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Artificial Intelligence in Forensic Anthropology and Odontology: Ensuring Evidentiary Integrity and Constitutional Rights

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I. INTRODUCTION: THE AI REVOLUTION IN FORENSIC SCIENCE

Artificial Intelligence, defined as the ability of machines to display a degree of self-awareness and, more practically, to without explicit programming. DL, specifically, employs multi-layered artificial neural networks learn from data to solve complex problems, is rapidly transforming forensic science. The core of this transformation lies in Machine Learning (ML) and its subset, Deep Learning (DL). ML utilizes algorithms to forecast results based on large datasets, enabling computers to draw inferences to automatically learn complex patterns from unstructured data (images, radiographs), a capability that directly addresses the intricate nature of human remains analysis.

The goal of integrating AI into forensic anthropology and odontology is to introduce automation, enhanced objectivity, and greater efficiency, moving these disciplines beyond human subjectivity and time-consuming manual processes. This shift, while promising enhanced evidentiary quality, necessitates a careful examination of its implications for core constitutional rights.

II. AI APPLICATIONS IN FORENSIC ANTHROPOLOGY AND ODONTOLOGY

AI methodologies are being deployed across key areas of skeletal and dental analysis, often outperforming traditional methods in speed and consistency.

2.1. Forensic Anthropology: Automated Skeletal Profiling

AI algorithms, primarily Convolution Neural Networks (CNNs) for image processing, are trained on large datasets of skeletal images (e.g., radiographs, CBCT scans) to create a biological profile of the deceased.

- Age and Sex Estimation: AI can analyze features like bone maturation, epiphyseal fusion (for age), and specific morph metric measurements (for sex) with high accuracy and reduced inter-observer variability. Studies have shown that some DL models can estimate the age of a juvenile from dental or hand-wrist radiographs with a mean absolute error (MAE) of less than 0.8 years, significantly improving consistency over traditional human assessments.
- Facial Reconstruction: AI facilitates the generation of highly accurate 3D models for facial reconstruction from unidentified skull remains. This not only improves investigative leads but also honors the principle of human dignity by providing a semblance of identity.
- Ancestry and Stature Estimation: ML models are being developed to analyze subtle skeletal features to estimate popular methods, though it carries significant risk of perpetuating societal biases if training data is not action affinity (ancestry) and stature. This process is faster and more consistent than traditional diverse.

2.2. Forensic Odontology: Dental Evidence Analysis

AI systems are particularly effective in odontology due to the highly structured and measurable nature of dental records and imagery.

- Identification and Age Estimation: AI-powered systems can rapidly cross-match postmortem dental images and restorative patterns against vast databases, accelerating Disaster Victim Identification (DVI). Deep Learning models,

notably CNNs, are used to assess panoramic radiographs to automatically identify developmental or regressive dental features, often outperforming traditional methods in standardization.

- Bite Mark Analysis: In this historically controversial area, AI provides objective pattern recognition and quantifiable analysis of bite mark impressions, aiming to replace subjective human judgment with algorithmic rigor, thereby enhancing the evidence's reproducibility and reducing the risk of wrongful convictions associated with flawed traditional methods.

III. CONSTITUTIONAL SAFEGUARDS AND EVIDENTIARY INTEGRITY

The adoption of AI in the courtroom must be rigorously balanced against the fundamental constitutional rights of the accused and the necessity of maintaining high standards for evidentiary integrity.

3.1. Challenges to Due Process and the Right to Confrontation

The central legal hurdle for AI-generated evidence is the "Black Box" Problem.

- The Black Box and the Sixth Amendment: Many sophisticated ML/DL models operate opaquely; the precise mechanism by which the AI arrives at a conclusion is difficult for human experts—and crucially, defense attorneys—to understand. This opacity directly challenges the Sixth Amendment right to confrontation (as applied in many jurisdictions, including elements of the Due Process under Article 21 of the Indian Constitution), as the defense cannot effectively cross-examine the expert regarding the reliability, methodology, and underlying logic of the AI tool.
- Algorithmic Transparency (Explainable AI - XAI): To ensure due process, forensic AI must move toward Explainable AI (XAI) models that can clearly articulate the features or data points that led to a specific decision. This is crucial for satisfying the judicial demand for transparency.

3.2. Privacy, Data Security, and Search & Seizure

AI forensic tools are data-hungry, relying on massive repositories of sensitive personal information.

- Right to Privacy (Article 21)[1]: The mandatory collection, storage, and cross-referencing of biometric and genetic data (skeletal scans, dental records, predictive ancestry data) directly implicates the right to privacy. Stringent legal standards, requiring judicial authorization based on probable cause and the principle of proportionality, are necessary to regulate the use of these invasive technologies and prevent the unauthorized creation of vast police/forensic databases.
- Right Against Self-Incrimination (Article 20(3))[2]: While bodily evidence is generally excluded from the protection against self-incrimination, the mandatory collection of biometric data for AI profiling must be carefully regulated to ensure it does not evolve into compelled testimonial evidence or an unreasonable invasion of bodily integrity.

3.3. Evidential Reliability and Legal Admissibility

For AI evidence to be legally admissible (e.g., under Section 45 of the Indian Evidence Act, 1872 (sec 39 of the Bhartiya sakshya adhiniyam.2023)), it must satisfy rigorous scientific standards.

- Admissibility Benchmarks: Courts must demand that AI evidence meet criteria comparable to international scientific admissibility standards:
  1. Tested and Validated: The algorithm's accuracy and error rate must be scientifically validated and disclosed.
  2. Peer Review and Publication: The methodology must be generally accepted within the relevant scientific community.
  3. Low Error Rate and Maintenance of Standards: Evidence must be presented that the specific application of the AI tool followed all protocols and that the data input, processing, and output maintained a verifiable Chain of Custody (especially

[1] Article 21 of Indian constitution stating: "No person shall be deprived of his life or personal liberty except according to procedure established by law".

[2] Article 21 of Indian constitution stating: "No person accused of any offence shall be compelled to be a witness against himself".

important for electronic records under Section 65B[3] of the IEA).

IV. CASE STUDIES: THE FOUNDATIONAL ROLE OF FORENSIC DISCIPLINES

Historical Indian cases underscore the foundational role of forensic anthropology and odontology, providing a necessary benchmark for the reliability of emerging AI tools.

4.1. The Naina Sahni Murder Case (Tandoor Murder Case, 1995)[4]

Naina Sahni was murdered by her husband, Sushil Sharma, in a high-profile 1995 case known as the Tandoor Murder in Delhi, India. Sharma, a Congress youth leader, shot her suspecting infidelity and attempted to dispose of her body by burning it in a restaurant tandoor.

On July 2, 1995, Sharma fatally shot 29-year-old Naina Sahni twice in the head and neck after a phone argument involving another man. He then transported her body to Bagiya restaurant, where he and manager Keshav Kumar tried to incinerate it in the oven, leading to smoke that alerted police.

In this case involving a charred body, forensic anthropology and pathology were critical.

The initial autopsy misidentified the cause as burns, but a second autopsy by experts including T.D. Dogra revealed gunshot wounds, shifting the investigation to homicide. Ballistics linked bullets to Sharma's licensed revolver, and DNA confirmed the victim's identity despite partial burning

- Role of Forensics: Experts successfully confirmed the identity of the victim despite extensive burning, established the cause of death (gunshot wounds), and linked the bullet to the accused's weapon.
- Evidential Integrity: The case emphasized the integrity of a second autopsy and meticulous scientific analysis when visual identification was impossible. While AI could have potentially expedited initial identification via automated dental/skeletal analysis, the case highlights that the ultimate conclusion rests on the validated interpretation of the human expert.
- Legal proceedings: Sharma fled but surrendered on July 10, 1995. Convicted in 2003 by the trial court with a death sentence, upheld by Delhi High Court and Supreme Court in 2013 but commuted to life imprisonment as not the "rarest of rare" due to personal motives.
- Significance: This case highlighted forensic odontology and anthropology via autopsies, circumstantial evidence, and became a landmark for second post-mortems in India.

4.2. The Nithari Killings (2006)[5]

The Nithari killings, also known as the 2006 Noida serial murders, involved the gruesome discovery of skeletal remains of numerous children and young women near a bungalow in Nithari village, Sector 31, Noida, Uttar Pradesh, India. The case implicated businessman Moninder Singh Pandher, the house owner, and his domestic help Surinder Koli, who were accused of kidnapping, rape, murder, cannibalism, and necrophilia targeting mostly poor children from the locality.

Skeletal remains of at least 19 victims, including 15 children, were found in a drain behind D-5 bungalow on December 29, 2006, after the disappearance of a girl named Payal triggered a search. Koli confessed to luring victims, killing them post-assault by Pandher, dismembering bodies, and disposing of them, but investigations revealed police negligence, with initial

[3] Section 63(4) of the BSA now governs digital evidence, essentially carrying forward the essence of the former 65B, requiring similar certification for electronic data like emails, messages, or digital files to be admissible in court

[4] Sushil Sharma v. (NCT of Delhi), (2013) 12 SCC 699

[5] Surendra Koli v. State of UP: (2011) 4 SCC 80 (conviction and death penalty affirmed) and

Curative petition(2025): Supreme Court acquitted Koli on November 11, 2025, recalling the 2011 judgment due to inadmissible confession under Evidence Act Sections 24 and 27 and

The finally Surendra Koli's acquittal in the Nithari Killings case (Rimpa Haldar murder): Surendra Koli v. State of UP: 2025 INSC 1308 (Neutral Citation), delivered on November 11, 2025.

mishandling of the scene and ignored leads like organ trafficking.

The CBI took over in January 2007; Koli received death sentences in 10 of 16 cases, Pandher in two, though many acquittals followed due to weak evidence beyond confessions. Recent 2025 Supreme Court rulings acquitted Koli in remaining cases, criticizing coerced confessions after 60-day custody, flawed probes, and failure to identify true perpetrators, sparking outrage among victims' families.

The discovery of numerous skeletal and skull remains necessitated extensive work by forensic anthropologists and odontologists.

- Role of Forensics: Experts were crucial in establishing the Minimum Number of Individuals (MNI), estimating the age and sex of the victims from commingled and fragmented bones, and constructing biological profiles.
- Impact on Justice: This case demonstrates the complexity of analyzing fragmented remains. AI-driven tools could significantly accelerate the process of sorting and profiling commingled remains (an estimated 80% reduction in initial processing time in some DVI scenarios), thereby increasing efficiency in complex mass fatality or serial crime investigations, but the fundamental methodology of identifying human vs. non-human, or adult vs. juvenile remains, remains paramount.
- Forensic and significance: Autopsies showed mutilations suggesting surgical precision, but chain-of-custody issues plagued evidence like bones and DNA. The case exposed systemic failures in policing vulnerable communities and highlighted organ trade suspicions, remaining a landmark for investigative lapses in India.

V.. ETHICAL PRINCIPLES AND REGULATORY IMPERATIVES

The convergence of AI and forensics demands a commitment to ethical standards that reinforce constitutional protections.

5.1. Mitigating Algorithmic Bias

The use of AI in estimating ancestry or predicting features risks amplifying pre-existing societal biases present in the training data.

- The Bias Challenge: If the training dataset lacks diverse representation, the AI model may perform poorly or generate biased results when applied to underrepresented demographics. For example, studies have shown that face recognition systems can have error rates up to 5-10 times higher for darker-skinned women compared to lighter-skinned men.
- Algorithmic Accountability: Legislative bodies must mandate the auditing of proprietary AI software. Developers must demonstrate the diversity and representativeness of their training data and provide data on the system's differential performance across various demographic groups to prevent discriminatory and unjust outcomes.

5.2. Upholding Human Dignity and Cultural Sensitivity

Forensic experts, particularly anthropologists, must uphold ethical codes when handling human remains, especially in sensitive contexts.

- International Ethical Codes: Adherence to standards (e.g., those from the International Committee of the Red Cross or the American Academy of Forensic Sciences) is vital when dealing with unclaimed bodies, Indigenous populations, and mass disasters. The collection and analysis of genetic material or sensitive biometric data for ancestry estimation must respect the dignity and privacy of the deceased and their communities.

VI. CONCLUSION AND FUTURE REGULATORY FRAMEWORK

The intersection of AI and forensic science demands a dynamic legal framework that proactively balances technological progress with constitutional justice. The integration of AI into forensic anthropology and odontology offers undeniable benefits for evidentiary integrity, notably by introducing objectivity and efficiency. However, these benefits are conditional on strict adherence to the due process and privacy rights of the individual.

Legislative preparedness and judicial vigilance are vital. Future regulatory action must focus on:

1. Mandatory XAI (Explainable AI): Ensuring that proprietary AI forensic tools are auditable and their decision-making processes are transparent.
2. Standardized, Audited Datasets: Enforcing the use of rigorously tested, diverse, and ethically sourced training data to mitigate algorithmic bias.
3. Clear Admissibility Benchmarks: Establishing high scientific standards and specific legal criteria for AI-generated evidence, going beyond the existing framework of Section Section 39 of the Bharatiya Sakshya Adhiniyam (BSA), 2023.
4. Technological innovation must enhance, rather than endanger, the pursuit of justice in the digital era. The integrity of the judicial process depends on the responsible governance of this powerful technology.