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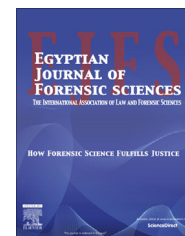
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## ORIGINAL ARTICLE

# Bite marks on skin and clay: A comparative analysis



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**Abstract** Bite marks are always unique because teeth are distinctive. Bite marks are often observed at the crime scene in sexual and in physical assault cases on the skin of the victims and sometimes on edible leftovers in burglary cases. This piece of evidence is often ignored, but if properly harvested and investigated, bite marks may prove useful in apprehending and successfully prosecuting the criminals. Due to the importance of bite marks, we conducted a progressive randomised experimental study conducted on volunteers. A total of 188 bite marks on clay were studied. Based on these findings, 93.34% of the volunteers could be identified from the bite marks on the clay. In addition, 201 impressions on skin were studied, and out of these cases, 41.01% of the same volunteers could be identified based on the bite mark impressions on the skin.

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## 1. Introduction

Bite marks are often observed at crime scenes on various parts of the human body, although they are more common in certain parts of the body.<sup>1</sup> In addition, no body part is immune to bite marks.<sup>2</sup> These marks are not uncommonly observed in physical assault cases<sup>3</sup> but are more common in sexual assault cases<sup>4</sup> and are observed in both homosexual and heterosexual cases. These pieces of evidence have been used successfully to prosecute offenders.<sup>5–7</sup>

Bite marks have also been observed on various edible leftovers at the crime scenes,<sup>8</sup> and these bite marks have also been used as evidence for identifying the criminals.

Bite marks on inedible objects have also been reported,<sup>9</sup> including on soap<sup>10</sup> and bullets.<sup>11</sup> Bite marks have also been studied on clay,<sup>12</sup> and one case has been solved based on bite marks on clay.<sup>13</sup>

According to Pretty and Turnbull, the central dogma of bite mark analysis is based on two assumptions.<sup>14</sup> The first is that human teeth are unique, and the second is that sufficient detail of the uniqueness is rendered during the biting process to enable identification.

Various experimental studies have been conducted on various food items, human skin and animal skin to determine similarities and dissimilarities of the bite marks and the teeth of

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the volunteers. Skins of dogs, pigs and sheep have been used to study bite marks.<sup>15-17</sup>

Studies have also been performed on wax,<sup>15</sup> chewing gum<sup>7</sup> and clay<sup>12,13</sup> to develop better methods.

Computers have also been used for this comparison,<sup>18</sup> and 3D studies have been conducted<sup>19</sup> using scanning electron microscopy.<sup>20</sup> Several studies have even used radiographs, including computed tomography (CT) scans, to compare bite marks.<sup>21,22</sup>

Bite marks are lifted using various photography techniques and other materials.<sup>23</sup> According to West et al. photographs of bite marks should be obtained as early as possible because of changes due to vital reactions.<sup>24</sup> According to McNamee and Sweet, the use of digital cameras has the advantage that it could provide instant preview and does not require scanning of the photographs.<sup>25</sup> Reflected ultraviolet imaging techniques may be the future of recording of evidence<sup>26</sup> and may be used for bite marks, as well.

Casts of the volunteers, suspects and offenders have been made using standard techniques, and the casts have been compared using various methods with different types of overlays and varying success rates. Different techniques for preparing the transparent overlays are used to determine the usefulness of various methods.

The data available have been questioned because they have been obtained using animal skin or skin from a small number of volunteers.<sup>15,17,27,28</sup>

West et al. felt that bite marks on human skin can be experimentally created to a level that permits comparison to bites delivered in combative or life threatening situations, and more research is needed using living subjects to explore a variety of experimental situations.<sup>24</sup>

Although clay may not be observed to have bite marks in actual cases, the American Board of Forensic Odontology advises to use clay as the test bite media.<sup>29</sup>

With various advantages and disadvantages, bite marks appear to be useful evidence for the identification of the perpetrator.<sup>30</sup>

This study was planned to provide reliable data by studying a large number of cases and comparing the results obtained using skin to that obtained using clay.

## 2. Materials and methods

This was a progressive random experimental study performed on volunteers of different age groups involving both genders. This study was conducted at the Government Medical College,

Patiala, India; Punjabi University, Patiala, India and Gian Sagar Medical College, Punjab, India. After obtaining consent from the volunteers/guardians, the volunteers were asked to bite on clay and skin with a force sufficient enough to create an impression. These marks were photographed with a digital camera keeping American Board of Forensic Odontology (ABFO) scale No. 2 in the view field immediately after the production of bite marks. Later, these photographs were converted to life-sized images using the Gorea and Jasuja Method.<sup>31</sup> Dental casts of the volunteers were prepared after taking impressions with alginate powder and subsequently using dental stone powder. From these dental casts, hand-drawn transparencies were prepared along with photocopied and scanned transparencies. These transparencies were superimposed on life-sized photographs, compared and analysed. Casts were also directly matched to determine the usefulness of comparison by this method. These observations were interpreted using ABFO guidelines.<sup>29</sup>

## 3. Results

### 3.1. Skin

Table 1 shows statistics of different grades of identification by four different methods of comparison in maxillary bite mark impressions and mandibular bite mark impressions. We observed that in the majority of cases, reasonable medically convincing results were obtained. The number of cases in which bite marks did not contribute was notably small with all the methods.

For maxillary bite marks, photocopied transparent overlays were found to be most effective (100 cases) followed by hand-drawn transparent overlays (95 cases). Scanned overlays were found to be least effective (79 cases). Direct matching with cast was better (87 cases) than scanned overlays (Table 1).

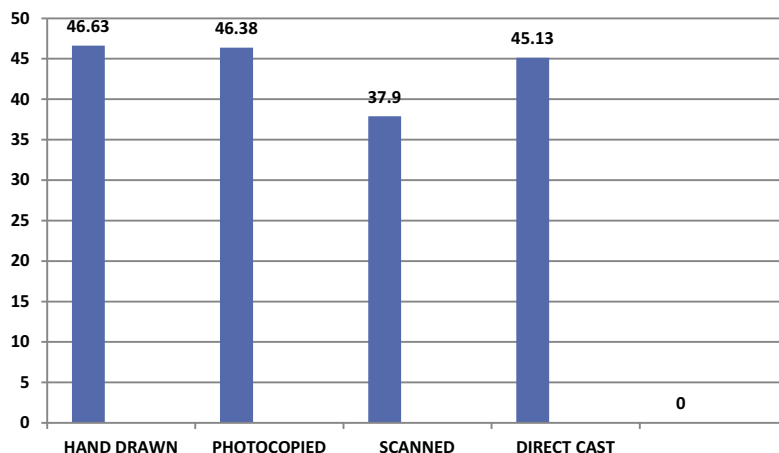
For mandibular bite marks, casts were found to be most effective (94 cases) followed by hand drawn overlays (92 cases) and photocopied overlays (86 cases). Scanned overlays were least effective (73 cases) (Table 1).

Table 1 depicts that in reasonable medically certain cases (except by direct cast matching), transparent overlays for maxillary bite marks were better than for mandibular bite marks.

The bar graph in Fig. 1 depicts that hand drawn and photocopied transparencies gave almost equal results (46.63% and 46.38%) for medically certain results and were closely followed by the direct cast method (45.13%). The least effective method according to this graph was scanned transparencies (37.9%).

**Table 1** Results of comparison of bite marks produced by maxillary and mandibular teeth on skin by different methods.

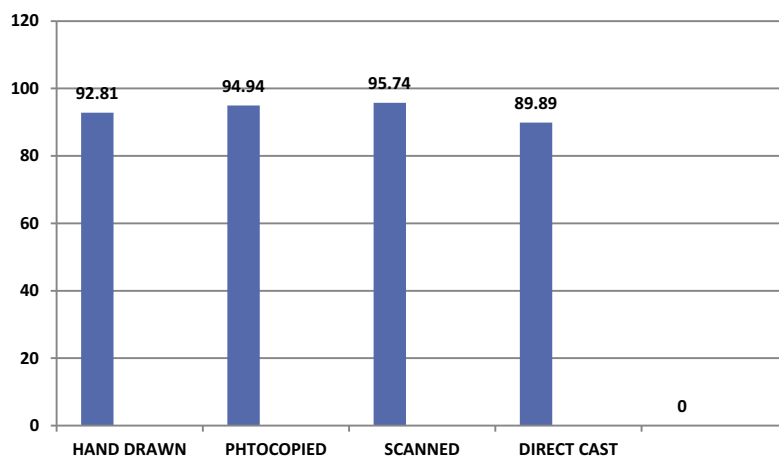
Grades	Hand drawn		Scan		Cast		Photocopy									
	Maxilla		Mandible		Maxilla		Mandible									
	No	%	No	%	No	%	No	%								
Certain	95	47.26	92	46.00	79	39.30	73	36.50	87	43.28	94	47.00	100	49.75	86	43.00
Probable	43	21.39	34	17.00	75	37.31	64	32.00	44	21.89	34	17.00	47	23.38	54	27.00
Possible	36	17.91	44	22.00	17	8.46	26	13.00	51	25.37	45	22.50	18	8.96	24	12.00
Insufficient	27	13.43	30	15.00	30	14.93	37	18.50	19	9.45	27	13.50	36	17.91	36	18.00
Total studied	201	100.00	200	100.00	201	100.00	200	100.00	201	100.00	200	100.00	201	100.00	200	100.00



**Figure 1** Bar diagram depicting results of comparison of bite marks on skin by different methods in %age of reasonable medical certain cases.

**Table 2** Results of comparison of bite marks produced by maxillary and mandibular teeth on clay by different methods.

Grades	Hand drawn				Scan				Cast				Photocopy			
	Maxilla		Mandible		Maxilla		Mandible		Maxilla		Mandible		Maxilla		Mandible	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Certain	173	92.02	176	93.62	180	95.74	180	95.74	171	90.96	167	88.83	180	95.74	177	94.15
Probable	12	6.38	5	2.66	3	1.60	1	0.53	9	4.79	7	3.72	3	1.60	2	1.06
Possible	2	1.06	2	1.06	2	1.06	2	1.06	6	3.19	7	3.72	3	1.60	4	2.13
Insufficient	1	0.53	5	2.66	3	1.60	5	2.66	2	1.06	6	3.19	2	1.06	5	2.66
Total studied	188	100.00	188	100.00	188	100.00	188	100.00	188	100.00	188	100.00	188	100.00	188	100.00



**Figure 2** Bar diagram depicting results of comparison of bite marks on clay by different methods in % age of reasonable medical certain cases.

3.2. Clay

For maxillary bite marks, on the clay photocopied (180 cases) and transparent overlays (180 cases) were found to be most effective followed by hand drawn transparent overlays (173 cases). Direct matching with casts was found to be least effective (171 cases).

For mandibular bite marks, scanned overlays were found to be most effective (180 cases) followed closely by photocopied

overlays (177 cases) and hand-drawn overlays (176 cases). Casts were least effective (167 cases) (see Table 2).

We found that in majority of cases reasonable medically certain results were obtained. The number of cases in which bite marks did not contribute was notably small for all the methods.

Comparison of maxillary bite marks was better than mandibular bite marks with direct cast matching and photocopied overlays, equal with scanned overlays and worse with hand-drawn transparency comparison.

**Table 3** Average percentage on skin and clay by different methods.

Method of comparison	Skin	Clay	Average
Hand-drawn	46.63	92.81	69.72
Photocopied	46.38	94.94	70.66
Scanned	37.9	95.74	66.82
Direct Cast	45.13	89.89	67.51
Average	44.01	93.345	68.67

In Fig. 2, the bar graph depicted that scanned overlays provided the best results for medically certain cases (95.74%) and was closely followed by photocopied overlays (94.94%). Hand-drawn transparencies were worse by approximately 2%. Although direct cast comparison (89.89%) was the least effective method, the difference was also slightly less than 3%.

The average success rate of successful comparison on skin with all the methods was 44.01%.

The average success rate of successful comparison on clay with all the methods was 93.34%.

#### 4. Discussion

Whittaker reported that matching of the bite marks on animal skin corresponded in only 76% of the cases.<sup>15</sup> In 44.01% of the cases, we could identify the volunteer based on these bite marks. The percentage of identification was quite low compared to the above-mentioned study, as it involved the individual's own skin and pain was a factor that prohibited the volunteers from causing good impressions.

Human tissue has been described as one of the least dependable substances for recording bite marks.<sup>32</sup> In a study by Gorea et al., skin of the volunteers was used, and it was observed that a match was possible in 60% of cases. The reason for the higher percentage of identification could be contributed to a different classification from that of the present study and a very small sample size (only 25 cases).

In 93.34 of cases we could link the bite mark on the surface of the clay to the volunteers. The usefulness of clay was demonstrated based on the fact that 100% of cases were identified accurately.<sup>12</sup> Again, the small number of cases could be the reason for the 100% identification rate. As photography has been used to lift the impressions of bite marks in a large number of cases, there can be some photographic distortion because photographs are susceptible to some degree of distortion.<sup>33</sup> (see Table 3).

#### 5. Conclusions

Comparative success rates vary depending on the substrate on which bite marks are present. The average rate of successful comparison on clay by all of the methods was 93.34%, whereas on, skin it was 44.01%.

The success rate also varied depending on the method of comparison. The differences between comparisons by various methods of overlays are not remarkable; therefore, any method can be used. Hand-drawn transparencies are less expensive and can be used as effectively as any other more technologically advanced method.

#### Funding

None.

#### Conflict of interest

None declared.

#### Informed consent

I give my consent for my ward for participation in the research project after knowing the details of my function in the research project "Bite Marks on various surfaces: Comparison and Analysis" and publication of the results in any academic journal for academic purposes.

#### Ethical approval

Necessary ethical approval was obtained from the institute ethics committee.

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