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RELIABILITY AND VALIDITY OF BITE MARK ANALYSIS: CRITICAL EXAMINATION AND IMPROVEMENT OF CURRENT PRACTICES

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BITE MARK ANALYSIS:

Bite mark analysis is a forensic practise/procedure in which the bite marks on the victim's skin are compared to the alleged biter's teeth. The purpose of bite mark analysis is to identify the biter with a reasonable degree of care and certainty. Bitemark analysis is a process that includes examining patterned injuries found at a crime scene, determining them to be bitemarks, and then comparing these marks with dental impressions from a person of interest (POI). This analysis relies on three main components:

1. The front teeth of the presumed biter (POI's anterior dentition),
2. Accurately transferring the biter's dental features onto a surface (like human skin) to create a bitemark, and
3. Conducting image analysis on the alleged bitemark to reveal the dental pattern, compare it with the dental features of the person of interest, and interpret the findings.

- The accuracy of bite mark analysis has been strongly disputed, and it is a specialist discipline that necessitates substantial training and experience.
- The current condition of the bite mark, the investigator's expertise, and the availability of bite marks with similar characteristics are only a few of the variables that might determine how accurate a bite mark analysis is.
- Bite mark analysis can be a useful tool in forensic investigations despite its difficulties.

Stages of Bite Mark Analysis:

The first stage of bite mark analysis involves confirming if the injury is indeed a bite mark and assessing its forensic significance.

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1. **Demographics:**

(a) Includes victim's name, case number, date of examination, referring agency, contact person, age, race, and sex of the victim, and examiner's name.

2. **Location of Bite Marks:**

(a) Non-sexual bite marks can be found on arms, legs, fingers, hands, chest, and ears.

(b) Sexual bite marks may be present on breasts, neck, thighs, genitalia, axilla, buttock, upper back, arms, cheeks, etc.

(c) Frequencies of occurrence: breast, arm, genitalia, back, thigh, legs, nipple, hand, buttock, abdomen, waist, face, neck, etc.

3. **Shape, Size, and Arrangement of Teeth:**

(a) Bite marks can be crescent, ovoid, round, or irregular in shape.

(b) Human incisors produce rectangular marks, while canines yield triangular marks.

(c) Vertical and horizontal dimensions of the bite mark are measured.

(d) Comparison of prominent dental features like tooth size, arrangement, and secondary features like gaps or broken teeth.

(e) Both prominent and secondary dental features must match for a bite mark to be considered a match.

(f) Note tooth numbers, missing teeth, and placement of tooth marks.

4. **Size of Dental Arch:**

(a) The size relationship of bite marks based on dental arches can indicate if it is a child or adult bite.

(b) Adult arches' average diameter from canine to canine is 25-40mm.

5. **Suction Marks:**

(a) Suction marks or hickeys are collections of punctate haemorrhages, resembling a 'sun-burst.'

(b) Usually found after sexually oriented crimes due to suction or negative pressure leading to blood leakage from capillaries.

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6. **Type of Injury:**

(a) Bite marks can cause petechial haemorrhages, contusions (ruptured blood vessels), abrasions (undamaging marks), avulsions (torn skin), lacerations (near puncture of skin), incisions (neat punctured or torn skin), and artifacts (bitten off piece of body).

(b) They can be classified into four degrees of impression: clearly defined, obviously defined, quite noticeable, and lacerated.

7. **Colour of the Wound:**

(a) The colour of the bite mark, e.g., red, purple, etc., should be noted during examination.

8. **Evaluation of Bite Mark Photographs:**

(a) High-resolution images are essential for examination, allowing amplification to life-sized dimensions without pixilation.

Availability and Implementation in India:

(a) The implementation of advanced bite mark analysis techniques, such as digital methods and computerized programs, may vary in different regions of India.

(b) Some forensic facilities and institutes in India may have access to these technologies, but the extent of their usage may differ based on resources and expertise.

(c) As technology advances, it is likely that more forensic institutions in India will adopt these digital methods for bite mark analysis to enhance accuracy and efficiency in criminal investigations and legal proceedings.

Comparison Techniques in Bite Mark Analysis:

A. **Direct Comparison Technique:** Cast on Photo Method In the direct method or cast on photo method, a straightforward comparison is made between photographs and models or a fingerprint powder lift model. This technique allows investigators to place models from the suspect directly over a life-sized photograph of the bite mark for clear demonstration. The finger print powder lift technique involves dusting the bitten skin with appropriate powder and a brush, then using fingerprint tape to transfer the marks onto a sheet of acetate. Caution is advised during the development of the print to avoid any damage.

B. **Indirect Method-Overlay:** Utilizing Transparent Overlays The indirect method involves the creation of transparent overlays to record the suspect's biting edges. This process

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entails free-hand tracing the occlusal or incisal surfaces of a dental model onto an acetate sheet, which is then placed over scaled 1:1 photographs for comparison. However, the use of transparent overlays is considered subjective, easily manipulable, and irreproducible. An alternative to free-hand tracing is the use of photocopier-generated overlays, which provide a more reliable means of matching the correct bite mark to the appropriate set of models. The four methods of bite mark overlay production are:

1. Computer-based
2. Radiopaque wax method
3. Xerographic
4. Hand-traced

Additional Special Methods for Bite Mark Analysis:

a. **Stereometric Graphic Analysis:** This technique involves analysing bite mark patterns using a stereometric approach, providing three-dimensional insight into the marks.
b. **Vectron:** Vectron is a specialized tool that aids in bite mark comparison, helping investigators analyse and interpret complex bite patterns.
c. **Scanning Electron Microscopic Analysis:** Utilizing advanced microscopic technology, this method allows for high-resolution examination of bite marks, revealing intricate details.
d. **Image Perception Technology:** This innovative approach involves the use of advanced software and algorithms to enhance image analysis and bite mark comparisons.
e. **Experimental Marks:** Researchers may conduct controlled experiments to better understand and interpret bite marks, contributing valuable insights to the field of bite mark analysis.

Factors Influencing Severity of Bite Marks:

The severity of bite marks is influenced by the force with which the biting teeth and tongue inflict the injury. The negative pressure created during the biting process can lead to extra-vascular bleeding, resulting in bruising at the centre of the bite mark injury. As the injury undergoes a healing process in the living person's skin, these bruises may exhibit colour changes over time. There are four degrees of impression that can be examined to detect the type of violence involved:

a. Significant pressure
b. First-degree pressure

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c. Violent pressure
d. Skin violently torn from the body.

CLASSIFICATION OF BITE MARKS:

Several classification systems have been suggested for categorizing bite marks:

1. **Cameron and Sim's Classification:** This classification is based on the type of agent responsible for the bite marks and the material on which the bite mark is found. The agents can be human or animal, and the materials can include skin, body surfaces, food items, or other materials.

2. **MacDonald's Classification:** This classification is widely used and focuses on the cause of the bite marks. It is an etiological classification that identifies three types of bite marks: a. Tooth Pressure Marks: These marks are produced when teeth directly apply pressure to tissues. Typically, incisal or occlusal surfaces of teeth cause these marks. b. Tongue Pressure Marks: These marks occur when the tongue presses tissue against rigid areas like the lingual surface of teeth or the palatal surface. These marks are sometimes referred to as "suckling" marks and often involve a combination of sucking and tongue thrusting. c. Tooth Scrape Marks: These marks result from the scraping of teeth across the bitten material. Usually caused by anterior teeth, they appear as scratches or superficial abrasions.

3. **Webster's Classification:** This classification categorizes bite marks based on the depth of tooth penetration into the foodstuff.

a) **Type 1:** Food items that fracture easily with limited tooth penetration, such as hard chocolate.
b) **Type 2:** Bite marks on food items where fragments break off, and teeth penetrate considerably, like marks on fruits.
c) **Type 3:** Bite marks showing complete penetration on food items with slide marks, such as cheese.

These classifications aid in the analysis and understanding of bite marks, providing valuable information in forensic investigations and criminal cases.

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COLLECTION OF EVIDENCE IN BITE MARK ANALYSIS:

Collection of Evidence from the Victim:

- DNA from salivary trace evidence is obtained by swabbing the bite site using the double swab technique.
- Photography is a crucial element of dental forensic examination to document maxillary and mandibular teeth, pathologies, and dental treatment.
- Close-up photographs of bite marks are taken under high resolution with colour balance maintained for accurate representation.
- The use of a scale and proper camera orientation helps minimize distortion during photography.
- Photographic evidence is commonly used for recording skin bite marks, but postural effects and secondary distortion should be managed.

Collection of Evidence from the Suspect:

- Extra oral examination includes assessing hard and soft tissues, TMJ status, facial asymmetry, and muscle zones.
- Intra oral examination includes examining salivary evidence, tongue size and function, and dental conditions.
- Dental casts are obtained with ADA specified material to create a master cast for further examination.

Analysis and identification of bite marks:

- Forensic science uses individual traits and characteristics of the teeth and jaws to identify the perpetrator of a bite mark.
- Recognition of a patterned injury as a human bite mark is followed by pattern analysis to provide information about the suspect or offender involved in the crime.
- Specific teeth marks and characteristics are used for comparisons with the suspects' teeth to determine the origin of the bite mark.

Physical Comparisons:

- Various methods are used to physically compare suspect dentition and physical bite mark injuries, including scanning electron microscopes, overlays, impressions, and 3D laser scanning of dental casts.

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- Computer-generated overlays have a high degree of specificity and accuracy, but they are not widely used among forensic odontologists.
- Biological techniques focus on salivary DNA recovery and the use of bacterial fingerprints for suspect identification.
- Uniqueness of The Human Dentition:
- The human dentition is unique, and occlusal profiles differ among individuals, allowing for the creation of a dental occlusal profile database.
- However, dental occlusal profiles are not constant throughout life and may require routine updates for accurate use in forensic analysis.

Bitemark Severity Index:

- The bitemark severity index is a scale from 1 to 6 used to measure the severity of bite marks.
- The index should be easy to use, reproducible, applicable to both the living and the dead, and allow for future statistical analysis.
- The index is used to assess the forensic significance of bite marks, with 3 and 4 having the highest forensic significance.
- Proper education for crime scene police officers is essential for the effective use of the bitemark severity index in bite mark analysis.

DENTIST AS AN EXPERT WITNESS:

First use of dental evidence in court:

In 1814, in[1] *Scotland, the use of a dentist as an expert witness was documented in the case OF MRS. JANET MCALISTER. DR. GRANVILLE SHEEP PATTISON, a lecturer of anatomy, and two students were charged in the high court in Edinburgh for violating Mrs. McAlister's grave. Dental evidence played a crucial role in the case, as a maxillary denture was discovered in the dissecting room, near the college where they had moved her body after burial. Dr. James Alexander, Mrs. Alister's dentist, testified as a witness for the prosecution. He confirmed that a set of dentures found matched only one of the heads in the dissection room.*

In 1831, a woman named **CAROLINE WALSH** disappeared after moving in with an Irish married

[1] Campbell JM, "Dentistry then Now," Glasgow: Pickering and Inglis, Ltd., 1963. (Last accessed on 02.07.2023 at 6.30 pm)

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couple. A woman later found on the streets in a destitute condition was claimed to be Caroline Walsh. However, it was revealed during the trial that this woman had lost her front teeth many years ago, whereas the real Caroline Walsh had perfect teeth. Although Mrs. Walsh was never found, the accused was still convicted based on the dental evidence presented in the case[2].

The first documented use of dental evidence in court in India was in 1193 AD. During this time, in the case of **JAI CHAND, THE RAJA OF KANAUJI**, who was murdered after his kingdom was destroyed by Muhammad's army, he was identified by his false teeth. This historical case marked the earliest recorded instance of dental identification being utilized as evidence in the Indian judicial system.

In the fascinating evolution of forensic dentistry, dentists have played a crucial role in providing expert testimony in court cases, helping to identify individuals and solve mysteries that would otherwise remain unsolved. Some historical cases that showcase the early use of dental evidence in legal proceedings are:

a) One notable case occurred in the United States during the 19th century. **DR.GEORGE PARKMAN**, a respected professor at Harvard University, vanished on November 23rd, 1849. Among the suspects was John White Webster, owing money to Dr. Parkman. Upon searching Webster's laboratory, human remains were discovered. To ascertain the identity, Dr. Parkman's dentist, Dr. Nathen Cooley Keep, was called upon. Three years earlier, Dr. Keep had crafted upper and lower dentures for Dr. Parkman, and he used these dentures to positively identify the body. Dr. Keep's expert testimony proved instrumental in convicting Webster, marking the first recorded instance of a dentist testifying in a U.S. court[3].
b) Another intriguing case involved **WILLIAM THE CONQUEROR**, who fell from his horse and died at the age of forty-four. Centuries later, in 1868, when his tomb was opened, the remains were found to be remarkably well-preserved. Forensic dentists utilized the remarkable durability and longevity of teeth, even in severely damaged or long-buried

[2] Smith FJ, editor, "The Late A. S. Taylor's Manual," 5th ed., London: J and M Churchill, 1905, pp. 139-141. (Last accessed on 03.07.2023 at 12.01 am)
[3] Dilnot G, Bles G, "The Trial of Professor Webster," Famous Trial Series, London: Literary Licensing, 1928. (Last accessed on 03.07.2023 at 12.45 am)

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bodies, to confirm the identity of the historical figure[4].

c) In 1870, the use of bite marks as evidence was explored in a trial where **MR.A.I.ROBINSON** was accused of murdering his mistress. The comparison of bite marks from Mr. Robinson's five maxillary teeth to the suspect's bite marks led to identification, but he was not found guilty[5].

d) Another intriguing case from 1873 involved a body found in the ashes of a burned cottage in Maryland. **MRS. WINFIELD S. GROSS** was suspected of murdering her husband for insurance money. The body was examined at the Baltimore College of Dental Surgery, and Dr. F. J. S. Gorgas provided a detailed description of the jaws and remaining teeth. The forensic dentist concluded that the remains did not belong to Mrs. Gross, ultimately leading to the arrest of Mr. Udderzook, Mrs. Gross's brother-in-law, who was found in possession of the victim's belongings.

e) In yet another historical event, following the assassination of **PRESIDENT ABRAHAM LINCOLN** in 1865, rumours circulated that the assassin, John Wilkes Booth, was still alive. In 1893, the body believed to be Booth's was disinterred and examined. The family dentist played a pivotal role in identifying Booth's body based on peculiar jaw formation documented in dental records during a dental visit for filling restoration[6].

f) After World War II, there were widespread rumours suggesting that **ADOLF HITLER** had managed to escape with his wife, Eva Braun. However, historical evidence has proven that both indeed died together in 1945. Their bodies were burned and buried by Russian soldiers, making it challenging to refute the rumours due to the lack of pre-death and post-death records. Eventually, a breakthrough came when remnants of a bridge were found among the pieces of Hitler's jaw. The bridge's unique reconstruction and signs of periodontal diseases provided vital clues for identification. In this critical process of dispelling the rumours, the work of Hitler's dentist, Hugo Blaschke, became crucial. By comparing the dental work recorded by Blaschke with that of Hitler's dental records, the authenticity of Hitler's death was confirmed, putting an end to the speculations surrounding his fate[7].

[4] Macbenzie RS, "Disintermint of the remains of William Rufus," Dent Cosm, 1869;11:77-78. (Last accessed on 03.07.2023 at 12.55 am)
[5] Hill IR, editor, "Forensic Odontology," Bichester, UK: The Old Swan, 1984. (Last accessed on 03.07.2023 at 1.04 am)
[6] Marco BB, "A system to assist in the identification of criminals and others by means of their teeth," Dent Cosm, 1898;40:113-116. (Last accessed on 03.07.2023 at 1.13 am)
[7] Highfield R, "Dental detective works gets to the root of Hitler mystery," London: Daily Telegraph, 1999. (Last accessed on 03.07.2023 at 1.31 am)

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These early cases highlight the significant contributions of dentists as expert witnesses in courtrooms, using their expertise to unravel mysteries, identify individuals, and bring justice to the victims. The history of forensic dentistry exemplifies the intersection of science, law, and human curiosity in unravelling the truth behind some of history's most fascinating cases.

FACTORS CONTRIBUTING TO UNRELIABILITY FOR BITE MARKS ANALYSIS:

There are several factors that contribute to the unreliability of bite mark analysis.

A. First, human skin is not a reliable surface to analyse because it changes over time depending on swelling, healing, and skin elasticity.
B. Second, bite marks can be distorted by the force of the bite, the position of the victim's body, and the clothing that the victim is wearing.
C. Third, there is no standardized method for collecting and preserving bite mark evidence.

REVIEW REPORTS ON BITE MARK ANALYSIS:

In recent years, there have been several calls for reform in the practice of bite mark analysis. In a 2009 report, the National Academies of Sciences, Engineering, and Medicine urged greater investigation into the validity and reliability[8].

According to the draft review, the scientific basis of forensic bitemark analysis is insufficient due to the lack of support for its three key premises.

i. Firstly, there is no evidence to suggest that human anterior dental patterns are uniquely specific to individuals.
ii. Secondly, the consistent transfer of these patterns to human skin has not been established.
iii. Lastly, the accuracy of analysing defining characteristics of bitemarks to include or exclude individuals as their source has not been demonstrated.

The report also called for the development of standardized methods for collecting and preserving bite mark evidence[9]. The draft review highlights three key unsupported premises in forensic

[8] National Institute of Standards and Technology, "Forensic Bitemark Analysis Not Supported by Sufficient Data: NIST Draft Review," available at: https://www.nist.gov/news-events/news/2022/10/forensic-bitemark-analysis-not-supported-sufficient-data-nist-draft-review (last accessed on 13-07-2023 at 01:34 pm).
[9] Id at 25.

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bitemark analysis.

1. Firstly, there is no evidence to prove the uniqueness of dental patterns formed by a person's front-most biting teeth. No population studies have been conducted to determine the prevalence of such distinguishing features.
2. Secondly, the accuracy of transferring these dental patterns to human skin is questionable. Bitemarks can be distorted by skin elasticity, victim movement during the biting, and subsequent swelling or healing, making it challenging to reflect the true dental characteristics of the biter.
3. Lastly, the ability of bitemark examiners to accurately analyse skin injuries is uncertain. Previous studies, including one from 2016, demonstrated inconsistencies among practitioners in identifying bitemarks and determining their source, be it adults, children, or animals.

A draft evaluation of the scientific underpinnings of bite mark analysis was published by the National Institute of Standards and Technology (NIST) in 202210. The NIST review found that bite mark analysis lacks a sufficient scientific foundation. The review also found that there is no evidence that bite mark analysis can be used to identify a biter with a reasonable degree of certainty11.The NIST review has been met with mixed reactions. Some experts have argued that the review is too critical of bite mark analysis, while others have argued that the review is justified. Despite the controversy, there is a growing consensus that the practice of bite mark analysis needs to be reformed. In order to improve the reliability and validity of bite mark analysis, there is a need for more research, the development of standardized methods, and the education of forensic dentists.

The American Board of Forensic Odontologists (ABFO) revised its guidelines in 2018 for collecting and assessing bitemark data from victims and potential biters. The evaluation process involves the following steps:

1. Determining if the pattern is indeed a bitemark by taking photographs of the mark, identifying arches and midline, and checking if individual teeth marks are distinguishable

[10] Centre for Statistics and Applications in Forensic Evidence, "NIST Finalizes Report of Forensic Bitemark Analysis," available at: https://forensicstats.org/blog/2023/03/20/nist-finalizes-report-of-forensic-bitemark-analysis/ (Last accessed on 13.07.2023 at 01.45 pm).
[11] National Institute of Standards and Technology, "Draft Report: NIST Technical Study on Bitemark Comparison," available at: https://nvlpubs.nist.gov/nistpubs/ir/2022/NIST.IR.8352-draft.pdf (last accessed on 13.07.2023 at 05.37 pm).

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and comparable to normal human variation.

2. Interpreting and analysing bitemark features, including locating the pattern, noting size, shape, and anomalies, and collecting evidence for further assessment.
3. Comparing the bitemark data to the dentitions of Persons of Interest (POIs) and non-POIs using various methods like overlays, test bites, and additional techniques such as transillumination or scanning electron microscopy.
4. Forming conclusions with levels of certainty: whether the subject and non-POI dentitions can be excluded, not excluded, or remain inconclusive as the cause of the bitemark pattern. The ABFO does not endorse terms indicating an absolute match to a specific dentition.

   It is important to note that the ABFO's language in the 2018 document reflects a sense of uncertainty in their conclusions, using terms like "excluded," "not excluded," or "inconclusive." The document does not endorse a definitive link between a specific dentition and a particular bitemark.

APPLICATIONS IN MEDICO-LEGAL CONTEXT:

Forensic Dentistry takes a diversified approach and specific expertise to be effective in both criminal and civil cases, it includes the inspection, analysis, and presentation of dental evidence, assisting in the detection and prosecution processes[12]. The identification of deceased individuals using an inclusive range of techniques, such as those employed by forensic dentists, is fundamental which includes the analysis of periodontal tissues[13], analysis of bite marks on human tissues[14], assessment of anatomical structures[15], and anthropological studies[16].

Law enforcement officials, forensic pathologists, forensic odontologists, forensic anthropologists, serologists, participants, and other parties must collaborate in a collaborative way while carrying out a forensic identification. Every individual on the team offers their own knowledge and perspective to the investigation and legal proceedings. The accuracy, reliability, and exhaustiveness of forensic identifications are guaranteed by this collaborative method.

[12] Chidambaram R, "Forensic Odontology: A Boon to Community in Medico-legal Affairs," J Nepal Med Assoc, 2016;54(201):46-54 (Last accessed on 03.07.2023 at 2.12 am)
[13] Shamim T, "Forensic Odontology," Journal of the College of Physicians and Surgeons Pakistan, 2010;20(1):1-2. (Last accessed on 03.07.2023 at 2.20 am)
[14] Sylvie LA, "Forensic Odontology: The Roles and Responsibilities of the Dentist," J Can Dent Assoc, 2004;70(7):453-458. (Last accessed on 03.07.2023 at 2.35 am)
[15] Supra Note No: 2
[16] Khudaverdyan AY, "The Anthropology of Infectious Disease of Bronze age and early Iron age from Armenia," Dental Anthropology, 2011;24(2):42-54. (Last accessed on 03.07.2023 at 3.13 am)

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In medico-legal applications, forensic dentistry is essential for assisting to identify an individual when employing more conventional methods of identification is challenging or impractical. Dental evidence, including bite marks, dental anomalies, restorations, and dental records, can offer crucial information that confirms or contradicts witness testimony and aid in identifying suspects or victims. Forensic dentists are instructed to carefully examine dental evidence, make comparisons, and clearly and impartially explain their conclusions within the bounds of the law.

EVIDENTIARY VALUE OF HUMAN BITEMARKS:

1. **General Considerations:**

- Once a pattern is identified as a human bitemark, its forensic significance or evidentiary value should be evaluated before comparing it to dentitions.
- Induced skin distortion and other factors related to human skin nature can impact the recording of dental features, arch size, and shape in the bitemark.
- Various factors influence the interpretation of bitemarks on human skin.

2. **Criteria for Determining Evidentiary Value:**

Conditions and features of bitemark evidence that indicate sufficient evidentiary value for comparisons to dentitions include, but are not limited to:

- Adequate and properly focused photographs of the bitemark with and without a reference scale.
- Properly illuminated and exposed images made with the image receptor parallel or correctable for the angle theta (θ) using image-management software.
- Locatable maxillary and mandibular arches with determinable midlines.
- Visible marks caused by individual teeth, recognizable based on class characteristics and relative location.
- Arch size and shape conforming to variations in the size and shape of human dentition.

COLLECTION OF EVIDENCE:

The process of collecting evidence in bite mark analysis involves the following steps:

Collection of bitemark evidence from the bite victim[17]:

1. **Documentation:** A written record detailing the location, appearance, colour, size, and

[17] Rai B, Kaur J. Bite Marks: Evidence and Analysis, Part 1. EvidenceBased Forensic Dentistry. 2013:87-99. (Last accessed on 03.07.2023 at 12.24 am).

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orientation of the bite mark.

2. **Photography:** Comprehensive photography capturing various angles, with and without ABFO No. 2 scale, in colour and black and white, using on and off-camera flash, and UV photography. Close-ups are taken at a 1:1 scale, and multiple body positions are photographed to assess the impact of movement.
3. **Salivary swab:** The deposition of saliva during the biting process is inevitable. A double-swab technique is recommended for recovery. Swabs are taken from the bitten surface using moistened cotton wool followed by a second dry swab. Control swabs are also taken from the victim for comparison.
4. **Impression of the bite injury:** Impression materials such as vinyl polysiloxane are used to capture irregularities produced by the teeth, such as cuts and abrasions on the bitten surface. These impressions are then cast in plaster to create a lasting record of the injury.

EVIDENCE COLLECTION FROM THE BITE SUSPECT:

1. **History and Dental Records:** Dental records obtained from the suspect's dentist play a crucial role in establishing the identity of the suspect.
2. **Photographs:** Both intraoral and extraoral photographs of the suspect are taken. Extraoral photographs include profile and full-face views, while intraoral photographs cover frontal, lateral, and occlusal views of both dental arches.
3. **Impressions and Study Casts:** Impression taking and fabricating study casts of the suspect's dentition are important for the examination of bite marks.
4. **Test Bites:** Test bites are performed to investigate the position, shape, and alignment of the suspect's incisal edges using materials like baseplate wax, aluwax, coprwax, and silicone.
5. **DNA Samples:** Non-invasive procedures like saliva extraction or invasive procedures using the suspect's whole blood are performed to collect DNA samples for comparison with biological evidence found at the crime scene.

BITEMARKS MADE BY DIFFERENT DENTITIONS:

Distinguishing bitemarks made by adult teeth from those made by children's teeth should consider not only size but also class characteristic differences between permanent and primary dentitions. Bitemarks made during the mixed dentition phase may exhibit characteristics of both

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permanent and primary dentitions[18].

Here are some specific ways to improve the practice of bite mark analysis:

- Conduct more research on the reliability and validity of bite mark analysis.
- Develop standardized methods for collecting and preserving bite mark evidence.
- Educate forensic dentists about the limitations of bite mark analysis.
- Use bite mark evidence in conjunction with other forensic evidence, such as DNA evidence.

In the case of State v. Green[19], it was highlighted that the dental expert must be aware of the scale displayed in the picture for accurate analysis. Therefore, it is crucial to include a measurement method like a ruler or tape measure in the photographs of the bite mark and the defendant's teeth[20]. Additionally, a plaster cast of the defendant's dental impressions can be utilized to create a plastic overlay, aiding in the marking of contact points, and forming a representation of the defendant's bite marks or the cutting edges of their teeth[21].

There is a significant issue at present regarding the improper use and misinterpretation of bite mark evidence in the field of forensic odontology. The scrutiny of forensic evidence in criminal cases, has reached unprecedented levels of legal and scientific examination. Certain subfields of forensic science, particularly those involving pattern-matching, have recently been acknowledged as having weak foundations and making exaggerated claims, casting doubt on their admissibility as evidence in court. Some of these forensic testimonies had been accepted for decades without raising any judicial concerns. The most significant and official criticism of these flaws was made in the 2009 report by the National Academy of Sciences' Committee on Identifying the Needs of the Forensic Science Community[22].

[18] American Board of Forensic Odontology, "ABFO Standards & Guidelines for Evaluating Bitemarks," available at: http://abfo.org/wp-content/uploads/2012/08/ABFO-Standards-Guidelines-for-Evaluating-Bitemarks-Feb-2018.pdf (Last accessed on 01.07.2023 at 08.49 pm).
[19] State v. Green, 305 N.C. 463 (1982)
[20] American Board of Forensic Odontology, "ABFO Standards & Guidelines for Evaluating Bitemarks," available at: http://abfo.org/wp-content/uploads/2012/08/ABFO-Standards-Guidelines-for-Evaluating-Bitemarks-Feb-2018.pdf (Last accessed on 01.07.2023 at 08.49 pm).
[21] North Carolina State Crime Laboratory, "Bite Mark Comparison," available at: https://ncpro.sog.unc.edu/manual/624-1#:~:text=Bite%20mark%20analysis%20is%20conducted,defendant%20left%20the%20original%20mark. (Last accessed on 01.07.2023 at 04.09 pm).

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A report in 2022 from the National Institute of Standards and Technology (NIST) is titled "Critical Examination and Improvement of Current Practices."[23]. The report provides a critical examination of the scientific foundation of bitemark analysis and identifies areas where research is needed to improve the reliability and validity of the discipline. The report finds that there is no scientific consensus on the three key premises of bitemark analysis:

1. That human anterior dental patterns are unique at the individual level.
2. That those patterns are accurately transferred to human skin consistently.
3. That defining characteristics of that pattern can be accurately analysed to exclude or not exclude individuals as the source of a bitemark.

The report also finds that there is a lack of empirical research on the accuracy and reliability of bitemark analysis. This is due in part to the difficulty of conducting controlled studies on bitemarks, as they are often found in the context of violent crimes. The report makes several recommendations for improving the reliability and validity of bitemark analysis, including:

a) Conducting more empirical research on the accuracy and reliability of bitemark analysis.
b) Developing standardized protocols for the collection, preservation, and analysis of bitemarks.
c) Increasing the transparency of bitemark analysis procedures.
d) Educating law enforcement and the courts about the limitations of bitemark evidence.

The report concludes that bitemark analysis is a promising forensic tool, but that more research is needed to establish its scientific foundation and reliability.

THE VALIDITY OF BITE MARKS:

The validity of bite marks in Indian courts is a complex issue. There is no clear consensus on whether bite mark evidence is reliable enough to be used as the sole basis for a conviction. On the one hand, bite marks can provide valuable information about the identity of the perpetrator. The shape and size of teeth, as well as the spacing between them, are unique to everyone. This means that bite marks can be used to exclude suspects from a crime scene, or to identify a suspect if there is a match. On the other hand, there are several factors that can make bite mark evidence unreliable. The condition of the bite mark can deteriorate over time, making it difficult to match

[23] National Institute of Standards and Technology, "NIST Technical Study on Bitemark Comparison," available at: https://nvlpubs.nist.gov/nistpubs/ir/2023/NIST.IR.8352.pdf (Last accessed on 05.07.2023 at 11.30 am).

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to a suspect's teeth. The bite mark may also be contaminated by other factors, such as dirt or food, which can make it difficult to identify the perpetrator. In addition, there is a lack of scientific consensus on the reliability of bite mark analysis. Some studies have shown that bite mark analysis can be accurate, while others have shown that it is not reliable enough to be used in court. As a result of these factors, the validity of bite marks in Indian courts is still being debated. Some courts have admitted bite mark evidence, while others have excluded it. Ultimately, the decision of whether to admit bite mark evidence is up to the judge in each case.

Here are some additional points to consider:

a) Bite mark evidence is often used to corroborate other evidence, such as eyewitness testimony or DNA evidence.
b) The reliability of bite mark evidence can be improved by taking careful photographs of the bite mark and by obtaining dental impressions from the suspect.
c) Bite mark analysis is a specialized field, and it is important to choose an experienced expert who is familiar with the latest research.

DENTAL SCIENCE IN LEGAL CONTEXT:

Forensic odontology encompasses the application of dental science to the legal field. There are four major areas of interest that it may be broadly divided into:

DENTAL IDENTIFICATION OF THE UNKNOWN BODY: This involves comparing dental records and X-rays with those of a deceased individual (or remains that cannot be identified by other means) to establish their identity.

- **TRAUMA AND THE ORAL TISSUES:** This area focuses on interpreting oral injuries and their relevance to legal matters.
- **DENTAL MALPRACTICE AND NEGLIGENCE:** Here, the treatment provided by a dentist is analysed, and the findings are presented in a court of law in cases involving allegations of malpractice or negligence.
- **BITE MARK COMPARISON:** This controversial aspect involves comparing bite marks found on a victim with the dental impressions of potential criminal suspects.

  Among these areas, bite mark comparison has been particularly contentious within the

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field of forensic odontology.[24]

FACTORS INFLUENCING THE EVIDENTIARY VALUE OF BITE MARKS IN FORENSIC ANALYSIS:

The evidentiary value of bite marks in forensic analysis can be significantly influenced by several factors. These factors include the distortion of the skin, degradation of DNA, time interval between the bite and examination, movement, overlapping of bite marks, and more. Human dentition consists of 32 teeth, each with five anatomical surfaces, resulting in a total of 160 dental surfaces with individual characteristics. The evidentiary value of bite mark evidence is influenced by the surface on which the bite mark pattern is transferred. Bite marks are commonly found on the skin of victims and occasionally on food items. However, skin is not an ideal material for accurately capturing dental patterns. Compared to modern dental materials, it provides a less clear medium for recording human dentition. Skin is highly viscoelastic, which means that indentations created by teeth during biting tend to rebound. This rebound effect hampers the skin's ability to accurately retain the three-dimensional structure of the biting edges of teeth, resulting in a lack of comprehensive records.[25] However, during bite mark analysis, only a limited number of teeth (typically four to eight) are often present in the bite mark evidence. Moreover, only the edges of the front teeth contact the skin, meaning that the information recovered from bite marks is considerably less comprehensive compared to other forensic identification techniques such as fingerprints or DNA. Additional factors such as restorations, decay, malposition, and injuries contribute to individuality but provide limited information during bite mark analysis. Research studies have shown that even models of dentition from different individuals may exhibit indistinguishable similarities when considering the front six teeth. The substrate onto which bite marks patterns are transferred also impacts the evidentiary value. Skin, the most common surface for bite marks, is an inadequate medium for accurately recording dental patterns compared to modern dental materials. Skin is highly viscoelastic, causing indentations left by teeth during biting to rebound and distort, leaving no potential record of the three-dimensional structure of the biting edges. This distortion is attributed to the elastic fibres in the dermis, which deform under pressure and subsequently recoil back to their original position. The degree of distortion depends

[24] Allen P. Wilkinson & Ronald M. Gerughty, "Bite Mark Evidence: Its Admissibility Is Hard to Swallow," 12 W. St. U. L. REV. 519 (1985). (Last accessed on 04.07.2023 at 1.30 pm).
[25] SCI-HUB, "Detection of Bite Marks in Foodstuffs," available at: https://sci-hub.se/https://pubmed.ncbi.nlm.nih.gov/28852538/ (Last accessed on 03.07.2023 at 8.25 am).

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on factors such as age and anatomical location. Additionally, bite marks are essentially bruises that consist of blood from crushed capillaries, further affecting precise measurements during bite mark comparison. The pliability, elasticity, and reactivity of skin pose significant limitations to the validity of forensic odontology, as highlighted in the National Academy of Sciences (NAS) report[26].

Bite mark distortion on the skin is influenced by the position and movement of both the biter and the bitten person during the injury. Violent crimes involving biting often occur during struggles when the skin is stretched, resulting in the formation of bite marks. However, when the skin returns to its normal shape, the transferred bite marks become distorted to an unknown extent. Distortion can also occur during photography and post-mortem procedures due to body movement and changes in position. Research studies have discussed the impact of Langer's lines (tension lines indicating collagen Fiber orientation) on bite mark appearance, noting that bites crossing these lines are more prone to distortion. The biting process and the skin's response to trauma can lead to further distortion due to edema and subsequent resorption.

Bite mark evidence contains valuable biological material, specifically DNA derived from leftover oral epithelial cells. However, the presence of nucleic acid-degrading enzymes in saliva, combined with the skin's temperature, can accelerate the degradation of DNA in living victims. Environmental factors also affect DNA integrity. Photographic distortion is another concern in bite mark analysis, particularly when the bite marks are not recorded with the American Board of Forensic Odontology (ABFO) scale at a 90° angle. Inadequate documentation may lead to photographic distortion. Some skin conditions, such as pityriasis rosea, can mimic bite marks, adding complexity to the analysis. Distinguishing bite mark patterns from those caused by animal or insect predation can also be challenging. Overlapping bite marks present further difficulties during comparison, and factors like clothing, bite force, and victim movement can affect the appearance of bite marks.

Bite marks undergo shape and clarity changes within a relatively short period, both in living individuals and after death. The time interval between the injury and examination can introduce distortion due to contraction and healing artifacts, particularly in cases of lacerations and

[26] DeVore DT, "Bite marks for identification? A preliminary report," Med Sci Law, 1971 Jul;11(3):144-145. (Last accessed on 04.07.2023 at 1.45 pm).

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abrasions. Such changes affect the dimensions and appearance of bite marks. Studies conducted using pig skin and human dentition have demonstrated that incorrect identifications increase significantly over time. Additionally, the skin and flesh undergo changes after death due to decomposition, animal predation, insect activity, and other environmental factors. Considering the inevitability of distortions, the comparison of bite marks on skin with dentition raises significant questions about its reliability in forensic analysis.

Forensic odontology in India:

A branch of forensic science identified as forensic odontology uses dental expertise to identify individuals and conduct legal investigations. Forensic dentistry is a relatively new but fast-growing specialty in India that has been extremely helpful in both criminal and civil matters.

Although forensic odontology has a long history in India, one of the oldest incidents of identification by teeth was recorded in 1191. The artificial anterior teeth on M. Raja Jayachandra Rathore of Canouj's body made it easy to identify him after he passed away on the battlefield. One of the first cases of dental identification in India is thought to have occurred in this case.

NIRBHAYA CASE (2013)[27] : **MUKESH & ANR VS STATE FOR NCT OF DELHI & ORS**[28]

The Nirbhaya case, also known as the Delhi gang rape case, which took place in 2012, is a notable and well-known case involving forensic odontology in India. On January 1, 2013, the Delhi Police requested assistance from the forensic odontology division in Dharwad in the "Nirbhaya" case, which occurred in New Delhi. The investigation of the bite marks discovered on the victim required assistance. The next day, a sub-inspector from the Vasant Vihar Police Station went to the SDM College of Dental Sciences & Hospital in Dharwad personally and handed over photos of the bite marks on the victim's body as well as dental models of five adult male suspects who were thought to be involved in the case. Bite marks are frequently discovered in sexual assault-related crimes and, like fingerprints, they might resemble the perpetrator's teeth. Five to six bite marks were found on the victim after inspection, which were meticulously verified and compared with the dental records of the five suspects. During the investigation, a 2D digital analysis on a computer was performed. A complete report that was delivered to the police after five days of investigation found that two of the suspects' dentition matched some of the bite marks. The doctor was called as an expert witness to the Saket Court in New Delhi on May 6, 2013, where the

[28] Mukesh & Anr v. State for NCT of Delhi & Ors, Criminal Appeal Nos. 607-608 of 2017

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defence attorneys cross-examined him. The honourable judge accepted the submitted testimony and report was significant in leading to the conviction of two of the defendants. Additionally, in its ruling on May 5, 2017, the Supreme Court of India upheld the analysis and report. The significance of forensic odontology in criminal investigations and legal proceedings is demonstrated in this case.

THE PAPER MILL COLONY CASE (2012):

In 2012, a startling incidence involving a horrifying crime against a woman took place in India. Visible bite marks on the victim's body were found, and these marks served as critical evidence in the inquiry. Odontologists were among the forensic specialists enlisted to examine the bite marks to compare them with the dental records of prospective suspects. The professionals were able to identify the distinctive features of the bite marks and associate them with a specific person by using cutting-edge dental examination techniques. The identification and conviction of the criminal guilty for the crime depended heavily on the forensic evidence.

THE PERUMBAVOOR CASE (2016):

The brutality of the Perumbavoor Case in Kerala, India, in 2016 horrified the entire country. The body of a young woman who had been raped and killed was discovered, and bite marks on it served as vital evidence in the investigation. To thoroughly investigate the bite marks and take teeth impressions of prospective suspects, forensic odontologists were called in. The experts were able to establish a direct connection between the bite marks discovered on the victim and the dental features of the perpetrator through thorough study and comparison. The authorities were able to identify and apprehend the criminal with the use of this crucial evidence, ensuring that he was held accountable for his acts in a court of law.

THE SKULLS OF ANNIGERI (KARNATAKA)[29]:

The Paper Mill Colony Case (2012): In 2012, a startling incidence involving a horrifying crime against a woman took place in India. Visible bite marks on the victim's body were found, and these marks served as critical evidence in the inquiry. Odontologists were among the forensic specialists enlisted to examine the bite marks to compare them with the dental records of prospective suspects. The professionals were able to identify the distinctive features of the bite

[29] The Hindu, "At Annigeri, a rare find of human skulls," available at: https://www.thehindu.com/news/national/karnataka/At-Annigeri-a-rare-find-of-human-skulls/article14938189.ece (last accessed on 03.07.2023 at 1.45 am).

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Forensic Odontology International:

In numerous international cases, forensic odontology has also been crucial in assisting with identification and offering important evidence. One such instance involved identifying **JOHN WILKES BOOTH**, the man who killed Abraham Lincoln. Following the killing, as Booth fled, there were claims that he managed to avoid capture. Booth's body was unearthed to confirm his death, and his family dentist, Dr. William Merill, recognized him based on his unusual jaw and the gold restorations he had only recently created for Booth. The identification of President John F. Kennedy's assassin Lee Harvey Oswald was another well-known instance in which forensic odontology was used. Two days after the murder, Oswald was found and later shot dead by Jack Ruby. When questions and rumours regarding Oswald's identity surfaced fourteen years later, his body was dug up and examined in 1981. Antemortem dental records were used by forensic odontologists to establish Oswald's identification and put an end to the rumours.

In cases of person identification in mass casualties or incidents involving prominent personalities, forensic odontology has also been applied. The identification of **SADDAM HUSSEIN'S SONS, UDAY AND QUSAY HUSSEIN,** who were murdered by the US forces in 2003, serves as an illustration of this. Dental records were used to identify the bodies despite being severely charred, demonstrating the significance of forensic odontology in such cases.

These instances highlight the important contributions forensic odontology has made both nationally and internationally, with a focus on its function in the administration of justice, identification, and criminal investigation.

In the case of **DOYLE V. STATE IN TEXAS**[30] in 1954, In a US court, dental evidence was used in an unconventional manner. The burglary suspect, Doyle, is suspected of leaving his teeth marks in a cheese slice that was only partially consumed. The evidence was examined by dentist Dr. William J. Kemp, a qualified dental expert for the State of Texas. The suspect was requested to bite into a different piece of cheese so that the bite marks could be compared. Dr. Kemp testified

[30] Doyle v. State in Texas, 263 S.W.2D 779 (1954)

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that Doyle was responsible for the crime because the bite patterns on both pieces of cheese matched. Forensic dentistry is a relatively new and developing subject in India. Despite having a long history in forensic science, the country is still in the early phases of applying scientific and technology approaches for crime detection and investigation as well as for the administration of justice. However, forensic odontology is proving to be extremely helpful in both criminal and civil cases, providing exciting chances for the legal system to advance[31].

STATE OF FLORIDA V. TED BUNDY[32]:

One notable case in Florida's legal history is the bite mark case involving Ted Bundy. This case played a significant role in solving the murder of Lisa Levy and Martha Bowman. On January 15, 1978, these two young girls were brutally killed using a wooden club. A witness saw a man with his face covered fleeing from the scene. The investigators were faced with a gruesome and merciless murder. Levy was strangled, beaten, and raped, while Bowman was strangled and severely beaten. Surprisingly, there were no signs of struggle, and the crime scene had been wiped clean, with the murder weapon missing. The investigators suspected that Ted Bundy, known for his accuracy, was responsible for these killings. However, in a court of law, evidence is essential, and mere presumptions are not sufficient. The investigators collected various pieces of evidence, including blood, some smudged prints, and sperm samples, but these were inconclusive. It was the recovery of a bite mark that became the centrepiece of evidence during the trial. The bite mark found on Lisa Levy's buttock and breast was carefully documented and photographed with a yellow scale as a reference. Dental impressions were taken from the suspects for comparison with the suspicious bite mark, but Bundy refused to cooperate. A search warrant was obtained, allowing investigators to obtain the impressions by any means necessary. Dr. Souviron, an experienced dentist, took photographs of Bundy's upper and lower jaw, noting the distinct uneven pattern. These dental photographs were then compared to the photographs of the impression on Lisa Levy's buttock, as it was more prominent than the one on her breast. The analysis focused on the shape of the teeth, their sharpness, the applied pressure, and the arrangement of the teeth, considering that the tissues near the impression had deteriorated over time. Peculiar features were identified, which contributed to Bundy being found guilty. The expert witness explained that the attacker had bitten twice, keeping the upper jaw in the same position while moving the lower jaw sideways. Bundy was ultimately sentenced to death by electric chair for his crimes. This case

[31] Bowers CM, "Problem-based analysis of bitemark misidentifications: the role of DNA," Forensic science international, 2006 May 15;159:S104-S109. (Last accessed on 05.07.2023 at 1.12 pm).
[32] State of Florida v. Ted Bundy, 479 U.S. 894 (1986)

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serves as an example of how bite mark evidence and expert testimony played a crucial role in securing a conviction[33].

SALEM WITCH TRIALS[34]:

In 1692, during the Salem Witch Trials, Rev. George Burroughs was accused of witchcraft and conspiring with the Devil, with biting his victims supposedly being evidence of his crimes. His bite marks and the bite marks of other people were compared to the victim's marks. The judges readily accepted the bite marks as evidence and this was the first time in what would become the United States that bite marks were used as evidence to solve a crime. He was later convicted and hanged. About two decades later, he was exonerated by the State, and his children were compensated for the wrongful execution.

GORRINGE CASE[35]:

One of the first published accounts involving a conviction based on bite marks as evidence was the "Gorringe case", in 1948, in which pathologist Keith Simpson used bite marks on the breast of the victim to seal a murder conviction against Robert Gorringe for the murder of his wife Phyllis. Another early case was Doyle's case which occurred in Texas in 1954. The bite mark, in this case, was on a piece of cheese found at the crime scene of a burglary. The defendant was later asked to bite another piece of cheese for comparison. A firearms examiner and a dentist evaluated the bite marks independently and both concluded that the marks were made by the same set of teeth. The conviction, in this case, set the stage for bite marks found on objects and skin to be used as evidence in future cases.

Another landmark case was **PEOPLE V. MARX**[36], which occurred in California in 1975. A woman was murdered by strangulation after being sexually assaulted. She was bitten several times on her nose. Walter Marx was identified as a suspect and dental impressions were made of his teeth. Impressions and photographs were also taken of the woman's injured nose. These samples along

[33] Kai Kreisköther, "Case Study," available at: https://www.researchgate.net/publication/261589036_Case_Study (last accessed on 02.07.2023 at 2.50 pm).
[34] University of Missouri-Kansas City (UMKC) School of Law, "The Salem Witchcraft Trials of 1692," available at: http://law2.umkc.edu/faculty/projects/ftrials/salem/SAL_ACCT.HTM (last accessed on 02.07.2023 at 2.45 pm).
[35] House of Lords, "Regina v. G & R (2003)," available at: https://publications.parliament.uk/pa/ld200304/ldjudgmt/jd040401/gorr-1.htm (last accessed on 02.07.2023 at 3.00 pm).
[36] Justia US Law, "People v. Jennings, 54 Cal. App. 3d 100 (Cal. Ct. App. 1975)," available at: https://law.justia.com/cases/california/court-of-appeal/3d/54/100.html (last accessed on 02.07.2023 at 2.23 pm).

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with other models and casts were evaluated using a variety of techniques, including two-dimensional and three-dimensional comparisons, and acetate overlays. Three experts testified that the bite marks on the woman's nose were indeed made by Marx and he was convicted of voluntary manslaughter.