Review Article

From Anatomy to Analysis: Current Trends and Future Directions in Bite Mark Forensics

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Abstract

Bite marks play a crucial role in forensic science. This review talks about their anatomy, characteristics, and the history of development within the discipline. It covers methods used in the analysis of bite marks, highlighting advancements in imaging and comparative analysis. It further talks about current challenges faced by the forensic experts and the effects of new technologies. It focuses on future directions for bite mark forensic science, emphasizing the necessity of standardized processes and inter-professional collaboration to improve precision and reliability.

Key Words: Bite marks, Forensic Odontology, Anatomy, Dental Structure, and Imaging Techniques.

Introduction

Bite marks are impressions which human or animal teeth leave on any surface, mainly skin. Generally, they are associated with crimes related to violence, sexual assault or rape, or child abuse. As in cases of violence, the bites can help characterize the size, shape of the teeth, and how deep they imprint on any surface.[1] this may prove useful in identifying suspects or the victims.[2]

Bite marks can be used in age and sex identification, diet analysis, and dental modification detection. They usually appear on victims, suspects, and objects like food or tools, especially in sexual offenses and child abuse cases. Forensic odontologists use them to link the crime scene, suspect, and victim.[3]

The bites help in crime detection since the ante-mortem dental profile is compared with the post-mortem dental profile to try and identify victims in mass disasters. Fresh marks suggest a fresh offense, and their appearance can hint at the perpetrator's motive and psychological state.

History

The application of bite marks has been in existence for a long time, but it was standardized only during

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the 20th century. Forensic odontology got academic recognition in the middle 1900s and evolved from the generalized dental traits to a more precise and systematic identification method.

Preliminary Use of Bite marks:

1. Powai Rape Case (2015) - Mumbai, Maharashtra

Forensic odontologists assisted Mumbai police by analyzing bite marks found on a 28-year-old victim, which contributed significantly to securing a conviction.[4]

2. Surat Child Rape and Murder Case (2017) - Surat, Gujarat

n this tragic case of a seven-year-old girl, bite mark evidence played a key role in identifying and convicting the suspect. The bite patterns on the victim's body were matched with the suspect's dental impression.[5]

Evolution of Techniques and Methodologies:

Bite mark analysis began as an intuitive process, based upon comparisons of photographs to casts of the dentition. It was, however, in violent crimes like child abuse, sexual assault, and murder that it would one day prove important. For example, serial killer Ted Bundy was convicted in 1978 based on dental evidence of a bite left on the body of a victim named Lisa Levy.[6]

Challenges and Controversies in Early Use:

Bite marks help in crime detection by comparing the ante-mortem and post-mortem dental profiles, thereby helping in victim identification in mass disasters. Fresh marks indicate recent offenses and may reveal the motive and mental state of the perpetrator.[7, 8]

Anatomy and Characteristics of Bite marks

Understanding the dental characteristics of Bite marks, structure of teeth always helps in solving such cases and identifies the victim or suspect. Sometimes unique characteristics of the person's tooth differentiate him from other people and helps in solving crime.

Dental Structure:

There are four types-teeth are found in the mandible and maxilla. There are incisors, premolars, molars, and canines. People have two cycles of teeth: 20 primary or deciduous teeth and 32 permanent teeth.

A tooth is divided into two parts: the crown and the root. The crown is covered by enamel, which is the hardest substance in the body, while the dentin beneath forms most of the tooth's structure. The pulp is at the center, and the root is covered by cementum.[9-12]

The shape and size of teeth determine the origin of a bite mark and make it different from other types of injuries. Maxillary incisors produce rectangular marks, while central incisors are the widest. The individual variations in the size, shape, and wear of teeth can connect a bite mark to a specific person.[13-15]

Affecting Factors:

Bite mark interpretation is influenced by pressure, skin type, movement, and surface texture. Deep marks are made by high-pressure bites, while low-pressure ones fade quickly. Marks appear clearer on smooth surfaces. They change in color, texture, and size as they heal. Decomposition further alters marks.[16, 17]

Types of Bite marks:

Nonhuman bites are different from human bites [figure 1&2]. Animal bites are deeper than human bites. They can be differentiated by tooth morphology and their tooth alignment, shape, structure etc.

There are 7 different types of bite marks.[18]

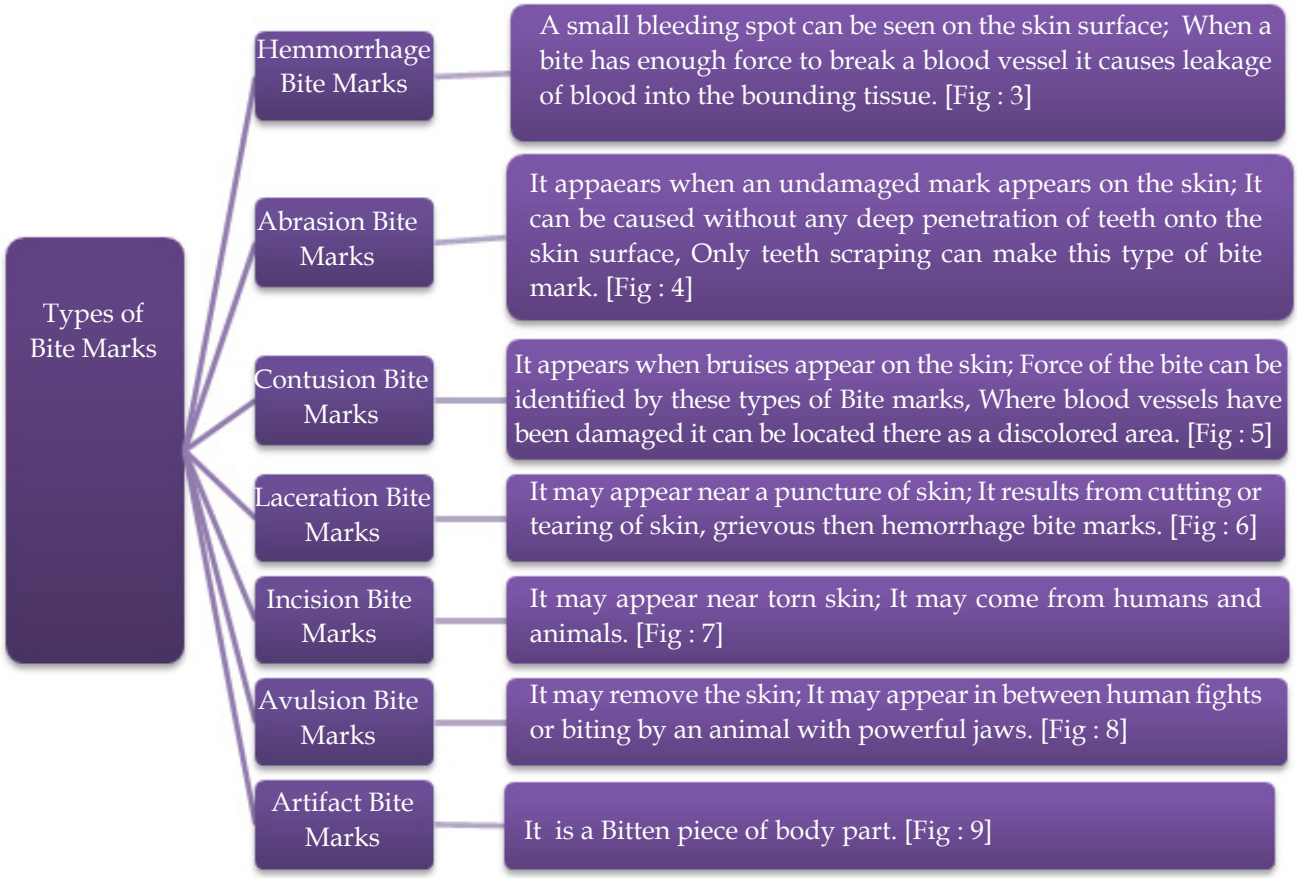

Fig 1: Types of Bite Marks

Fig 2, 3 Human & Animal Bite mark

Fig 4, 5 Hemorrhage & Abrasion bite mark

Fig: 6, 7 Contusion & Laceration bite mark

Fig: 8, 9 Incision & Avulsion bite mark

Fig: 10 Artifact bite mark

Methodologies in Bite marks

Bite marks are evidence that disappears with time, so its collection and preservation are the most important steps that forensic odontologists have to take. Both Collection and preservation must be done with care.

Collection and Preservation of Bite marks:

It is vital to include inoculation of a description of the bite mark, location, size, shape, color, kind of injury, and other details that may help gather dental evidence. Among those evidence that are derived from victim and suspect include history, photographs, tissue samples, imprints and saliva samples. Here some guidelines are accepted by the American Board of Forensic Odontology (ABFO).[19, 20]

PHOTOGRAPHY:

Orientation and close-up photos should be taken with and without the placement of a scale next to the Bite marks. Scale placement should be in the same plane as the Bite marks, showing both linear and circular references to help eliminate distortion, good film resolution, along with proper color balance, are needed

SALIVARY SWABBING:

When there is no variation in the bite site from the time the bite was inflicted salivary samples must be retrieved.

IMPRESSIONS:

Impressions of the bite site region should be taken when the surface detail is of an adequate amount to provide useful information. The material used should meet the American Dental Association requirements and sufficient must be provided to ensure that the body site contour is adequately supported and repeatable.[21, 22]

Comparison of Bite marks:

After collection and preservation of Bite marks it is necessary to compare it with suspect and victims Bite marks to give an opinion about the event that had happened. Comparison of Bite marks also helps in age estimation and sex determination of deceased.

AGE ESTIMATION FROM BITEMARKS:

Bite marks help in the estimation of a person's age by different appearance and characteristics.

The following are the possible assistance by Harvey on dental age estimation.[23, 24]

1. Dental bacteria appearance,
2. The earliest manifestation of mineralization,
3. The completeness of the interrupted tooth,
4. Development velocity of enamel and neonatal line,
5. Clinical outburst,
6. Length of the roots of teeth,
7. The extent to which the deciduous are resorted,
8. Attrition of the crown,
9. Formation of cementum.

SEX DETERMINATION FROM BITEMARKS:

Teeth are used to determine sex in addition to age. Forensic dentists examine teeth and cranium features, particularly in partial remains, to aid in gender determination. Traits such as tooth shape, crown size, root length, and skull patterns characterize male and female features. PCR amplification ensures accurate sex identification from remains.[25, 26]

3D TECHNIQUE:

3D scanners and computer-assisted analysis improve the accuracy in forensic odontology applicable both for skin and objects. It reduces exposure to pathogens, simplifies the handling of evidence, improves communication between members, and allows remote testimony from experts.[27]

Contact 3D scanner [Fig: 11] have the risk of damaging evidence and are not suitable for concave surfaces, so non-contact methods such as laser scanning are preferred. Although 3D laser scanners [Fig: 12] are accurate, they may distort sharp incise edges and therefore affect tooth morphology. Accuracy margins must be considered in forensic applications.[28]

In 2003, Thali et al introduced photogrammetric for the presentation of 3D skin bite marks. This technique creates a 3D replica from overlapping 2D

images and is cost-effective, using free software with low technological requirements. Its accuracy matches laser scanners and is widely used in recording 3D skin injuries in forensics.[29-31]

Bite marks can only be identified using identifiable dental features such as nicks or chips. Absence of these, especially in orthodontic patients or in skin bites, makes identification of criminals impossible. 3D scanners and computer methods show promise but have issues with small sample sizes and invalidated software.[32, 33]

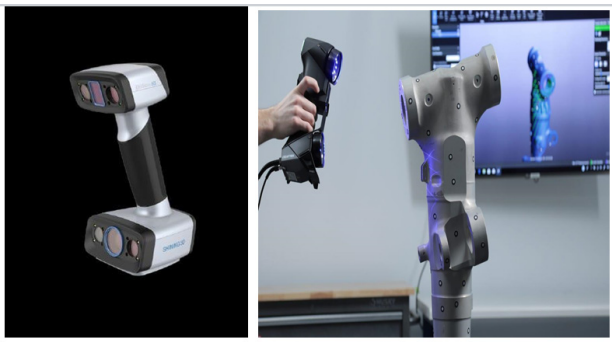

Fig 11: 3D Contact Scanner & Fig 12: 3D Laser Scanner

Current Trends and Future Directions

As we all know, Forensic is still developing in India. It will take some time to develop in many forensic fields, Forensic Odontology is also one such field. There is still a lot of research going on in this field, with time something new will come here in India.

Advances in Technology and Methodology:

Post-mortem dental examination is essential for the identification of a person, usually by matching dental radiographs with ante-mortem records. Digital technology has also revolutionized forensic odontology to enhance diagnostic visualization and treatment processes to the advantage of forensic dentistry and medicine.[34]

DENTAL IMAGING EXAMINATION:

Some research used digital imaging and/or data processing software for the evaluation of pulp area, size, tooth length, and root anatomical form in permanent and primary teeth. Research studies concluded that the outcome was informative for age estimation and individualization purposes.[35-38]

Researchers observed the appearance of the Dental Radiography images of teeth with a single root canal and teeth that were previously endodontic ally treated to conclude that it possessed very specific morphological traits. Images were recorded in a digital data bank system.[39]

However, the manuscript has highlighted that mental foramen position, ramous height and width, and mandible angle as established by Lateral Cephalography and Digital Panoramic Radiography formed the keystones for gender determination and age prediction of a given person.[40, 41]

Researchers determined that postmortem full-body Computed Tomography (CT) [Fig: 13] imaging could be a useful tool in individual dental identification processes after confirming the viability of dental identification using this type of imaging.[42]

The "Fusion Function of Imaging Analysis Software" enables the analysis of tooth root apexes in postmortem CT scans or dental radiographs across different imaging modalities. Forensic dentistry has advanced with the use of dental cone-beam CT, where algorithms assist in image processing and matching tooth morphology for improved dental radiograph analysis.[43]

Fig 13: Computed Tomography

AI in FORENSIC ODONTOLOGY:

AI-based models have advantages in identifying individuals from dental casts, radiographs, and records. The limitation of human error is obviated. A proof-of-concept study related to the identification of bite mark using artificial neural networks appears promising but requires further developments and training to enhance accuracy.[44]

Interdisciplinary Approaches in Forensic Odontology:

Forensic odontology is divided into three main categories: (1) identification of individuals in criminal cases or mass disasters, (2) examination of injuries to jaws, teeth, and oral tissues, and (3) evaluation of bite marks in cases of abuse, assault, or self-defense.[45]

Identification by dental means gains more importance because the dental tissues are often preserved even if the deceased person is skeletonized, decomposed, burnt, or dismembered. Dental tissues are often used to determine the age, sex, and ethnicity of a person.[46]

TEETH - A SOURCE OF DNA:

Teeth are resistant and their morphology is well preserved, with enamel protecting the pulp from external damage. The hydroxyapatite crystals in enamel help stabilize and bind DNA, making it possible to easily recover DNA from teeth. However, the crushing of teeth destroys the morphology, though DNA may still be recovered.[47]

IDENTIFICATION METHODS OF DENTURE:

Identification prostheses that don't deform by extreme temperatures are more efficient. Registration of Denton-prostheses with adequate markings including metallic bands, micro-engraving, barcodes or electronic microchip is encouraged.[48]

Legal Implications in Bite Marks

The question was the subject of several high-profile cases in recent years where a number of dental professionals on both sides presented valid arguments for or against the contention that the markings inoculated the defendant. These glaring discrepancies in interpretation have sometimes made some people doubt the validity and scientific objectivity of the bite marks.[49]

LEGAL STATUS OF BITE MARKS:

1. **ADMISSIBILITY**: Since judges and juries are not necessarily equipped with scientific knowledge, they need expert testimony to determine admissibility. The Frye test in 1923 sets down three requirements for admissibility: 1) the discovery must be verified by a principle, 2) it must follow well established methods, and 3) it must be accepted by experts in the relevant scientific field.[50]
2. **IMPARTIALITY**: Criminal defense attorneys question the objectivity of bite mark investigators, as most forensic dentists work for law enforcement, which could create bias towards prosecution, though not all show this bias.[50]

Conclusion

Bite marks are an important part of forensic science, and their contribution to the criminal case is unique. The technological advancements in analysis still face problems like subjectivity and variations in human dentition. To overcome such issues, future developments must focus on standardizing procedures, improving education for forensic professionals, and fostering multilateral cooperation. These measures would enhance the probative value and admissibility of bite mark evidence in court, thus improving criminal justice outcomes.

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