NFSU JOURNAL OF FORENSIC SCIENCE
ISSN: 3049-2408 (Online)
Journal Homepage: https://jfs.nfsu.ac.in/

From Yesterday to Tomorrow: Exploring Methods in Bite Mark Analysis

Sarang S. Damle[1*], Nikhil V. Rathod[1]
[1]Department of Forensic Science, Dr Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar, Maharashtra, India.
[sarangdamle99@gmail.com] (Corresponding Author)*

Abstract

Taking account from the National Crime Records Bureau there were 31,677 cases of sexual assault registered in the single year 2021, which implies roughly 80 cases daily. To address such serious crimes forensic professionals must be aware and focus on traditional pieces of evidence such as DNA, Seminal Stains, bitemarks or struggle marks, and other confirming shreds of evidence. Bite mark analysis is a vital component of forensic investigations, offering a distinct form of evidence in criminal proceedings. By leveraging the uniqueness of dental structures, bite marks can contribute significantly to personal identification and the resolution of crimes involving assault, sexual offenses, and homicide. We portrayed the collection, packaging, and preservation methods of bitemark, and included the DNA extraction from saliva. Structural distinctive features which are used to differentiate human dentition from animal dentition. Accidental and intentional crimes then easily distinguished. In the case of wildlife forensics also bitemarks have wide scope and importance for determination of species and tagging them with their habitat. Furthermore, newer delopement in Artificial Intelligence and machine learning have Modernizing the field by providing less human interfering methods for bite mark analysis. AI models, particularly deep learning neural networks (CNNs), now helps in accurately differentiating human and non-human bite marks, while 3D imaging and digital image processing and enhancement helps in precision of bite mark comparison. In recent times with rapid evolution in computational capabilities, we are able to use complex applications of computer science for the purpose of three-dimensional comparison of bitemarks, use of digital image processing and image modifications. the statement on which most of us will agree is Bite marks are always being interest of investigators in cases of sexual assault and child abuse.

Keywords: *Bite Marks, DNA, Teeth, Sexual Abuse*

1. Introduction

We aim towards personal identification from bite marks in forensics. Bite marks play an important role in offenses against person like crimes against women, sexual assault, child abuse, and kidnapping are majorly convicted on the supportive basis of odontology pieces of evidence. Bite marks may prove a cost and time-efficient type of evidence for analysis [1]. Bite marks are often seen in cases of domestic violence which draws the attention of law enforcement in large amounts. In such a scenario

encouragement must be provided to victims to report cases and seek help. The bite mark may be in the form of a horseshoe, a doughnut, or an individual teeth mark. It is not mandatory to have both upper and lower jaw marks. For documentation, photography is the best possible method. Tripod at an acute angle and proper lighting is an important aspect as far as we are concerned about top view photography. The second and most important step is to take a swab from the bite area for detection or collection of serologically important saliva evidence. If the person is a secretor, then we may also be able to detect the blood group [2]. Likewise, the Dactyloscopy, forensic odonatological impressions also individual to that person which makes the use of bite impressions or teeth shape of utmost importance for proving or disproving the presence of someone in a criminal attempt. The bite marks produced by the teeth pattern of animal is very different that of those created by humans. Dog bites humans 8 times if we compare with biting of human to human. In cases where fingerprints and DNA pieces of evidence are not found then the court may consider bitemarks as strong evidence. Everyone's dental pattern differs in the case of the shape of bridges, crowns, and dentures. Such individual shapes led to the production of distinctive patterns. Bitemarks are generally difficult to locate and most of the cases in which such pieces of evidence are overlooked. Children are mostly victims of dog bite cases [3]. In the medical room animal bites are a routine issue. The bites produced by domestic mammals and wild mammals, reptiles, and even poisonous fishes need to be addressed differently, specific guidance and sops must be developed to minimize such emergencies. Animal bites are the main source of production of perforations, and bacterial and fungal infections in the human body. The main task faced by the medical team is to minimize the spread and risk of rabies. Domestic and roaming dogs are those who are greater in cases of bite to humans. The flat teeth of animals are mainly used to penetrate the skin of humans and make openings for bacterial growth whereas, domestic cats have more pointed teeth which creates more puncture-like injuries, and bacteria coupled with the saliva of cats creates bacterial growth in wounds. In the case of wild animal's monkeys are common in urban areas near green neighbours. Some less amount also with the bites produced by jaguars and bats, snakes, sharks, and piranhas. On the other side, human oral flora is complex in nature and consists of various types of germs capable of producing of number of infections. Lacerated wounds are mainly associated with bite marks when bites are too deep and force [4].

Self-produced Bitemarks are usually seen on the shoulders and arms of victims or suspects. Bite marks are always seen in cases of violent crimes such as homicide, sexual assault, child abuse, domestic violence and any type of offense in which two bodies come in contact with each other and one body struggles with another. In the year 1692, bite marks were used for the conviction of crime. Reverend George Burroughs was accused of performing supernatural abilities or rituals in Salem Massachusetts. Bite marks from a woman's wrist were identified as his, hence on this direct linking evidence, the case was convicted which led to a good development in forensic odontology. In the era of 1970s, dental use for forensic purposes started to grow in the United States of America with the foundation of American organizations in forensic dentistry. With the help of modern technologies, today's science can develop bite-mark impressions with the help of computer-aided drafting coupled with artificial intelligence and machine learning [5]. Forensic odontology is the application of dental expertise for the administration of criminal justice and helps society to meet the criminal justice. Forensic odontology mainly focuses on the identification of unknown remains by teeth, jaw cranial facial bones analysis, Oro facial trauma associated with personal abuse, dental jurisprudence, and research of new related technologies in dentition. In the era of 1950s, the first case in the United States was solved using bitemarks related to burglary based on bitemarks it's partly eaten cheese found at the scene of the crime [6]. We can say that the dentition pattern of every person is unique even in the case of monozygotic twins. The imprint produced on the skin shows the property of individuality or uniqueness. Hence, we may define bitemark as dental fingerprints. By thorough analysis and comparison, the investigator can identify the perpetrators from the comparative analysis of specimen and standard dental patterns which we recover from the scene of the crime and also from standards collected from the suspect employing dental stone. Bitemarks are not like mechanical tool marks or any type of contact marks involved in only cases where struggle has been taking place. The location of the skin also plays an important role in case of the development of bite

marks. The development of bitemarks also depends on age, gender, systemic health of the victim the force applied by the perpetrator, and most commonly the part on which bitemarks are produced [7]. One prominent case that gave us the limitations of bite mark evidence is the wrongful conviction of Ray Krone, who was sentenced to death based primarily on bite mark analysis. After years DNA evidence Proves Innocence of Krone, exposing the lapses in the initial forensic conclusions. This case, among others, has prompted calls for the forensic science community to standardize bite mark analysis methodologies and validate them through empirical studies for reliable usage. In light of these controversies, many forensic experts now adhering for the integration of A.I and ML technologies, such as 3D imaging and AI-driven analysis, to reduce the subjectivity comes with traditional bite mark comparison methods. These advancements offer the potential to create more objective, quantifiable results, thereby improving the reliability and Scientific Rigor of bite mark evidence.

2. Human Dentition:

The adult human dentition consists of 32 teeth arranged in two arches one is an upper or maxillary jaw and another is a lower or mandibular jaw. Both Archives are symmetrical in nature. Each quadrant consists of the following types of teeth two incisors, 1 cuspid, 2 premolar, and 3 molar teeth. The Cuspid is also known as the “Eye tooth”, it is located at the corner of the arch and has a pointed cusp. Each premolar has typically 2 cusps whereas the molar has three to five cusps and a wide biting surface to chew and crush food. The third molar is called a wisdom tooth and it is the last tooth in one arch. The tooth consists of a crown and root, the crown is the upper portion above the gum which is visible to the naked eye whereas the root is present inside the gum. Incisors and cuspids have single roots whereas the molar and premolar consist of two to three roots. The outer covering portion of the crown is made of enamel, the hardest tissue in the human body. The dentin is present below the enamel. Dentin is considered a live part of human dentition which is capable of transmission of pain. The tissue that is present in the gum and holds the roots of teeth is no other than the periodontal ligament [10, 11].

2.1 Animal Dentition

Animals usually have a dental formula of 2:1:3:3 or 2:1:4:3. Dentition pattern in animals’ changes based on their eating habits and the nature of the food on which they are fed. The common dentition patterns are as follows,

1. **Heterodont Dentition:** the dental pattern in which different types of tooths are present within the same arrangement. Ex. Canine, molar, premolar, incisors etc.
2. **Homodont Dentition:** usually found in animals because the teeth have the same shape and function. Ex. Snake, fishes.
3. **Diphyodont Dentition:** the types of teeth that develop during the later development of an individual. Ex. Permanent teeth.
4. **Polyphyodont Dentition:** the teeth or their set continuously being replaced by another type of teeth. Ex. Sharks teeth.

2.2 Types of dentitions present in animals:

Animals exhibit distinct dental patterns based on their dietary habits. Carnivorous animals, exemplified by wild cats like tigers and leopards, as well as wolves and wild dogs, are equipped with sharp and pointed teeth designed for tearing carcasses. On the other hand, herbivores, including goats, elephants, cows, and oxen, display a dental configuration featuring flat and broad teeth, crucial for the efficient chewing and grinding of green vegetation. Insectivorous animals, encompassing reptiles and arthropods, possess sharp, sometimes venomous teeth that serve to capture and immobilize prey. This dental

characteristic holds particular significance in forensic odontology, forensic toxicology, and forensic biology. Another category, rodents, is identified by their continuously growing incisors, specifically adapted for cutting down materials like skin, cloth, or plastic articles. Each dental adaptation reflects the unique dietary and functional needs of these animal groups.

3. Characteristics of Bitemarks

3.1 Bitemarks Caused by Humans:

Types of bitemarks usually seen in the case of humans:

Suction marks in bite patterns suggest tongue thrusting, often accompanied by scratch marks. Drag marks cause abrasion with deep penetration, forming a Sunburst pattern. Avulsive bites are violent, tearing tissue, common in heinous crimes. One arch bite exhibits a singular pattern, necessitating superimposition for reconstruction. The absence of tooth marks occurs with flat teeth, lacking distinct impressions, due to surface dullness over time [12].

3.2 Bitemarks Caused by Animals:

Description of typical setting:

Different species or genera produce different types of marks such as carnivores, herbivores, and reptile creatures.As far as we are concerned about forensics the bite cases we handle are snake biting or accidental biting during poaching or hunting.We are also able to classify the bite marks of reptiles as poisonous or non-poisonous. Which is most important to determine the cause of death. In wildlife forensics, we generally encounter bite marks by wild animals commonly by wild or large cat families [13].

3.3 Types of bite marks caused by animals:

Puncture marks, often observed in carnivorous animals like lions, tigers, wild dogs, and foxes, are characterized by deep impressions. Incisor wounds result from the brutal application of force by sharp, pointed teeth, typically found in carnivores. Snake bites, a prevalent form of animal bite, involve two sharp puncture-like holes injecting poison into the victim's circulatory system, often leading to fatal consequences [14].

3.4 Diseases caused due to bite marks:

Scenario 1. Biting human-to-human

In such cases, the particularity of skin is broken and blood or bodily fluids are exchanged mainly following diseases that are easy to be transmitted.

Scenario 2. Bites by animals to humans:

Commonly we can classify the diseases based on the nature of the biter for easy understanding of associated infections.

Domestic Animals: the bites caused by domestic animals like dogs, and cats can pose a potential threat to humans by inserting pathogens through a mode of bite mark injury. Following are examples of common diseases associated with the biting of domestic animals.

3.5 Forensic Significance of Snake Bites and their Analysis:

As forensic investigators, we must answer some basic questions that arise on the scene of crime during crime scene investigation such as,

i. Is it Snake Bite Marks?
ii. If yes then from which snake it usually resembles?
iii. That snake is poisonous or not?

To answer such questions following points will help us during the course of the investigation.

The investigator must not fumble between incisor marks and bite marks. Differentiated bite marks prove important to understand the cause of death and manner of death. When we confirm the presence of snake bite markings, we must focus on the species identification of that snake. This will tell us about what venomous or non-venomous species will be and provide appropriate medication accordingly. In cases like snake bite investigation forensic experts take two skin samples one from a contaminated area and one from a plain non-infected area for comparative study. The venom components characterization also takes place. The pathological analysis is carried out to detect the agglutination or coagulation reaction of venom and its further characterization. The actual timing of biting may be used as a timeline analysis from a forensic point of view [16, 17].

4. Forensic Significance of DNA extraction from Bite Marks I.e., Saliva sample

Before we proceed with the collection of salivary secretions from bite marks, we must first perform forensic photography along with dimensional measurements. The swabbing technique is generally considered a routine practice as far as we are concerned about dried saliva stains. The sterile cotton swab is moistened using common distilled or saline water and gently rubbed on the surface of the bite marks. The bitemarks are considered fragile or volatile evidence from a salivary fluid collection point of view.

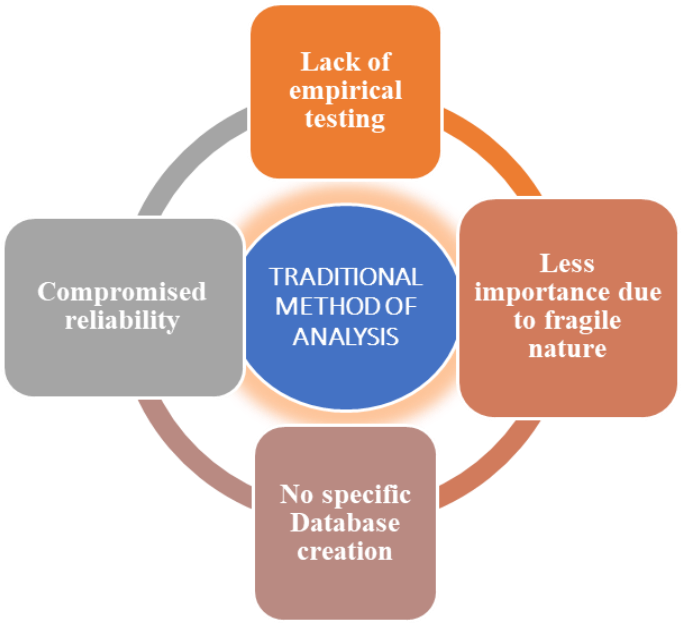

Figure 1. Limitations of Traditional Bite Mark Analysis Methods.

We as forensic professionals generally try to collect the saliva sample as soon as possible to avoid tampering or misconduct.

1. Bite marks may prove a leading clue in terms of investigation because it will provide the most reliable biological evidence which is the deoxyribonucleic acid.
2. DNA further proves helpful in narrowing down the list of suspects to individual perpetrators because of its uniqueness.
3. Such DNA analysis from bite marks gives conclusive proof and stands firmly in a court of law as a piece of corroborative evidence that has strong evidentiary value.
4. Such type of analysis may even be used to solve cold criminal cases and bring the victim to justice.
5. Research and development in the field of forensic odontology is crucial which is being constantly guiding the investigators to work efficiently and providing a direct non-changeable link.
6. Such DNA evidence may be used for reconstruction of the scene of crime in case of gruesome crime [18].

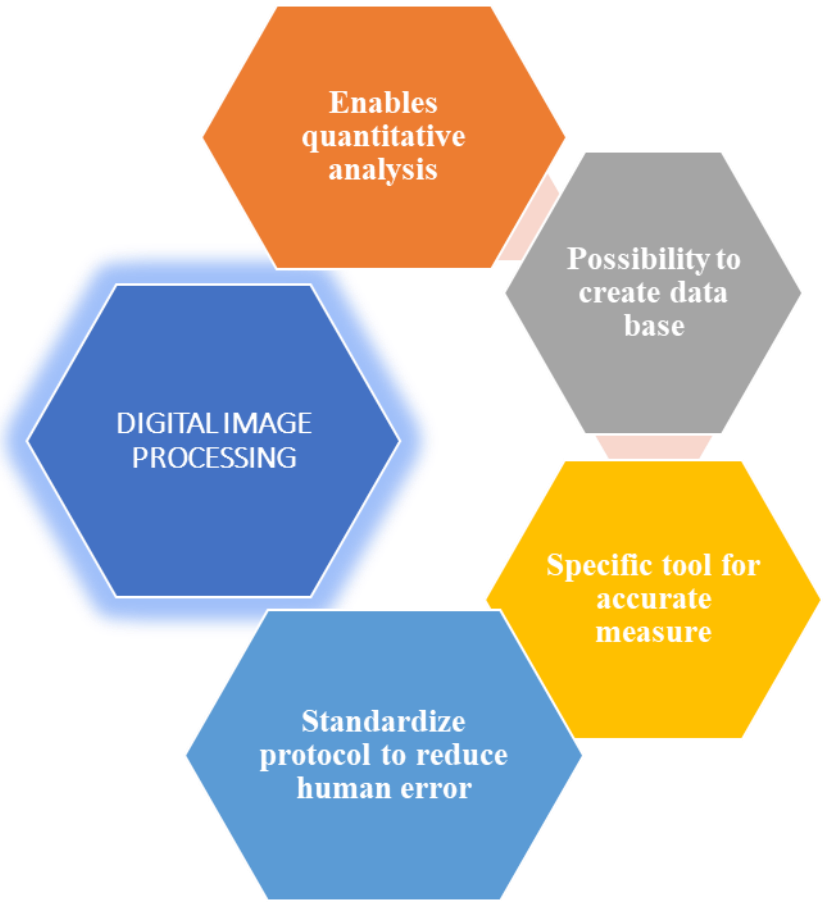

Figure 2. Advantages of Digital Image Processing in Bite Mark Analysis.

Latest research in DNA extraction techniques have tremendously improved the sensitivity and selectively of DNA recovery from saliva and saliva prone evidences. Updated methods, such as polymerase chain reaction (PCR) protocols and next-generation sequencing (NGS), allows multiplication of even trace amounts of DNA, including degraded samples usually found in older or compromised sheds of evidence . Chávez-Briones et al. (2015) demonstrated that newer swabbing method, combined with

automated DNA extraction kits, can provide higher quality DNA from saliva traces on skin or other surfaces, even after sustained exposure to contaminated conditions.

While routine practice for the collection and preservation of bite-marks, such as photography and casting, have been important in forensic odontology, newer computerized advancements have meaningfully improved the validity and reliability of bite mark analysis. Most useful and notable development is the use of 3D technology. This allows for precise, non-destructive documentation of bite marks, capturing each and every minute details which may be overlooked using routine methods. It also enables the creation of dental database that can be used to keep as record for habitual offenders. This technology not only improves the preservation of evidence but also allows for better analysis, as forensic experts can view the bite mark from multiple angles, conduct digital superimpositions, and apply different A.I based algorithms for comparison.

5. Bite marks Analysis and Comparison

The focused comparative study of jaw and bitemarks of household and wild animals for criminal investigation. The species study was made at the Mammalian Collection Field Museum of Natural History in Chicago, Illinois. A new technique was developed to measure interchained distance. The notable cases of death from human attack brought the attraction of researchers toward this field of study. For the study, the skulls were collected from the Field Museum of Natural History in Chicago, Illinois. Overall, 486 skull samples were analysed. Carnivore animals may possess fatal injuries due to deep tissue damage that occurs due to applied high amount of force [19]. In case of bite marks and injuries caused due to bitemarks, we mainly rely on DNA evidence along with the unique dental pattern. During the era of 1960-1970, the United States of America and the United Kingdom started the study of bitemarks for forensics purposes [20]. Forensically speaking the first notable collection of saliva is noted in the year 1999. Also, DNA profiling proved to be a revolutionary study and modern method in forensic biology [21]. Many authors, the investigator Mr. Sorup used bite marks for the first analysis with that of recovered from the crime scene [22]. Bitemarks are also crucial to differentiating between post-mortem injuries or post post-mortem bids or anti-mortem bites. Bitemark analysis and its collection are subject to awareness because increasing cases of crime against women are generally associated with such type of evidence. Like other centralized databases, we must develop a system for an oral pattern of rental patterns to Criminal individualization [23]. The uniqueness or individuality of bite marks creates an imperishable impression in front of the judge while dealing with any criminal case. White Marsh is often used to distinguish different types of criminal attempts. The first recorded bite mark case in the United States of America was in the state of Ohio vs Robinson in 1870. The Ted Bundy case was also convicted by taking accounts from forensic odontology.

6. Empirical Data Supporting the bite-mark as evidence

Newer studies have supported the scientific reliability of bite mark analysis in medico legal cases. For better understanding, Murmann et al. (2006) conducted a side by side analysis of dental patterns between humans and animals, providing that bite mark identification could be accurate in up to 70% of the cases when using controlled methodologies. Moreover, Daniel and Pazhani (2015) analysed the Accuracy bite marks recovered from food substrate and found an 85% identification success rate. These empirical studies Demonstrate substantiate the reliability of bite mark analysis in forensic investigations.

Legal aspects of Bitemarks:

In today's modern era, different types of techniques and tools have been developed for CSI such as ultraviolet lighting [24]. In today's technological era different types of computer-based systems which we

call software developed to identify and analyse dental patterns, with the progressive growth of forensic image processing and with the help of software like Adobe Photoshop we can identify or analyse dental patterns of deceased people. In case of mass disaster, we generally use disaster and victim identification that is DAVID, and automated dental identification system i.e., ADIS [25].

Table 1. Human vs Reptile dentition arrangement [8].

Dentition characters	Humans	Snakes
Incisors (I)	8	Absent
Canines (C)	4	Modified as fangs
Maxillary Teeth (M)	12	Special elongated fangs
Total Teeth	32	Differ species by species

Bite mark shreds of evidence in forensic investigation are mainly associated with violent crime. Which is generally accepted throughout the globe and presented as evidence in court. Such hard evidence may highly influence the jury to understand the nature of the crime [26].

Table 2. Human vs Wild Animal dentition arrangement [9].

Dentition characters	Humans	Tiger and Cat family	Dog Family
Incisors (I)	8	6 Upper, 6 Lower	6 Upper, 6 Lower
Canines (C)	4	2 Upper, 2 Lower	2 Upper, 4 Lower
Premolar	8	4 upper,4 lower	4 Upper, 4 Lower
Molar	12	6 Upper, 4 Lower	6 Upper, 4 Lower
Total Teeth	32	30-32	30

Table 3. Cases associated with Bitemarks [15].

Case Type	Human Bite Mark	Animal Bite Mark
Assault and abuse cases	The bite marks of humans are evident proof of assault or attempt to dominate the victim.	Sometimes found in cases involving the modus Operandi of serial killers mainly hedonistic criminals.
Forensic individualization	We can easily identify the possible suspect if the collection and preservation are up to the mark.	Mainly used to award the bite mark to individual species.
Odonatological specifications	Comparison based on the sample collected from a suspect on dental stone.	In many scenarios, the comparison or recording does not take place because of not so much prominence.

Homicidal cases	Compared to suicidal cases the occurrence of bite marks is more in cases of homicide.	Less are cases in which animals are used as weapons against humans.
Children related offenses	The cases that are associated with child abuse or sexual torture may involve human bite markings.	Not so important but it is possible in very rare type of cases where animals are used as weapons by insane criminals or serial killers.
Sexual harassments	The bite marks are evident proof of being assaulted by someone else.	Rarely involved in sexual harassment.

7. Bite marks and Digital Image Processing

Bitemarks were easily obtained on more smooth or pliable surface then comparatively solid surface, for purpose of recording using computerized edge detection and manual method also the pliable surfaces were preferred [27]. Dental patterns were also used for purpose of sexual dimorphism, different parameters were taken under consideration while analysing this using computer aided tech. the statistical method employed to resolve the inter-canine distance the angle, angle between central and lateral incisor to determine the gender. From such study it was determined that the mean of this values found in male is higher than that of female [28]. Different methods were used for purpose of comparison of bite marks to determine their origin, superimposition is one of those practices, it can also be done using the cost effective and day to day use software such as adobe photoshop and the results are fairly accurate [29]. Other than the criminal identification, bitemarks were helpful in determination of snake species from bite pattern observed on victims body, the CNN (Convolution Neural Network) model from deep learning is helpful for determination of particular snake specie and categorize them venomous or non-venomous one [30]. Such study or application of technology is really helpful in country like India where **around 58,000 lives are lost in each year since 2000.** The Three-dimensional printing is also useful for differentiating the human and non-human teeth also employed to understand the morphological alterations performed by person to alter his/her identity or to assess odonatological health issues [31].

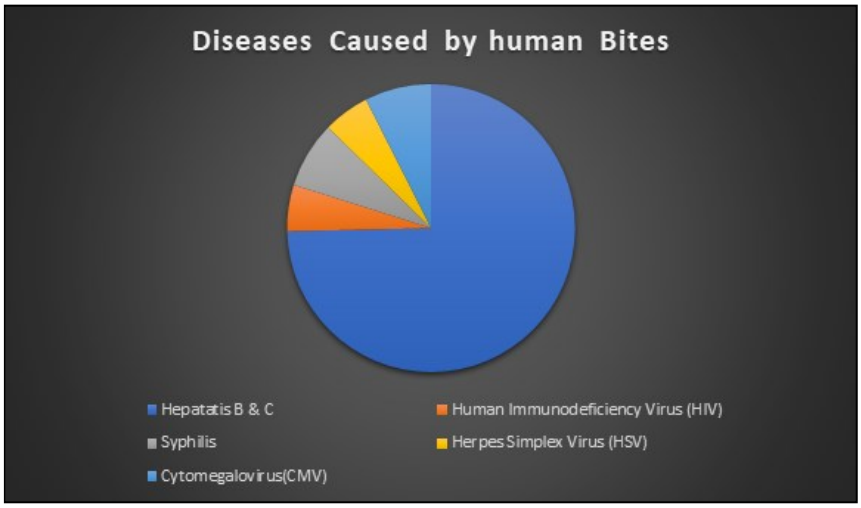

Figure 3. Pie-chart 1 - Diseases caused by human bites [32-36].

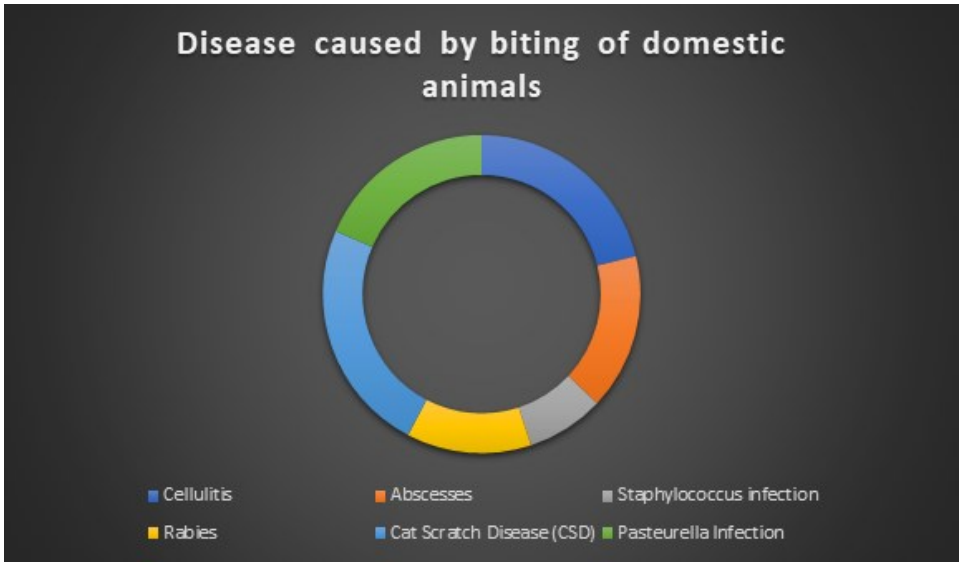

Figure 4. Pie-chart 2 - Diseases caused by domestic animal biting [37-41].

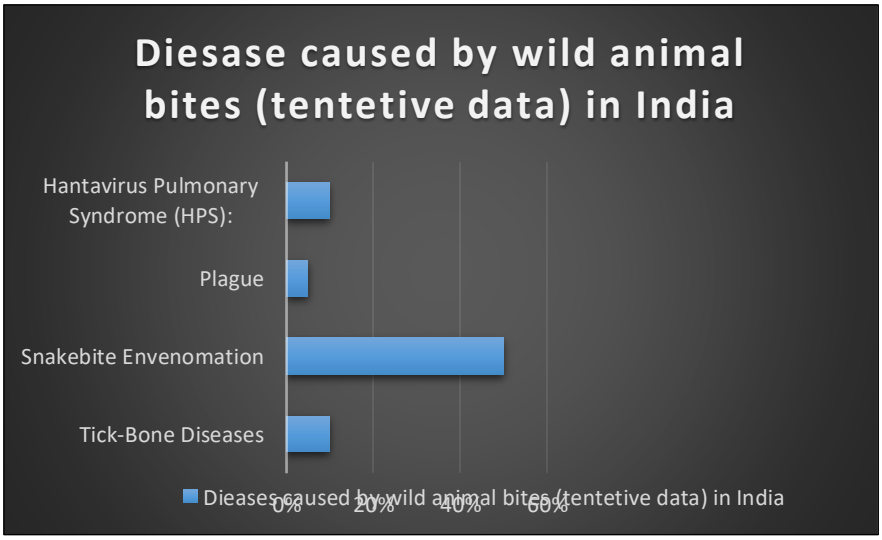

Figure 5. Bar-graph 1 - Diseases caused by wild animal bite marks

8. Notable Cases where bite-mark analysis is used

First case involves the medico legal analysis of bite impressions found on a victim during a hunting investigation in a wildlife reserve. The bite marks were firstly believed to be from a human, possibly related to an assault, but forensic scientists were able to show through minute comparison that the marks matched the dentition of a large non-vegetarian animal , specifically a Cat family animal. This outcomes

not only guided the investigation away from a criminal act but also helped wildlife personnel to track down the animal responsible [42, 43].

Forensic findings, differentiating between human and animal bite marks can be vital in concluding the cause of death and manner of injury. One such notable case involved a child found with bite marks in a domestic violence investigation. Primarily, the marks were suspected to be from human intervention, but further medicolegal analysis revealed that the injuries were prominently with canine bite patterns. This features, made possible through a side by side analysis of dental patterns and bite properties, shifted the investigation toward an accidental injury caused by the family pet animal, releasing the key suspect.

9. Controversies and Admissibility of Bite Mark Analysis in Court

Bite mark analysis has been an important aspect of forensic odontology for years, but its admissibility in court has harsh history of significant discussions. Scientists and lawyers argue that the methodology lacks scientific rigor, leading to controversial convictions in several crucial cases. One case in which State government of Florida state v. Ted Bundy, where bite mark evidence played a pivotal role in Bundy's conviction for killing. Although the forensic odonatologists Celebrates this case as a success for bite mark analysis, others point out that the subjectivity and less reliability of such evidence and nature of the analysis makes it prone to misleading. In todays modern era, the validity of bite mark evidence has been tremendously questioned. Bowers (2018) conducted a comprehensive review of bite mark cases, noting down several cases where bite mark evidence contributed to misleading convictions. This review highlighted the field's lack of standardized methods for analysing and statistically Comparing bite marks, particularly in cases where skin tonicity and the nature of bites complicate identification.

10. Discussion

By reviewing the articles, we concluded that the bite marks are always in focus for forensic and criminal investigation aspects, since the 18th century the use of forensic dentistry began to develop in western and developed nations which gives rise to its admissibility in court of law. The distinguishing shape and dimensions of human dentition present in different races will provide distinctive analysis and individualizing capabilities for bite marks. The formation of teeth and eating habits are seen largely impacted by the creation of bite markings, hence it is easier to differentiate between animal bite marks, reptile bite marks, and human bite marks. In the case of wildlife forensics, we generally encounter big cat family members, wild dogs, and marine creatures as well as reptile creatures such as cobras, snakes, and insects that resemble snakes. The diseases caused by them also have a comparatively more serious impact on human well-being. Human bite marks are kind of different settings that of animal ones. The cases involving body offenses are the main sources of such type of evidence dynamics. In cases of a sexual offense, it is very important to rapidly attend to such evidence by standard operating procedures. In crime scene reconstruction bite marks may lead the case by establishing the connection between offender and victim, in modern technology er computer-aided drafting software is used for the recreation of such type of impression or struggle evidenced by accurate measurements and excellent photographic documentation. In the modern era, forensic professionals should focus on such types of evidence and analysis and better collection and analysis techniques. The recently advanced field in forensic biology and serology, DNA fingerprinting which also helps to narrow down the list of suspects by individualizing them also plays a significant role in bite marks and its collection. The freshly obtained marks should be photographed and immediately swabbed either with saline water or distilled water. The determining factor between bite marks and their analysis is the differentiating and individualizing them based on the pattern observed on the surface, which provides valuable insights such as the gender or dental pattern of the offender, the age of the offender, and force applied by them which signifies the intensity of that activity and struggle of the victim. In the case of animals also we can identify them based on their dental

arrangement's teeth shapes, and dimensions. The snake bite reason behind accidental and sometimes intentional deaths also has a significant role in insurance fraud investigations and related forensics workings.

11. Conclusion

In forensic science we don't rely on only one piece of evidence, to prove the link between criminal and crime & and to eliminate an alibi, we always look for pieces of evidence as possible as we find at the scene of the crime. It is always believed that rationalized thinking and analysing the physical shreds of evidence, in the court of law nowadays direct and physical evidence take a more reliable stand than observer testimony. Bite marks are the type of evidence that proves to be lethal in case of establishing the link between the crime, offender, and crime scene. Gruesome cases like sexual harassment, child abuse, and domestic outbreaks of viciousness are prime scenarios in which we deal with such type of evidence that directly proves the presence of the offender and involvement in criminal activity. Hence as a corroboration to the main evidence, the bite marks play an imperative role in a court of law. Looking ahead, developments in similar technology similar as artificial intelligence(AI), machine literacy, and 3D imaging are heading to modify bite mark analysis further. AI tech, particularly deep literacy model and neural network produce the eventuality to motorized bite mark side by side analysis, reducing issue of subjectivity abetting the reduced mortal logical miscalculations.

12. Acknowledgment

My first and foremost sense of gratitude to my guide Mr. Nikhil V. Rathod Assistant Professor, Department of Forensic Science Dr Babasaheb Ambedkar Marathwada University, Chh. Sambhajinagar. I heartily thank to Mr. Swaroop Sonone, Assistant Professor, Department of Forensic Science, JSPM, Pune for providing me the, support, help and suggestions.

References

[1] M. A. Khan, M. Verma, A. K. Verma, and A. K. Pathak, "Analysis and identification of bite marks in forensic odontology.

[2] N. D. Sperber and H. Lubin, "Bite mark evidence in crimes against persons," *Journal of American College Health Association*, vol. 29, no. 4, pp. 165–167, 1981, doi: 10.1080/01644300.1981.10392996.

[3] R. Lessig, M. Weber, and V. Wenzel, "Bite mark analysis in forensic routine case work."

[4] V. Haddad Junior, "Lesions caused by human and domestic and wild animal bites," *Revista da Sociedade Brasileira de Medicina Tropical*, vol. 55, p. e0372-2022, 2022.

[5] W. K. Gregory, *Origin and evolution of the human dentition*, vol. 2, no. 1. Рипол Классик, 1920.

[6] C. M. Bowers, "Review of a forensic pseudoscience: Identification of criminals from bitemark patterns," *Journal of Forensic and Legal Medicine*. [Online]. Available: https://doi.org/10.1016/j.jflm.2018.11.001.

[7] S. Kaur, K. Krishan, P. M. Chatterjee, and T. Kanchan, "Analysis and identification of bite marks in forensic casework," *Oral Health Dent Manag*, vol. 12, no. 3, pp. 127–131, 2013.

[8] E. P. Westeen, A. M. Durso, M. C. Grundler, et al., "What makes a fang? Phylogenetic and ecological controls on tooth evolution in rear-fanged snakes," *BMC Evolutionary Biology*, vol. 20, p. 80, 2020, doi: 10.1186/s12862-020-01645-0.

[9] J. Abraham, A. Pandey, and P. V. Parikh, "A comparative study on human and domestic animal bitemark patterns: An aid in forensic investigation," *Indian J. Vet. Res.*, vol. 27, no. 2, pp. 1–6, 2018.

[10] J. T. Wright, "Normal formation and developmental defects of the human dentition," *Pediatric Clinics of North America*, vol. 47, no. 5, pp. 975–1000, 2000, doi: 10.1016/s0031-3955(05)70254-6.

[11] R. Haji, *Venomous snakes and snake bite*. Zoocheck Canada Inc., 2000, pp. 1–14.

[12] S. Kaur, K. Krishan, P. M. Chatterjee, and T. Kanchan, "Analysis and identification of bite marks in forensic casework," *Oral Health Dent Manag*, vol. 12, no. 3, pp. 127–131, 2013. [Online]. Available: https://doi.org/10.1016/s0011-8532(22)01767-0.

[13] D. C. Murmann, P. C. Brumit, B. A. Schrader, and D. R. Senn, "A comparison of animal jaws and bite mark patterns," *Journal of Forensic Sciences*, vol. 51, no. 4, pp. 846–860, 2006.

[14] G. M. Fonseca, E. Mora, J. Lucena, and M. Cantin, "Forensic studies of dog attacks on humans: A focus on bite mark analysis," *Research and Reports in Forensic Medical Science*, pp. 39–51, 2015.

[15] I. A. Pretty, "Forensic dentistry: 2. Bitemarks and bite injuries," *Dental Update*, vol. 35, no. 1, pp. 48–61, 2008.

[16] K. Rothe, M. Stokes, and W. Handrick, "Animal and human bite wounds," *Deutsches Ärzteblatt International*, vol. 112, no. 25, p. 433, 2015.

[17] M. Jha, A. K. Jaiswal, T. Millo, and M. Gupta, "Snake bite poisoning: A forensic review," *The Indian Police Journal*, vol. 38, 2009.

[18] M. L. Chávez-Briones, R. Hernández-Cortés, G. Jaramillo-Rangel, and M. Ortega-Martínez, "Relevance of sampling and DNA extraction techniques for the analysis of salivary evidence from bite marks: A case report," *Genet Mol Res*, vol. 14, no. 3, pp. 10165–10171, 2015.

[19] D. C. Murmann, P. C. Brumit, B. A. Schrader, and D. R. Senn, "A comparison of animal jaws and bite mark patterns," *Journal of Forensic Sciences*, vol. 51, no. 4, pp. 846–860, 2006.

[20] J. Furness, "A new method for the identification of teeth marks in cases of assaults and homicide," *British Dental Journal*, vol. 1214, p. 261, 1968.

[21] D. Suite and G. G. Shutler, "Analysis of salivary DNA evidence from a bite mark on a body submerged in water," *Journal of Forensic Sciences*, vol. 44, no. 5, pp. 1069–1072, 1999.

[22] F. Strom, "Investigations of bite marks," *Journal of Dental Research*, vol. 42, p. 312, 1963.

[23] R. Nagarajappa, M. Mehta, N. Shukla, J. S. Tuteja, and A. Bhalla, "Awareness of forensic odontology among dental practitioners in Kanpur city, India: A KAP study."

[24] M. K. Sunil, U. Malik, S. Malhotra, A. Gulzar, and R. Sharma, "Bite marks: An indispensable tool for forensic odontological evidence."

[25] P. Anuja and N. Doggalli, "Software in forensic odontology," *JSS Dental College and Hospital, JSS AHER*, Mysore, Karnataka, India.

[26] M. N. Aksu, "The past and present legal weight of bite marks as evidence."

[27] M. J. Daniel and A. Pazhani, "Accuracy of bite mark analysis from food substances: A comparative study," *Journal of Forensic Dental Sciences*, vol. 7, no. 3, pp. 222–226, 2015, doi: 10.4103/0975-1475.172442.

[28] A. Maji et al., "A novel computer-assisted method of bite mark analysis for gender determination," *Journal of Environmental and Public Health*, vol. 2018, 2018.

[29] L. Chintala et al., "Human bite marks: A computer-based analysis using Adobe Photoshop," *Journal of Indian Academy of Oral Medicine and Radiology*, vol. 30, no. 1, pp. 58–63, 2018, doi: 10.4103/jiaomr.jiaomr_87_17.

[30] R. Kamalraj, "Deep learning model for identifying snakes by using snakes' bite marks," in *2020 International Conference on Computer Communication and Informatics (ICCCI)*, Coimbatore, India, 2020, pp. 1–4, doi: 10.1109/ICCCI48352.2020.9104200.

[31] G. Jani, A. Johnson, J. Marques, and A. Franco, "Three-dimensional (3D) printing in forensic science–An emerging technology in India," *Annals of 3D Printed Medicine*, vol. 1, 2021, doi: 10.1016/j.stlm.2021.100006.

[32] M. J. Alter, "Epidemiology of hepatitis C virus infection," *World Journal of Gastroenterology*, vol. 13, no. 17, pp. 2436–2441, 2007.

[33] CDC, *Viral Hepatitis Surveillance, United States, 2016.*

[34] T. A. Peterman and B. W. Furness, "The resurgence of syphilis among men who have sex with men," *Current Opinion in Infectious Diseases*, vol. 20, no. 1, pp. 54–59, 2007.

[35] L. Corey and A. Wald, "Maternal and neonatal herpes simplex virus infections," *New England Journal of Medicine*, vol. 361, no. 14, pp. 1376–1385, 2009.

[36] A. Kenneson and M. J. Cannon, "Review and meta-analysis of the epidemiology of congenital cytomegalovirus (CMV) infection," *Review of Medical Virology*, vol. 17, no. 4, pp. 253–276, 2007.

[37] R. L. Oehler, A. P. Velez, M. Mizrachi, et al., "Bite-related and septic syndromes caused by cats and dogs," *The Lancet Infectious Diseases*, vol. 9, no. 7, pp. 439–447, 2009, doi: 10.1016/S1473-3099(09)70110-1.

[38] J. Schalamon, H. Ainoedhofer, G. Singer, et al., "Analysis of dog bites in children who are younger than 17 years," *Pediatrics*, vol. 117, no. 3, pp. e374–e379, 2006, doi: 10.1542/peds.2005-1451.

[39] J. M. Gilyoma, J. B. Mabula, and P. L. Chalya, "Bite injuries at Bugando Medical Centre, Mwanza, Tanzania: A five-year experience," *East and Central African Journal of Surgery*, vol. 15, no. 2, pp. 110–115, 2010, doi: 10.4314/ecajs.v15i2.55890.

[40] M. Kimura, Y. Yamashita, K. Kusuhara, et al., "Erysipelothrix rhusiopathiae infection in humans: A case report and literature review," *International Journal of Infectious Diseases*, vol. 93, pp. 42–46, 2020, doi: 10.1016/j.ijid.2020.01.005.

[41] J. N. Williams, R. T. Matthews, and P. M. Stewart, "Analysis of canine bite injuries in a metropolitan area," *Journal of Forensic Science and Medicine*, vol. 6, no. 3, pp. 182–187, 2020.

[42] T. S. Naru and A. Singh, "Challenges in forensic analysis of human bite marks," *Journal of Forensic and Legal Medicine*, vol. 72, p. 102058, 2020, doi: 10.1016/j.jflm.2020.102058.

[43] A. J. Karell, "Bite wound infections and the role of prophylactic antibiotics," *Clinical Microbiology and Infection*, vol. 25, no. 5, pp. 613–619, 2019, doi: 10.1016/j.cmi.2018.11.006.

Author Contributions

All authors listed on this manuscript have made substantial contributions to its creation and are accountable for all aspects of the work. Each author has participated in the following aspects of the research and manuscript preparation:

- **Conceptualization:** NR, SD
- **Methodology:** Not Applicable (Review Article)
- **Investigation:** Not Applicable (Review Article)
- **Formal Analysis:** NR, SD
- **Data Curation:** SD
- **Writing - Original Draft:** SD
- **Writing - Review & Editing:** NR
- **Visualization:** SD, NR
- **Supervision:** NR
- **Funding Acquisition:** Not Applicable (Review Article)

About the Authors

Mr. Sarang S Damle:

Mr. Sarang S Damle is a student at Department of Forensic Science Dr B.A. Marathwada University, Chh. Sambhajinagar (Aurangabad), Maharashtra and he is currently pursuing his MSc Forensic Science degree.

Mr. Nikhil Rathod:

Mr. Nikhil Rathod completed his masters in Forensic Science in Biology and Serology from Government Institute of Forensic Science, Chh. Sambhajinagar (Aurangabad), Maharashtra. Currently he is an Assistant Professor Department of Forensic Science Dr B.A. Marathwada University, Chh. Sambhajinagar.