

# Impact of Postmortem Decomposition and Secondary Trauma on the Preservation of Tool Marks in Bone and Cartilage

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## Abstract

Marks left by tools on bone and cartilage provide essential forensic evidence in cases of homicide, revealing details about the weapons involved and the sequence of the assault. However, changes occurring after death, including natural decay and additional damage from factors such as heat exposure, water submersion, animal activity, autopsy procedures, and improper handling, often alter these marks by blurring fine scratches, changing cut widths, and creating misleading patterns that reduce their reliability for analysis and court decisions. This legal review identifies a significant gap in current scholarship: while forensic studies explain the formation of such marks in detail, few analyses connect patterns of post-death alteration to legal standards for evidence acceptance, particularly in light of India's recent criminal laws such as the *Bharatiya Sakshya Adhinyam, 2023*, *Bharatiya Nagarik Suraksha Sanhita, 2023*, and *Bharatiya Nyaya Sanhita, 2023*. Relying solely on statutes, landmark cases including *State of Maharashtra v. Suresh (2001)* and *Selvi v. State of Karnataka (2010)*, established guidelines from NIJ and OSAC, and micro-CT imaging mechanism, this study-based examination avoids original data collection. Results show the Indian courts' heavy dependence on expert opinions without specific measures for degraded evidence, in contrast to reliability requirements under Daubert in global jurisprudence. Recommendations include required initial 3D imaging, clear protocols for identifying false marks, adapted reliability tests, training for judges in bone forensics, and updates to BNSS for decay assessments. These steps would improve evidence strength, prevent errors in interpretation, lower risks of unjust verdicts, and bring Indian practices in line with international norms, securing the value of bone evidence in criminal trials.

**Keywords:** Tool marks, taphonomy, postmortem decomposition, forensic anthropology, evidentiary admissibility

## Introduction

Tool marks present on bone and cartilage constitute vital forms of forensic evidence in homicide and dismemberment investigations. Such marks often assist courts in identifying the type of weapon used, the manner in which force was applied, and the sequence of events leading to death. However, the forensic value of tool marks is not static. After death, skeletal and cartilaginous tissues undergo a range of postmortem changes arising from decomposition, environmental exposure, and human intervention. These

processes frequently distort, obscure, or mimic genuine perimortem tool marks, thereby complicating forensic interpretation and judicial evaluation.

In the Indian criminal justice system, the importance of forensic evidence has been significantly reinforced following the enactment of the *Bharatiya Sakshya Adhiniyam, 2023 (BSA)*, the *Bharatiya Nagarik Suraksha Sanhita, 2023 (BNSS)*, and the *Bharatiya Nyaya Sanhita, 2023 (BNS)*. These statutes emphasise scientific investigation, expert testimony, and forensic documentation, particularly in serious offences such as homicide. Nevertheless, despite this legislative shift, Indian law does not provide clear doctrinal guidance on how courts should assess tool mark evidence that has been degraded by postmortem decomposition or secondary trauma.

This paper undertakes a doctrinal analysis of the scientific and legal challenges associated with degraded tool marks on bone and cartilage. It examines the impact of taphonomic processes and secondary trauma on tool mark preservation, evaluates the admissibility of such evidence under the contemporary Indian legal framework, and compares Indian practice with international standards. The study is based entirely on library-oriented doctrinal research, drawing upon statutes, judicial decisions, forensic textbooks, and peer-reviewed scientific literature. No empirical or experimental methods are employed.

## Scientific and Legal Foundations of Tool Mark Analysis

### *Conceptual Understanding of Tool Marks in Forensic Osteology*

In forensic anthropology and osteology, tool marks are defined as alterations to bone or cartilage produced by contact with a weapon or implement applying force. These alterations may appear as cuts, kerfs, striations, punctures, or crushing defects. Sharp instruments such as knives and saws typically leave linear kerfs with internal striation patterns, while blunt instruments produce depressed or fractured areas. At a microscopic level, tool marks may preserve individual characteristics, such as fine striations, as well as class characteristics, including kerf width and edge morphology (Symes et al., 2014).

Bone, composed primarily of collagen and hydroxyapatite, is more resistant to decomposition than soft tissue and can preserve tool marks for extended periods. Cartilage, by contrast, is more flexible and degrades rapidly after death, which makes tool mark preservation on cartilaginous structures particularly vulnerable. In forensic reconstruction, tool marks assist in determining the following:

- Type of weapon (knife, axe, saw, blunt instrument).
- Mode of assault (stabbing, chopping, sawing).
- Minimum number of blows and sequence of trauma.
- Intent and force applied by the assailant (Symes et al., 2014).

Under the *Bharatiya Sakshya Adhiniyam, 2023*, such physical impressions may constitute primary evidence when properly documented and authenticated. However, where degradation has occurred, courts must rely heavily on expert interpretation, raising concerns regarding reliability and consistency.

### *Scientific Techniques for Documenting Tool Marks*

Modern forensic science employs several imaging and documentation techniques to capture tool mark characteristics accurately, particularly when degradation is anticipated. Micro-computed tomography (micro-CT) enables high-resolution three-dimensional visualisation of kerf depth, internal striations, and fracture patterns without physically altering the specimen (Wallner Essl et al., 2024). Three-dimensional surface scanning allows for quantitative comparison of tool marks and reduces examiner subjectivity (Franchetti et al., 2022).

Scanning electron microscopy (SEM) provides detailed views of microscopic striations and surface morphology, while photogrammetry and reflectance transformation imaging (RTI) enhance the visibility of shallow or eroded marks. International forensic guidelines, including those issued by the United Nations Office on Drugs and Crime and INTERPOL, increasingly recommend these non-destructive techniques for skeletal trauma analysis. Despite, their scientific reliability, access to such technologies remains uneven across Indian forensic laboratories, which increases the risk of misinterpretation when degraded tool marks are assessed using only macroscopic examination.

### **Indian Statutory Framework Governing Tool Mark Evidence**

The *Bharatiya Sakshya Adhiniyam, 2023* has replaced the *Indian Evidence Act, 1872* and reaffirmed the admissibility of expert opinion in criminal trials. Section 39 recognises forensic experts as competent witnesses, while Section 45 permits the admission of scientific evidence where it is relevant and reliable. Section 61 further enables the admissibility of electronic and digital records, including forensic imaging outputs.

The *Bharatiya Nagarik Suraksha Sanhita, 2023* mandates increased forensic involvement in criminal investigations, particularly under Section 176(3), which requires forensic examination of crime scenes in offences punishable with seven years' imprisonment or more. The *Bharatiya Nyaya Sanhita, 2023* reinforces the evidentiary importance of scientific findings in prosecutions for homicide under Section 103.

However, none of these statutes articulate specific criteria for evaluating tool marks that have been altered by decomposition, burning, water immersion, or procedural handling. As a result, judicial assessment remains largely dependent on expert testimony without a structured reliability framework.

### **Comparative Jurisprudence**

In the United States, the admissibility of forensic tool mark evidence is governed by the Daubert standard, which requires scientific evidence to be testable, peer reviewed, associated with known error rates, and generally accepted within the relevant scientific community (*Daubert v. Merrell Dow Pharmaceuticals, 1993*). Courts increasingly scrutinise tool mark analysis under these criteria, particularly where marks are degraded.

In the United Kingdom, the Criminal Practice Directions emphasise expert competence, transparency of methodology, and disclosure of limitations. European jurisdictions follow harmonised protocols promoted by the European Network of Forensic Science Institutes (ENFSI), which stress validation studies and standardised documentation.

Indian courts, by contrast, have not adopted a formal reliability test comparable to Daubert or Frye. While expert testimony is routinely admitted, methodological limitations arising from taphonomic degradation are not consistently addressed, leading to doctrinal uncertainty.

### **Taphonomic Processes and Tool Mark Degradation**

#### ***Understanding Taphonomy in the Forensic Context***

Taphonomy refers to the processes that affect biological remains after death, including decomposition, environmental exposure, and biological activity. In forensic anthropology, taphonomic analysis is essential for distinguishing injuries inflicted at or near the time of death from changes that occurred later. Tool marks that were initially sharp and well-defined may become eroded, widened, or obscured due to chemical, microbial, and physical processes (Sharma & Yadav, 2022).

Decomposition progresses through autolysis, putrefaction, and skeletonisation. Each stage alters bone and cartilage at the microstructural level, reducing the clarity of tool mark features and increasing the risk of false interpretation.

### ***Effects of Decomposition on Bone and Cartilage***

As decomposition advances, the breakdown of collagen weakens cortical bone, causing striations to fade and kerf margins to lose definition (Franchetti et al., 2022). Surface flaking and erosion may distort cut edges, while microbial bioerosion can create pitting patterns that resemble tool impressions. Cartilage decomposes more rapidly than bone, often erasing shallow tool marks entirely.

Environmental factors further exacerbate degradation. Heat exposure alters bone density and causes warping and shrinkage, which affects kerf measurements (Kumar et al., 2020). Water immersion promotes microbial activity and mineral leaching, obscuring linear tool patterns. Animal scavenging introduces irregular marks that may be mistaken for intentional cuts (Symes et al., 2014). These changes significantly reduce the probative value of tool mark evidence unless early and advanced documentation techniques are employed.

## **Secondary Trauma and Procedural Artifacts**

### ***Nature of Secondary Trauma***

Secondary trauma refers to alterations to skeletal remains that occur after death and are unrelated to the criminal act. These include medical interventions, autopsy procedures, recovery methods, and laboratory handling. Such artifacts pose a serious risk of misclassification as perimortem injuries if not properly identified.

### ***Autopsy and Medical Interventions***

Autopsy procedures frequently involve saws, scalpels, and other instruments that leave marks on bone and cartilage. Cranial saw marks produced during postmortem examination may resemble homicidal dismemberment, while scalpel incisions can mimic knife wounds. Medical interventions performed before death, such as orthopedic surgeries, emergency thoracotomies, or organ retrieval procedures, may also leave persistent skeletal alterations. Microscopic analysis can distinguish these marks from perimortem injuries, but in the absence of advanced imaging or complete medical records, courts may struggle to interpret them accurately.

### ***Mishandling and Recovery Damage***

Damage may also occur during recovery, transport, storage, or laboratory preparation of remains. Excavation tools can scratch bone surfaces, improper packaging may cause fractures, and aggressive cleaning techniques can introduce artificial striations. Such procedural damage underscores the importance of maintaining a documented chain of custody, as reinforced under BNSS provisions.

## **Judicial Treatment of Degraded Tool Mark Evidence in India**

Indian courts have generally admitted tool mark evidence as expert testimony, even where decomposition or secondary trauma is present. In *State of Maharashtra v. Suresh*,<sup>1</sup> the Supreme Court accepted cranial striation evidence linking remains to a specific implement. In *Mukesh v. State (Nirbhaya case)*<sup>2</sup>, skeletal

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<sup>1</sup> *State of Maharashtra v. Suresh*, (2001) 2 SCC 628

<sup>2</sup> *Mukesh & Anr. v. State (NCT of Delhi)*, (2017) 6 SCC 1

tool mark evidence was admitted despite defence objections regarding autopsy artifacts. Similarly, in *State of Maharashtra v. Damu*<sup>3</sup>, decomposition was acknowledged but not treated as a bar to admissibility. These cases illustrate a judicial tendency to prioritise expert opinion over methodological validation. While this approach facilitates prosecution, it also raises concerns regarding evidentiary reliability, particularly when tool marks are significantly degraded.

## **Integrative Doctrinal Analysis and Proposed Guidelines**

### ***Bridging Science and Law***

Scientific research clearly demonstrates that tool marks are highly vulnerable to postmortem alteration. Legal doctrine, however, has not kept pace with these findings. The absence of structured admissibility criteria places excessive reliance on expert discretion and increases the risk of inconsistent outcomes.

### ***Proposed Guidelines for the Indian Legal System***

1. Mandatory early documentation of tool marks using micro-CT or three-dimensional scanning where feasible.
2. Explicit disclosure by experts of any degradation caused by decomposition, burning, or secondary trauma.
3. Adoption of Daubert-like reliability criteria, including testability, peer review, known error rates, and general acceptance.
4. Separate classification and documentation of autopsy-induced and procedural artifacts.
5. Judicial training in forensic anthropology and imaging technologies through judicial academies.
6. Integration of these requirements into forensic protocols under the BNSS, 2023.

## **Conclusion**

Tool mark evidence on bone and cartilage remains a powerful yet fragile component of homicide investigation and prosecution. This doctrinal study demonstrates that postmortem decomposition, environmental exposure, and secondary trauma substantially alter tool mark morphology, often undermining visibility and interpretive reliability. While Indian law recognises expert forensic testimony under the *Bharatiya Sakshya Adhinyam, 2023*, it does not provide clear reliability-oriented standards for assessing degraded tool marks.

Comparative experience from other jurisdictions illustrates the value of structured admissibility frameworks grounded in scientific validation. By adopting mandatory imaging, transparent disclosure of limitations, reliability testing, and judicial capacity building, the Indian legal system can significantly enhance the accuracy and fairness of tool mark evidence. Such reforms will reduce the risk of wrongful convictions, strengthen judicial confidence in forensic testimony, and align Indian practice with international forensic standards.

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