1906, two colliers were charged with breaking into a store and stealing. During examination of the premises, some cheese was found. A piece had been bitten out leaving marks of the teeth. The impressions of the suspects were taken and the teeth on the models fitted the marks in the cheese. This case is another landmark in forensic dentistry since it was the first recorded instance where expert guidance was given [10].
Whittaker D. K. *et al*. [11] conducted a study on 84 bitemark cases. Bitemarks were voluntarily created on wax and pig skin. Comparison was done based on a visual method depending upon arch curvature, width of teeth, angulations of teeth and spacings between teeth. Only 68% cases were matched and they stated that visual matching using subjective criteria is less accurate. The present study uses computer based method which is more objective in nature and the results were statistically significant (96%).
Sweet. D and Parhar. M *et al*. [12] described the computer based method and they used this method on number of cases involving human bites on skin and they stated that this method as an accurate method. In the present study 25 bitemarks on food stuffs were compared with the subjects teeth using this method among them 24 were matched. The results indicate that the computer based method is an accurate method and also indicates that human teeth are unique.
In the present study 25 bitemark cases were done on the food stuffs. Food stuffs used in the study were cheese, chocolate, apple, mango, mango jelly, ice cream cone. In all cases overlays prepared from the casts of upper and lower teeth were matched with the bitemark photograph of food stuffs and analysis carried out with computer based method similar to the method which was used by sweet. D and Parhar. M *et al*. [12]

Webster. G [9]. conducted a study on 30 bitemarks on food stuffs and proposed a classification. He used food stuffs like cheese, chocolate and apples and all the bitemarks were matched with the biters teeth. It is similar to the present study where food stuffs like cheese, chocolate, apple, mango, mango jelly were used which are commonly used by the Indian population. In the present study all the bitemarks were matched with the biters teeth.

Similar study was done by Balwant Rai. S *et al.* on 103 volunteers, where they have used cheese as foodstuff material to bite but they have used different techniques for analysis like direct cast method and photography based method and the result was 81%. The present study used computer based method and results found with this method were 100% [13].

The first case of legal admissibility of bitemark evidence was used a piece of cheese left at the crime scene in 1954 that led the perpetrator to convict and court gave the opinion that it was almost as convincing as finger print evidence [14, 15]. The present study uses 5 bitemarks on cheese for analysis among 5 bitemarks 4 bitemarks were matched but 1 bitemark did not match with the subject's teeththis may be due to the melting natute of cheese and room temperature

Similarly in the thief investigation done by Suzuki *et al.* [16] used bitemarks on apples as an evidence and identified a thief. In the present study 5 bitemarks on apples were taken and analysed all the bitemarks were matched with the subject's teeth. bitemarks on apples are more dimensionally stable than cheese and mango.

Lessing *et al.* [17] done an investigation on the bitemarks left on the apple by the perpetrator. The analysis was different from the computer based method. In their study they took impression of the apple and matched with the cast of the suspect.

Chocolate, Cheese left in crime scene can be used as important evidence in investigation as in case reported by Mckenna *et al* where bitemarks on chocolates led to the conviction of thieves. Similarly Pierce LJ *et al.* [18] reported a case where a bitemark on cheese led to the conviction of thieves. Because of importance bitemarks on chocolates the present study used chocolates and cheese as one of the food stuff used in bitemark analysis.

The perpetrator tend to eat food stuff in consciousness so bitemark appear clear with good gross, class and individual features whereas bitemarks humans depends upon the movement of the victim and perpetrator, aggressiveness of the perpetrator and the consciousness of the victim and perpetrator. The appearance and features of the bitemark in humans indicates whether the victim is an active or a passive participant (like unconscious, dead). Aggressiveness of the perpetrator and movements of the victim as well as perpetrator may result in multiple bitemarks, incomplete bitemarks where only a half or some teeth seen. Skin is a poor medium for bitemarks as it is resilient furthermore inflammatory changes in it results in distortion. Postmortem changes in deceased victims also results in distortion of the bitemark. All these factors should be considered during bitemark analysis.

Previously many authors tried to fabricate overlays of suspect's teeth by various methods like photographic, wax imprint, radiographic, xeroradiographic methods. The disadvantage of these methods was that they are more subjective in nature. The present study uses the computer based method which is more objective method compared to the previous methods. The computer based method uses Adobe photoshop software in which various tools digitally selects the incisal edges of the teeth and fabricates overlays. These overlays can be easily compared with the life size image of the bitemark. Another advantage of this method is the reproducibility. This method reduces examiner variability and also reduces human errors.

Conclusion

Bitemarks usually associated with sex crimes, violent fights, child abuse and thefts. If the teeth leave definitive marks it should be possible to individualize them to a particular person. Hence, matching the bitemark to a suspect's dentition may enable law to implicate the suspect in the crime. Bitemarks on the skin, food stuffs or on any other material considered as a type of physical evidence and it has an evidentiary value in court of law. The present study was done on identification and analysis of human bitemarks by computer based superimposition technique using Adobe Photoshop software. This method showed statistically significant results. In conclusion, bitemarks have an evidentiary value in court of law. Computer based superimposition is an accurate method in human bitemark analysis.

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