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# BITE MARK ANALYSIS IN FORENSIC INVESTIGATIONS: A COMPREHENSIVE CRITICAL REVIEW

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**ABSTRACT** Bite mark analysis occupies a unique and contentious position within forensic science, representing both a historically significant identification method and a cautionary tale about the need for scientific rigor in forensic disciplines. This comprehensive review traces the evolution of bite mark evidence from its ancient origins through its heyday in late 20th century criminal investigations to its current status as a heavily scrutinized methodology. We examine the anatomical foundations of bite mark analysis, classification systems, standardized protocols, and the growing body of research challenging its fundamental assumptions. While bite mark evidence played prominent roles in landmark cases like the Ted Bundy trial, modern forensic science has revealed significant limitations in its reliability and validity. The review concludes with an evidence-based assessment of current best practices and future directions, emphasizing the need for either substantial methodological reform or replacement with more scientifically validated techniques.

**KEYWORDS :** Forensic odontology, Bite mark analysis, Dental pattern identification

## INTRODUCTION

Bite mark analysis has long held a significant place in forensic odontology, serving as a valuable tool in criminal investigations—particularly in cases involving violent crimes such as sexual assaults, child abuse, and homicides. The foundational premise of this technique lies in the belief that human dentition is sufficiently unique to allow for individual identification, and that bite patterns can be transferred and preserved on skin or other substrates during an assault[1] [2]. Over the decades, bite marks have been instrumental in narrowing suspect pools, corroborating victim statements, and, in some cases, contributing to convictions where other forms of evidence were limited[3].

In forensic investigations, bite marks are often among the few forms of physical evidence left on a victim, making their proper identification and interpretation critical. Organizations such as the American Board of Forensic Odontology (ABFO) have established guidelines for analyzing these injuries, defining bite marks as patterned injuries resulting from contact with dental structures[4]. The method gained widespread acceptance through its successful application in high-profile cases and was once considered a powerful form of physical evidence.

Bite mark analysis has faced growing criticism due to its limited scientific support, with concerns about examiner variability, subjective interpretation, and susceptibility to cognitive bias[5–7]. These issues have contributed to wrongful convictions, with at least 26 cases documented by the Innocence Project where bite mark evidence played a key role[8].

This review explores the historical development, forensic relevance, and current challenges of bite mark analysis. It aims to provide a balanced perspective on the technique's role in forensic investigations, critically assessing its strengths and limitations, and offering evidence-based recommendations for future practice in light of advancing scientific standards.

### Historical Development

The use of dental evidence in identification contexts traces back to ancient civilizations, with the earliest recorded case occurring in 66 AD when Agrippina identified her murdered lover through distinctive dental features[9]. During the European witch trials of the Middle Ages and Renaissance, bite marks featured prominently as supposed evidence of supernatural activity, most notably in the 1692 Salem Witch Trials where bite mark comparisons helped convict several accused witches[10]. These early applications, while lacking scientific basis, established the cultural precedent for viewing bite marks as evidentiary objects.

Modern forensic odontology began taking shape in the late 19th century when Dr. Oscar Amoedo documented the use of dental characteristics to identify victims of the 1897 Paris charity bazaar fire[11]. The 20th century saw bite mark analysis evolve into a systematic forensic discipline, with several landmark developments establishing its role in criminal investigations. In 1954, bite mark evidence secured its first U.S. conviction in Doyle v. Texas, setting an important legal precedent[12]. The 1975 establishment of the American Board of Forensic Odontology (ABFO) created an institutional framework for standardizing practices and certifying practitioners[13]. Perhaps most famously, bite mark evidence played a pivotal role in the 1980 conviction of serial killer Ted Bundy, bringing the technique to widespread public attention[14].

The ABFO's 1999 publication of formal guidelines for bite mark analysis represented an attempt to professionalize and standardize the discipline[15]. However, these efforts failed to address growing scientific concerns about the method's reliability. The 2009 National Academy of Sciences report delivered a devastating critique, finding that "no scientific studies support the two key premises of bite mark analysis: that human dentition is unique and that this uniqueness transfers predictably to human skin"[16]. Subsequent reviews by the Texas Forensic Science Commission (2016) and the President's Council of Advisors on Science and Technology (2016) recommended severe restrictions on bite mark testimony, with some experts advocating for its complete

discontinuation[17–18]. Currently, while some jurisdictions continue to admit bite mark evidence, its use has declined significantly in favor of more reliable forensic methods like DNA analysis[19].

### Classification And Morphological Characteristics

Bite marks demonstrate considerable variability in appearance and characteristics depending on multiple factors including the biting force, anatomical location, and the properties of the bitten material.

MacDonald's classification system provides a useful framework for categorizing bite marks based on their mechanical formation[20].

- Type 1, or tooth pressure marks, result from direct compressive forces and typically present as well-defined indentations corresponding to the biting edges of teeth.
- Type 2, tongue pressure marks, occur when suction forces create characteristic bruising patterns between the dental arches.
- Type 3, tooth scrape marks, appear as linear abrasions caused by teeth dragging across a surface[21].

This classification system, while helpful for descriptive purposes, does not address the critical issue of individualization potential.

Human bite marks typically present as elliptical or ovoid patterns measuring 25–50 mm in diameter, though significant variation occurs based on the biter's dental anatomy and the bitten material's properties[22].

The ABFO identifies several key characteristics used in analysis: the overall arch form, presence of individual tooth marks (with incisors typically creating rectangular impressions), and any unique dental features such as rotations, spacing abnormalities, or restorations[23]. Central ecchymosis (bruising) often appears in bite marks due to tongue pressure during the biting action, sometimes creating a distinctive "negative space" between the upper and lower dental arches[24].The biomechanical properties of skin significantly affect bite mark appearance and persistence. Research demonstrates that bite marks on highly elastic tissues like cheeks often show poor definition, while marks on more fixed tissues like breasts or back skin tend to retain better detail[25]. Postmortem changes further complicate analysis, with factors like livor mortis, decomposition, and tissue desiccation potentially altering mark characteristics over time[26]. These variables create substantial challenges for accurate pattern analysis and comparison, particularly when dealing with marks on living victims where the appearance changes rapidly due to healing processes[27].

### Forensic Examination Protocol

Proper bite mark analysis requires strict adherence to standardized protocols designed to maximize evidentiary value while minimizing potential errors. The examination process typically involves three phases: documentation of the bite mark, collection of comparative evidence from suspects, and analytical comparison[28].

### Victim Documentation Protocol

Photographic documentation forms the cornerstone of bite mark evidence collection. Best practices mandate using an ABFO No. 2 scale placed in the same plane as the injury, with images captured at 90° perpendicular angles to minimize distortion[29]. Multiple lighting conditions (including oblique, direct, and alternative light sources) help reveal subtle details, while both color and black-and-white photography provide complementary information[30]. For living victims, serial photography at 24-hour intervals documents the mark's evolution, as bruising patterns often change significantly during healing[31].

Saliva DNA collection employs the double swab technique: a first moistened swab rehydrates cellular material followed by a dry swab to collect residual moisture[32]. After air-drying, swabs should be stored in breathable paper envelopes at refrigeration temperatures to prevent DNA degradation[33]. Control samples from unbitten areas help distinguish the biter's DNA from the victim's own genetic material[34]. Three-dimensional bite marks require impression techniques using materials like polyvinyl siloxane that capture fine detail without distorting the tissue[35]. Subsequent casting in dental stone creates permanent models for analysis, though practitioners must carefully document the materials' expiration dates and lot numbers to address potential chain-of-custody challenges[36].

### Suspect Examination Protocol

When investigators identify a suspect, forensic odontologists conduct comprehensive dental examinations to obtain comparison data. This includes detailed clinical examinations, and the creation of study models using high-quality dental stone[37]. Bite registrations help document the suspect's occlusal patterns, while both extraoral and intraoral photographs provide visual references[38].

Saliva samples collected from suspects enable DNA comparison with biological material recovered from bite marks. The collection protocol mirrors that used for victims, emphasizing proper drying and storage to preserve sample integrity[39]. Recent advancements in DNA analysis now permit recovery of usable genetic material from increasingly small or degraded samples, though contamination risks remain a significant concern[40].

### Analytical Comparison Methods

Bite mark analysis employs two primary comparison methodologies: metric analysis and pattern association. Metric analysis involves precise measurements of features like intercanine width, tooth dimensions, and arch form parameters[41]. Computer-assisted measurement tools can enhance precision, though their accuracy remains limited by the quality of the original bite mark documentation[42].

Pattern association techniques compare the overall arrangement of tooth marks through either manual overlay methods (using transparent acetate sheets) or digital superimposition approaches[43]. Recent studies demonstrate that digital methods using software like Adobe Photoshop® reduce some subjective biases inherent in manual comparisons, though they cannot compensate for fundamental issues like skin distortion[44].

The bite mark exhibited distinct arch and class characteristics typical of a human dental arch, with clear impressions of both anterior and posterior teeth. Analysis revealed several individual features, including rotation of the upper right central incisor, spacing between the upper left lateral incisor and canine, buccal displacement of the upper left lateral incisor, and notching and mottling on specific teeth. These unique traits closely matched the suspect's dentition as analysis was carried out using an indirect comparison method, suggesting a strong forensic correlation. However, precise metric analysis was limited due to the absence of scale in the initial photographs taken by police authorities and the healing observed in images taken two months later. Despite these limitations, the findings support the conclusion that the suspect is likely the biter. The analysis was carried out using an indirect comparison method.

### Scientific Limitations And Controversies

Despite its historical use in criminal prosecutions, bite mark

analysis faces substantial and growing scientific criticism regarding its validity and reliability. These concerns center on three fundamental issues: the assumption of dental uniqueness, the reliability of pattern transfer to skin, and the subjectivity of analysis methods. Research challenging the uniqueness assumption demonstrates significant overlap in dental patterns within populations. A 2012 study found that certain dental characteristics previously considered unique actually appeared in up to 20% of examined populations[45]. Even distinctive features like rotated teeth or unusual spacing patterns showed substantial recurrence when examining large sample sizes[46]. These findings directly undermine bite mark analysis's foundational premise that dental configurations can reliably individualize perpetrators.Skin distortion presents another critical limitation. Biomechanical studies show that biting forces can alter mark dimensions by up to 40% depending on tissue properties, bite force, and anatomical location[47]. This distortion variability makes accurate pattern matching extremely challenging, particularly when comparing marks from different body regions or created under differing mechanical conditions[48]. Postmortem changes introduce additional complications, with decomposition processes potentially obscuring or altering bite mark features[49].

Examiner subjectivity constitutes perhaps the most damning criticism. Proficiency testing reveals alarmingly high rates of disagreement among qualified analysts, with one study showing only 33% consensus on whether specific marks even qualified as human bites[50]. Cognitive biases like contextual information effects and confirmation bias further compromise analysis reliability, as demonstrated by studies showing analysts' conclusions vary based on unrelated case details provided to them[51].

These scientific limitations have produced significant legal consequences. The 2004 exoneration of Ray Krone (Arizona v. Krone) marked the first DNA-based overturning of a bite mark conviction, with subsequent exonerations revealing systemic issues in bite mark analysis practice[52]. Court decisions like Brewer v. State (Mississippi, 2012) and People v. Collins (California, 2016) have increasingly limited bite mark testimony, with some jurisdictions now requiring explicit warnings about its limitations[53–54]. The cumulative weight of scientific criticism and wrongful convictions has led many forensic practitioners to conclude that bite mark evidence should be restricted to exclusionary purposes rather than positive identification[55].

### Emerging Technologies And Future Directions

Recent technological advancements aim to address some limitations of traditional bite mark analysis, though significant challenges remain. Three-dimensional imaging techniques like structured light scanning now permit detailed volumetric documentation of bite marks, potentially reducing distortion artifacts inherent in photographic methods[56]. When combined with computer-assisted comparison algorithms, these approaches show promise for improving analysis objectivity, though validation studies remain limited[57]. Biomechanical modeling represents another promising direction. Finite element analysis allows simulation of tissue deformation under biting forces, potentially enabling distortion correction in bite mark patterns[58]. Early-stage research into computational biting dynamics may eventually permit more accurate reconstruction of original dental patterns from distorted skin marks[59]. However, these techniques currently lack the precision required for courtroom applications.

DNA analysis advancements have arguably had the greatest impact on bite mark evidence. Modern techniques can recover usable DNA profiles from increasingly small or degraded saliva samples, often making biological analysis more reliable than pattern matching[60]. Emerging methods like salivary microbiome profiling may provide additional identification tools, though their forensic applications remain experimental[61].

The future of bite mark analysis likely lies in one of two directions: either substantial methodological reform with rigorous scientific validation, or gradual replacement by more reliable forensic techniques.

### For The Field To Regain Scientific Credibility, It Must Address Several Critical Needs:

- Conducting large-scale population studies to validate the uniqueness of dental patterns
- Developing standardized protocols for correcting image distortion
- Implementing objective comparison methods with clearly defined error rates
- Integrating bite mark analysis with other forensic disciplines to overcome its limitations

Until such reforms occur, the most prudent approach may involve using bite marks only for investigative leads or exclusionary purposes rather than positive identifications[62]. The growing availability of alternative identification methods like DNA analysis reduces reliance on bite mark evidence while providing more scientifically valid results[62].

## CONCLUSION

Bite mark analysis has long held an important place in forensic science, particularly in cases involving violent assaults where patterned injuries can serve as critical evidence. Its capacity to reveal distinguishing dental traits has contributed to suspect narrowing and investigative direction, especially when corroborated by other forms of evidence. When carefully applied within a multidisciplinary framework, bite mark analysis can provide valuable insights into the nature and mechanism of injury, offering contextual support in complex forensic cases.

However, despite its historical significance and practical utility, the technique continues to face challenges regarding its scientific reliability for definitive identification.

Inconclusive validation studies, subjective interpretation, and the lack of standardized protocols have led to growing skepticism about its admissibility and weight in criminal proceedings.

Looking ahead, the future of bite mark analysis lies in embracing technological advancements such as high-resolution digital imaging, 3D reconstruction, machine learning algorithms, and population-based dental pattern databases. These innovations could significantly improve objectivity, reproducibility, and evidentiary strength. With rigorous methodological reform and interdisciplinary integration, bite mark analysis may continue to evolve into a more scientifically robust tool within modern forensic practice.

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