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Review Article

TITLE - BITE MARKS – A VITAL INVESTIGATION IN THE FIELD OF FORENSIC MEDICINE AND FORENSIC ODONTOLOGY – SYSTEMATIC REVIEW.

Dr. Karthik Shunmugavelu[1], Dr P Vinod Kumar[2]*
[1]Senior Resident / Consultant Dental Surgeon / Consultant Oral and Maxillofacial Pathologist, Department of Dentistry/Oral and Maxillofacial Pathology, PSP Medical College Hospital and Research Institute Tambaram Kanchipuram Main Road Oragadam Panruti Kanchipuram district Tamilnadu 631604
[2]Associate Professor, Department of Forensic Medicine, Sree Balaji Medical College Chromepet Chennai

Abstract

Background

The application of dental knowledge, which is common among dental healthcare providers, to the fields of law enforcement and death investigations is known as forensic odontology.

Material and Methods

Major databases such as Medline were explored detailed literature search resulting in a systematic review of bite marks.

Results

Four original research scientific articles dated between 2020 – 2024 about bite marks were highlighted.

Conclusions

Forensic dentists are important in a variety of situations, even though postmortem dental identification is a well-known practice in cases when a deceased person cannot be recognized by traditional methods like fingerprints, scars, markings, tattoos, medical implants, and DNA. Detailed information regarding bite marks and their vital role in the field of forensic medicine and forensic odontology is discussed in this systematic review.

Keywords: *Forensic, Medicine, Odontology, Bite Marks, Legal*
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Corresponding author: *Dr.Karthik Shunmugavelu**
Email: drkarthiks1981@gmail.com
Senior Resident / Consultant Dental Surgeon / Consultant Oral and Maxillofacial Pathologist, Department of Dentistry/Oral and Maxillofacial Pathology, PSP Medical College Hospital and Research Institute Tambaram Kanchipuram Main Road Oragadam Panruti Kanchipuram district Tamilnadu 631604

Introduction:

Forensic dentists are commonly called upon to carry out activities such as assessing the age of persons, both living and deceased, in addition to the common dental identification procedure that occurs after death. They also participate in bite mark assessments and offer their assistance in civil lawsuit situations. The latter entails ascertaining if a mark is the consequence of a bite and, if it is, identifying the person or animal accountable for leaving the mark on a surface, such as the skin of a human being or an inanimate object. This complex engagement highlights the wide range of uses for forensic odontology outside of its usual use for postmortem dental identification.

Material and Methods

"Bite" "forensic" AND "legal" were the words used in the MEDLINE database using an advanced search strategy targeting different article categories between 2020 to 2024. The result was 37 articles, out of which we selected 4 articles based on the inclusion criteria. The inclusion criteria were case studies and scientific literature between 2020-2024. The exclusion criteria were of scientific literature devoid of scientific literature irrelevant to the specific search 'Bite Marks'.

This systematic review was conducted to determine the importance of bite marks following the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PubMed, Lilacs, Embase, Scopus, and Web of Science were the sources of electronic databases. The search strategy used Boolean operators (AND and OR): [ALL ("Bite marks") AND (forensic OR medicine OR odontology OR legal OR judiciary OR evidence) AND (crime)]. The following data were collected: first author, year, country of study, type of study, and outcome. The quality of studies was assessed using the STROBE (Strengthening the Reporting of Observational Studies) checklist.

Results

Four articles were included in this systematic review based on the selection criteria and PRISMA flow chart. We analyzed and mentioned the four articles reviewed. This included only relevant research articles and excluded articles about nonspecific search terms.

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Author	Title	Journal	Outcome
Cardoza A.	Forensic Odontology and Bite Mark Analysis: Understanding the Debate.	Journal of the California Dental Association. 2023 Dec 31;51(1):2210332.	Vital tool
Dr. Mohammad Abdurrahman Khan, Dr. Manisha Verma, Prof. Dr. Anoop Kumar Verma, Prof. Dr. Anjani Kumar Pathak	Analysis and Identification of Bite Marks in Forensic Odontology-A Review Article,	IJDSIR- August - 2022, Vol. – 5, Issue - 4, P. No. 28 – 37.	Medicolegal
Kaleelullah RA, Hamid P.	Forensic Odontology, a Boon and a Humanitarian Tool: A Literature Review.	Cureus. 2020 Mar 24;12(3):e7400.	Criminal investigation
Sultan, Amina; Sengar, Poonam; Juneja, Akanksha; Karim, Bushra Ahmad; Sharma, Anuradha. Evaluating the knowledge and perception of electronic health records and computer-based patient maintenance among dental professionals.	Evaluating the knowledge and perception of electronic health records and computer-based patient maintenance among dental professionals.	SRM Journal of Research in Dental Sciences. 2023 Dec;14(4):157-164.	Electronic dental record

Table 1 – An overview

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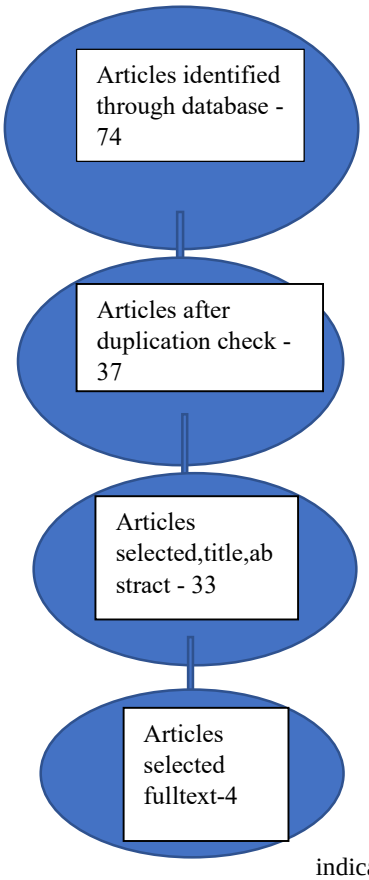
Figure 1 – PRISMA flowchart



DISCUSSION

HISTORY OF FORENSIC ODONTOLOGY IN VICTIM IDENTIFICATION

The Agrippina and Lollia Paulina cases, which occurred in 49 AD, marked the beginning of ancient dental identification. After Lollia passed away, her teeth were found to have some distinguishing characteristics that allowed for her identification (1). Luntz gave a case concerning Warren, a man who was assassinated by the British and for whom Paul Evere had done ivory denture work. This was the dentist's first identification case (2).

General Zia-ul-Haq, the late President of Pakistan, was recognized from his dental records after he perished in an aircraft accident in 1988. An example of a mass catastrophe dental identification occurred after the Charity Bazaar fire in Paris when antemortem (AM) and postmortem (PM) dental data were compared to identify the deceased (3).

2004 saw the successful identification of Tsunami victims in southeast Asia via forensic odontology (4). Dental data were also used to identify the late Indian Prime Minister who was assassinated in a terrorist strike (5). There is a wealth of historical data demonstrating the significant influence that forensic odontology has had as an identifying technique (6).

HISTORY OF FORENSIC ODONTOLOGY IN CRIMINAL INVESTIGATION

Modern bite mark investigations originated with the 1975 People vs. Marx case in Los Angeles, CA, where evidence indicated that the victim had been bitten on the bridge of her nose. The prosecution presented suspect biter/bite mark evidence in the trial, marking the introduction of this evidence as a "novel" scientific approach. The defense subjected the bite mark evidence to a Kelly-Frye scientific evidence challenge, a standard that requires new scientific techniques to be widely accepted in the relevant scientific community for admissibility. Despite the challenge, the court upheld the use of bite mark evidence, contributing to the suspect's murder conviction. (7)

In the subsequent appeal, the bite mark evidence faced another challenge, but it was accepted by the appellate court. This successful appeal set a precedent for the use of bite mark analysis and testimony in courts across all 50 states, establishing its credibility and admissibility in future cases. (7)

The People v. Bundy case in Florida in 1978 greatly increased the importance of bite mark evidence, but the Marx verdict set the legal standard for its use in U.S. courts. Ted Bundy bit a victim in the buttocks during his murderous attack on a sorority home (see Figure 4). This bite mark was a major factor in Bundy's murder trial, which resulted in his conviction and execution. Bundy conceded that the bite mark evidence was important. Bite mark analysis gained widespread acceptance and was employed in the court system as a result of the attention this high-profile case generated; this marked its mainstream adoption from that time until the 2000s. (7)

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THE EXAMINATION, COMPARISON, AND ASSESSMENT OF BITE MARKS

Analyzing and assessing bite marks in forensic investigations involves considering various factors that influence their significance. It is crucial to examine only those marks displaying at least the class characteristics of the biter. Even seemingly less significant bite marks can contribute to an investigation, particularly in cases like child abuse, where distinguishing accidental from non-accidental injuries is challenging. (8)

The American Board of Forensic Odontology offers distinct conclusions for identifying a bite mark:

- Exclusion: The injury is not a bite mark.
- Possible bite mark: The injury pattern may or may not be caused by teeth, but biting cannot be ruled out.
- Probable bite mark: The pattern strongly suggests origin from teeth but could conceivably be caused by something else.
- Definite bite mark: There is no reasonable doubt that teeth created the pattern. (9)

The initial analysis focuses on determining whether the injury is indeed a bite mark, followed by providing a statement on its forensic significance. During evaluation, it is essential to ascertain the cause of the mark, considering that bite marks may be inflicted by both humans and nonhumans. (10)

Human incisor teeth create rectangular marks, while canine teeth produce triangular marks in cross-sections. Animal bites, such as those from dogs or cats, typically result in small, circular punctures in the skin, with a potentially greater number of incisor teeth and increased spacing between them. (8)

The size of dental arches varies, with adult arch widths ranging from 2.5 to 4cm between canines. Children's arches are smaller than adults, and "dogs' and cats" arches are smaller than those of children.

When evaluating bite mark photographs, it is crucial to thoroughly analyze both in vivo and in vitro aspects, rather than relying solely on superimposing marks in photographs onto models.

In arch evaluation, noting the shape of the arch and establishing central lines for upper and lower arches is essential. Suction marks at the center of arch marks were once considered indicative of human bite marks, but it is now understood that these marks may result from injury to blood vessels compressed between the biter's jaws.

To identify characteristics within the arch marks, it is necessary to determine the occlusal level of specific teeth or sharp cusps. Recognizing tooth numbers, noting the placement of tooth marks in the arch, and identifying missing teeth are crucial aspects of mark evaluation. (8)

For dentists dealing with potential bite mark evidence, swift action is crucial. When encountering suspected bite marks:

- Saliva Swabs: Use the double swab technique to collect saliva. Air-dry swabs for 45 minutes before submitting them for testing. (11)
- Photographs: Capture extensive photos using an intra-oral camera having the long axis of the lens perpendicular to the surface. Include a reference scale for measurements. (8,12)
- Impression: Create an accurate impression using recommended dental materials. (8,12)
- Record Injury Details: Make notes on appearance, color, size, and orientation. Differentiate between marks from upper and lower teeth.

DNA Collection

Collect saliva or blood samples from the victim. Submit the samples promptly to preserve their forensic value. Immediate and precise evidence collection is essential for conducting effective forensic analysis. (8)

In forensic physical comparison of exhibits, common methods involve comparing suspect teeth patterns with life-sized photographs of injuries using transparent overlays. Computer-based methods are considered the most accurate. Other techniques include direct comparison of study casts, test bites, and the use of radiographic imaging. Despite efforts to standardize procedures, conclusions often rely on expert judgment, leading to disputes and challenges to the scientific basis (13).

The American Board of Forensic Odontology aims to establish guidelines, involving independent examination by multiple odontologists. Challenges persist due to differing expert opinions, skin elasticity, and debates over dental uniqueness. (9)

Regarding the bitemark severity index, ranging from 1 to 6, it measures severity but faces challenges such as low knowledge levels among crime scene officers. The scale's highest forensic significance lies in the middle (3 and 4), while the extremes have lower significance. Education on using the index is crucial for accurate forensic assessment. (8,14)

OPTOGENETICS

Teeth, encased in a protective calcified structure, are a prime source of DNA due to their resilience against environmental challenges. A single tooth, when morphologically assessed, yields valuable information about the individual. Dental tissues, resistant to incineration, immersion, trauma, and mutilation, make teeth an excellent DNA source. Genomic DNA, extracted from dentin, enamel, or pulp, is commonly used for forensic applications(15). Mitochondrial DNA (mtDNA), maternally inherited, serves in identifying siblings when genomic DNA is unavailable. Schwartz et al. (1991) demonstrated the resilience of teeth's high molecular weight (HMW) protein under adverse conditions, affirming teeth's protective role for DNA (16). Polymerase chain reaction (PCR) amplifies isolated DNA for identification, with only 2%-5% of genes coding for proteins, while polymorphisms in the noncoding portion correlate with individuals. Radicular pulp tissue and various dental structures provide alternative DNA sources

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(17). Techniques, including horizontal sectioning through the cervical route, are employed for DNA extraction, crucial for morphological identification (18). DNA fingerprinting is a powerful method for molecular-level DNA analysis. Dental identification in mass disasters involves comparing antemortem (AM) and postmortem (PM) records (19). Historical dental identification considered factors like orthograde filling, carious and noncarious teeth, and dental extractions [16]. Microanatomy is crucial in DNA extraction for identifying degraded human remains. Adapting techniques to remove enamel, cementum, and pulp is essential under adverse conditions. Mitochondrial DNA's fragmented pattern across tissues enhances estimating DNA survival in forensic specimens. (15)

DENTAL ANALYSIS IN SEX DETERMINATION

Dental indices, like the incisor, mandibular canine, and crown indices, are derived from linear tooth measurements and can be utilized for sex identification. The most significant dimensional difference between males and females is observed in mandibular canines. Sex determination also involves using crown diameters and the combination of root length. Nonmetric features such as the digital accessory ridge, Carabelli's trait in upper molars, and shoveling of upper central incisors are occasionally employed for this purpose. The pronounced digital accessory ridge in canines is more prominent in males, while females generally have fewer cusps in the mandibular first molar. The presence of bar bodies in tooth pulp aids in distinguishing between males and females. Vemuri et al. conducted a study at different temperatures, revealing fibroblast differences and chromatin condensation in females. Amelogenin or 'Amell,' a human enamel protein, exhibits distinct patterns between males and females. The 'Amell' gene is located on the X and Y chromosomes in males, while females have two ALEL genes on the X chromosome (20).

ODONTOGENETICS IN BLOOD GROUPING

Each person possesses a distinct blood group, and beyond blood itself, blood group antigens are also found in bodily fluids such as semen, sweat, amniotic fluid, and saliva. Given the abundance of blood vessels in the tooth pulp, it is highly likely that blood group antigens are present in this dental component. Research by Ballal and David demonstrated a correlation between the blood group extracted from dentine and pulp and that obtained from the extraction socket. Pulp changes during post-mortem intervals are observed belatedly, with the tooth cavity providing protection, rendering pulp tissues highly effective for blood group identification. ABO blood grouping and Rh typing are commonly conducted through absorption-elution or absorption-inhibition methods (15,21,22).

Aswath et al. conducted a study focusing on the sensitivity and specificity of dental pulp in discerning ABO blood group and Rh factor (23). Another investigation by Sasmita et al. involved comparing blood grouping results obtained from the deciduous teeth of children to those of their parents, yielding significantly positive outcomes. This established a clear correlation between a child's DNA and that of their parent. In contrast, Kramer's research revealed that attempting to detect blood grouping from cardiac-related sources like dentine and enamel proved to be unreliable and inefficient. The potential reason behind this inconsistency may be attributed to the calcification of these tissues (24).

ODONTOGENETICS IN AGE ESTIMATION

Age estimation holds significant importance in the realm of identifying individuals. Dental maturity, being unaffected by nutritional and endocrine status, serves as a reliable tool for identification purposes. The process of age estimation encompasses various methods, including anthropometric measurements, skeletal maturation, dental age estimation, and a combination of dental development with anthropometric measurements (15).

Several techniques are employed for age determination, starting with the eruption of primary teeth between 6 to 30 months, and their subsequent exfoliation serves as a means to estimate a child's age. Moorrees et al.'s seminal publications remain widely regarded as the most dependable data in this domain (25). Morris utilized stages of root resorption for age estimation, and Gordon et al. introduced a globally accepted classification system based on schematic diagrams (26). Factors considered in age determination include the appearance of a tooth gem, earliest detectable mineralization, degree of completion of an un-erupted tooth, rate of enamel formation, presence of neonatal lines, crown attrition, and transparency of root dentine (27).

In dentine, incremental lines such as Vonebener's and contour lines like Owen's are utilized to estimate the age of fetuses and deceased individuals. The size of the pulp chamber serves as an indicator of secondary dentine formation, with Moore using the pulp chamber diameter ratio in conjunction with the crown diameter to estimate age (28). The full eruption of third molars suggests an age above 17 years, while incomplete root formation, as observed in X-rays, suggests an age likely below 25 years (29).

Gustafson introduced a set of six dental changes associated with age, including attrition, apical migration of the periodontal ligament, deposition of secondary dentin, cemental opposition, root resorption, and transparency of root dentine. Age estimation was conducted using a specific formula (30,31).

The formula Age = 11.43 + 4.56x, where x represents the total score, demonstrates a positive correlation between an increase in the total score and advancing age. Gustafson's 1950 study delved into dental changes in individuals, allowing for reasonably accurate age estimation (31). As individuals age, the transformation of L-aspartic acid to D-aspartic acid occurs (30).

In the investigation by Foti et al., age identification in both living and deceased children was explored using linear regression. The application of their formula relies on factors such as the total number of erupted teeth, the type

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of tooth germ observed during clinical examination, and radiographic findings. Kvaal et al. emphasized that the intensity of fluorescence can estimate the color of human dentin and cementum, contributing to the "half technique" age identification formula, which is applicable up to 20 years of age (32,33).

Mandibular canines, with the most notable dimensional difference in males, become indicative of an estimated age of 12 years (34). Historical records underscore the historical importance of age identification in living adolescents. In ancient settings, the eruption of the second molar was considered a criterion for judging adults as fit for service (35).

Teeth play a crucial role in determining an individual's race, with distinct characteristics aiding in race estimation. Caucasians, in particular, exhibit a high prevalence of certain dental features. Carabelli's work supports the simplification of the Fisher system for race determination. On the contrary, Asians often present a high prevalence of shovel incisors and a complex Fisher system, contributing to the intricate nature of race identification (15).

Evaluations encompassing socioeconomic status, personal habits, oral health, and occupation provide valuable insights into an individual's dental condition. Individuals with low-income status often exhibit poorly maintained teeth, a higher prevalence of cavities, inadequate fillings, and prosthetic replacements made from economical materials. Conversely, individuals with higher income levels typically display well-treated, aesthetically pleasing teeth. The presence of orthodontic appliances may serve as an indicator of high-income status. (15)

Certain dental issues, such as open bite, crossbite, and protruded incisors, may suggest inappropriate habits, like thumb-sucking in children. Personal habits like smoking and tobacco chewing can also contribute to identifying dental problems. Defects related to dental health, arising from conditions like bulimia and anorexia, manifest as erosive changes in the teeth. These changes are often evident in the upper and lower incisal edges of incisors. (15)

Occupational factors also play a role, with specific professions showing distinct dental wear patterns. For instance, glass blowers, shoemakers, and musicians who play wind instruments may exhibit attrition on the incisal edges. Additionally, the cavity index can serve as an indicator of dietary habits, revealing whether an individual consumes more carbohydrates or sugars, leading to a higher incidence of cavities (36).

The unique human occlusion profile offers a small hyper variation that can be utilized to establish a database, although it lacks the constancy observed in DNA over a lifetime. In ancient history, bite marks served as a means of individual identification. Notably, William the Conqueror authenticated royal documents by imprinting his characteristic bite marks into wax seals. In Britain and Europe, debtors working as servants verified their identity through bite marks instead of signatures. (15)

Identifying and reporting a bite mark involves crucial steps such as recognition, documentation, preservation, dental profiling of both evidence and suspect, DNA profiling via salivary swabs, and the subsequent reporting of vital evidence. The American Board of Forensic Odontology's (ABFO) No. 2 standard reference scale is widely acknowledged in forensic science, serving as a geometric reference scale for reconstructing bite marks, skin trauma, scenes, or objects from images. (9)

Various methods, including fingerprints, dusting powder, 3D laser scanning of dental casts, confocal scanning, and electron microscopy, are employed to physically compare suspect dentition with bite mark injuries. Van der Waals et al. proposed analyzing bite marks using image perception technology, demonstrating the possibility of coloring areas with equal intensity values to depict a 2D image as a pseudo-3D surface object. (15)

Guidelines from organizations like the ABFO and the British Association of Forensic Odontology recommend evidence collection from both victims and suspects, with deviations from these recommendations subject to scrutiny. It is crucial to avoid overestimating the value of bite marks, as they are not as reliable as DNA in identification processes (37).

Engaging in comparative dental identification requires meticulous attention to detail due to the intricacies involved in the process. Utilizing antemortem (AM) records, such as case history, radiographs, photographs, full mouth impressions, and an assessment of the presence or absence of pathologies and periodontal health, proves instrumental in positively identifying diseases when contrasted with post-mortem (PM) findings. In situations where AM dental records are unavailable and alternative identification methods are impractical, PM dental profiling becomes a viable option (18).

The examination of an individual's teeth and the condition of the oral cavity offers valuable insights into various aspects, including socioeconomic status, sex, ancestry background, and dietary habits. This comprehensive approach aids in unraveling a multitude of information about an individual (15).

Conclusion

Bite Marks Analysis is integral to forensic dentistry, aiding in crime resolution and the identification of individuals involved in criminal activities, even in post-mortem cases. Forensic dentists play a crucial role in handling dental evidence, contributing significantly to law enforcement efforts in criminal and civil cases, particularly in medicolegal conditions. (8) Collaboration with forensic pathologists is key, as dental evidence stands out as a reliable method in autopsies.

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There was no source of funding

CONFLICT OF INTEREST

There was no conflict of interest

AUTHOR BIOGRAPHY

Dr. Karthik Shunmugavelu (Corresponding author)
BDS, MDS OMFP, MSC LONDON, MFDSRCS ENGLAND, MFDSRCPS GLASGOW, FACULTY AFFILIATE RCS IRELAND, AFFILIATE RCS EDINBURGH, MCIP, FIBMS USA, MASID AUSTRALIA
Senior Resident / Consultant Dental Surgeon / Consultant Oral and Maxillofacial Pathologist, Department of Dentistry/Oral and Maxillofacial Pathology, PSP Medical College Hospital and Research Institute Tambaram Kanchipuram Main Road Oragadam Panruti Kanchipuram district Tamilnadu 631604
Mobile 0091-9789885622/9840023697
https://orcid.org/0000-0001-7562-8802

Dr P Vinod Kumar
MBBS, D.DVL, MD FM
Associate Professor, Department of Forensic Medicine
Sree Balaji Medical College Chromepet Chennai
pv25kumar@gmail.com
9444786753

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