




Artificial intelligence in forensic science: a systematic review. Part I: personal identification

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Abstract

Artificial intelligence (AI) has emerged as a promising tool in forensic sciences, offering new opportunities for personal identification through automated analysis of biological and imaging data. AI-based approaches have been increasingly applied to tasks such as sex estimation, human identification, ancestry estimation, and kinship analysis. This systematic review aims to synthesize the available evidence regarding the applications, methodological characteristics, and performance of AI models in forensic personal identification. A systematic literature search was conducted in PubMed/MEDLINE and Scopus following PRISMA guidelines. Studies investigating AI applications for forensic identification were included. Data extraction focused on study characteristics, dataset type, AI model architecture, forensic task, validation strategy, and reported performance metrics. A total of 89 studies published between 2012 and 2026 met the inclusion criteria. The majority of studies focused on sex estimation (63%), followed by human identification, ancestry estimation, multi-task prediction, and kinship verification. Most studies relied on imaging datasets, particularly computed tomography and radiographic images. Deep learning models represented the most frequently used analytical approaches. Reported accuracy values were generally high, with a median accuracy of 91.4% and an interquartile range of 88.9–95.0% in studies reporting single-value accuracy metrics. Deep learning approaches tended to achieve slightly higher performance than traditional machine learning models. AI shows considerable potential to support forensic personal identification, particularly in imaging-based applications. However, methodological heterogeneity, population-specific datasets, and limited external validation remain important challenges. Future research should prioritize standardized validation protocols, multi-population datasets, and transparent reporting to ensure the forensic applicability of AI-based identification systems.

Keywords Artificial intelligence · Forensic identification · Forensic anthropology · Machine learning · Deep learning · Sex estimation

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Introduction

Forensic personal identification represents one of the core objectives of forensic science, particularly in cases involving unidentified human remains, mass disasters, and criminal investigations. Establishing the identity of deceased individuals is essential for legal investigations and humanitarian reasons, including disaster victim identification (DVI) and providing closure for families. The reconstruction of the biological profile—typically including sex, age, ancestry, and stature—plays a fundamental role in the identification process, especially when soft tissues are absent or when bodies are severely decomposed, fragmented, or skeletonized [1].

Traditionally, forensic identification relies on multiple complementary disciplines, including forensic anthropology, forensic odontology, and forensic genetics. Dental structures and craniofacial features are particularly valuable due to their durability and individual variability, making them useful for identifying victims in both criminal investigations and mass disaster scenarios [2]. In parallel, DNA profiling has become the gold standard for human identification, providing highly reliable genetic evidence that can link biological samples to individuals with high statistical confidence [3]. Additionally, morphological and metric analyses of skeletal structures remain fundamental tools in forensic anthropology for estimating biological characteristics when genetic material is unavailable or degraded [4].

In recent years, the rapid development of computational technologies has introduced new possibilities for forensic investigations through the application of artificial intelligence (AI). AI is a broad term describing computational systems capable of performing tasks that typically require human intelligence. Within AI, machine learning (ML) refers to algorithms that learn patterns from data to make predictions or classifications without explicit programming. Deep learning (DL) represents a subset of machine learning based on multi-layer artificial neural networks, particularly effective for analyzing complex imaging and high-dimensional datasets. [5]. These techniques have already demonstrated significant potential in several fields of medicine and science, enabling automated analysis of complex biological, imaging, and genetic data [6].

The integration of AI into forensic sciences is gaining increasing attention, with applications spanning forensic pathology, crime scene analysis, forensic radiology, and human identification [7]. Machine learning algorithms can assist forensic experts by identifying patterns in large datasets, improving classification accuracy, and supporting decision-making processes while potentially reducing subjective bias [8]. In particular, AI-based approaches have been explored in various identification-related domains,

including facial reconstruction, skeletal analysis, genetic profiling, and microbiome-based identification [9, 10].

Despite the growing number of studies investigating the application of AI in forensic identification, the available evidence remains dispersed across different forensic disciplines and methodological approaches. Existing studies often focus on specific domains—such as forensic genetics, anthropology, or imaging—without providing a comprehensive synthesis of AI applications across the broader context of forensic personal identification. Therefore, a systematic evaluation of the current literature is needed to better understand the potential, limitations, and methodological challenges associated with the implementation of AI in this field.

Therefore, the aim of this systematic review was to analyze and synthesize the available evidence regarding the application of AI techniques in forensic personal identification.

Materials and methods

Study design and research question

This study was designed as a systematic review aimed at evaluating the application of AI techniques in forensic personal identification. The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [11].

The study protocol was defined a priori, including the research question, eligibility criteria, and data extraction strategy, in order to ensure methodological transparency and reproducibility. The study protocol was prospectively registered on the Open Science Framework (OSF) platform. A publicly accessible view-only version of the protocol is available at: https://osf.io/39phc/overview?view_only=c223168473564131acc86a269e1beacd.

The aim of this review was to investigate the performance, applicability, and limitations of AI-based approaches used for forensic personal identification, including human identification from imaging data, sex estimation, ancestry or population affinity estimation, and facial recognition in forensic contexts.

The research question was structured according to a modified PICO framework adapted for methodological studies in forensic science: Population/Data: forensic imaging, odontological, anthropological, or other biological datasets; Intervention: AI-based analytical methods; Comparator: conventional forensic methods or human expert assessment when available; Outcome: identification performance metrics (e.g., accuracy, sensitivity, specificity, area

under the curve (AUC), equal error rate (EER), and rank-based accuracy).

Eligibility criteria and search strategy

Studies were selected according to the following inclusion criteria: original research articles involving AI-based methods (e.g., machine learning, deep learning, neural networks, or related computational approaches); forensic or medico-legal applications related to personal identification; studies employing imaging, anthropometric, odontological, or other biological data for identification purposes; studies reporting quantitative performance metrics (e.g., accuracy, sensitivity, specificity, AUC, EER, or rank-based accuracy); peer-reviewed articles published in English.

Exclusion criteria were: studies focused exclusively on clinical diagnosis without relevance to forensic identification; editorials, letters, conference abstracts without full data, and opinion papers; studies lacking objective performance metrics. Studies exclusively focused on forensic age estimation were excluded from this review, as this topic is addressed in a separate systematic review within the same three-part series on artificial intelligence applications in forensic science. Conference proceedings and abstracts were excluded due to limited methodological detail and lack of full peer-reviewed publication.

A systematic literature search was conducted in MEDLINE (via PubMed) and Scopus from database inception to the final search date (1 March 2026). The electronic search was supplemented by backward and forward citation tracking in order to identify additional relevant studies. The complete database-specific search strategies are reported in Supplementary Appendix 1. Reference lists of the included studies were also manually screened to identify additional eligible articles.

Study selection and data extraction

All records retrieved from the databases were exported and imported into Zotero reference management software, where duplicate records were identified and removed. Two independent reviewers performed the screening process in two stages: title and abstract screening; full-text assessment for eligibility. Disagreements between reviewers were resolved through discussion and consensus.

Data extraction was conducted using a standardized data extraction form developed prior to the screening phase. The following information was collected from each included study: author(s), year of publication, and journal; dataset characteristics (sample size, population, and type of data); AI model architecture; task type (e.g., classification, identification, or prediction); reported performance metrics;

comparator methods (human experts or conventional forensic techniques, when available); and methodological limitations. Data extraction was independently performed by two reviewers and subsequently cross-checked to ensure accuracy and completeness.

Risk of bias, methodological quality assessment, and data synthesis

Methodological quality and risk of bias were evaluated using tools appropriate for diagnostic and predictive studies involving AI. Depending on study design, the following frameworks were applied: QUADAS-2 for diagnostic accuracy studies; PROBAST, adapted for AI prediction models. Particular attention was paid to potential sources of bias specific to AI-based studies, including dataset imbalance, lack of external validation, and possible overfitting of predictive models. In addition, adherence to AI reporting standards (e.g., CLAIM or TRIPOD-AI) was qualitatively assessed when applicable.

Given the expected methodological heterogeneity in datasets, model architectures, and outcome metrics, a narrative synthesis was planned as the primary method of analysis. Included studies were grouped according to their main application domain: dental-based human identification; facial recognition in forensic contexts; sex estimation; ancestry or population affinity estimation. When sufficient methodological homogeneity was identified among studies, quantitative comparison of reported performance metrics was considered.

Results

Study selection

The literature search identified a total of 1,266 records through database searching, including 396 records from PubMed/MEDLINE and 870 records from Scopus. After removal of 185 duplicate records and one retracted article, 1,080 records remained for title and abstract screening. During the screening phase, 863 records were excluded based on title and abstract because they did not meet the eligibility criteria. The full texts of 217 articles were then sought for retrieval. Of these, 14 reports could not be retrieved, leaving 203 articles assessed for full-text eligibility.

Following full-text evaluation, 114 articles were excluded for the following reasons: not related to forensic personal identification ($n=107$); not focused on AI-based personal identification ($n=5$); clinical setting without forensic relevance ($n=1$); ethical commentary article ($n=1$). Ultimately, 89 studies met the inclusion criteria and were included in

the qualitative synthesis of this systematic review [12–100]. The study selection process is summarized in Fig. 1 (PRISMA flow diagram).

Characteristics of included studies

The included studies were published between 2012 and 2026 and covered multiple forensic applications of AI, including sex estimation, ancestry estimation, human identification, and kinship verification.

The studies were conducted across several geographic regions. The majority of studies originated from Asia, particularly China, Japan, Turkey, and South Korea, followed by Europe, South America, and North America. Sample sizes varied substantially across studies, ranging from 10 individuals in microbiome-based identification research to over 200,000 radiographic images in large dental datasets.

The main characteristics of the studies included in this systematic review are summarized in Table 1, while a detailed description of each study is provided in Supplementary Table S1.

Data types and imaging modalities

A wide range of anatomical structures and imaging modalities were analyzed across the included studies. The most frequently used data sources included: computed tomography (CT) scans, particularly cranial and pelvic CT datasets; dental panoramic radiographs (orthopantomograms); conventional radiographs (X-ray images); three-dimensional skeletal reconstructions; photographic images of skeletal elements; facial and ear biometric images; genetic and microbiome profiles.

Among imaging-based approaches, CT-derived measurements and radiographic datasets represented the most

Fig. 1 PRISMA Flow diagram of the systematic review

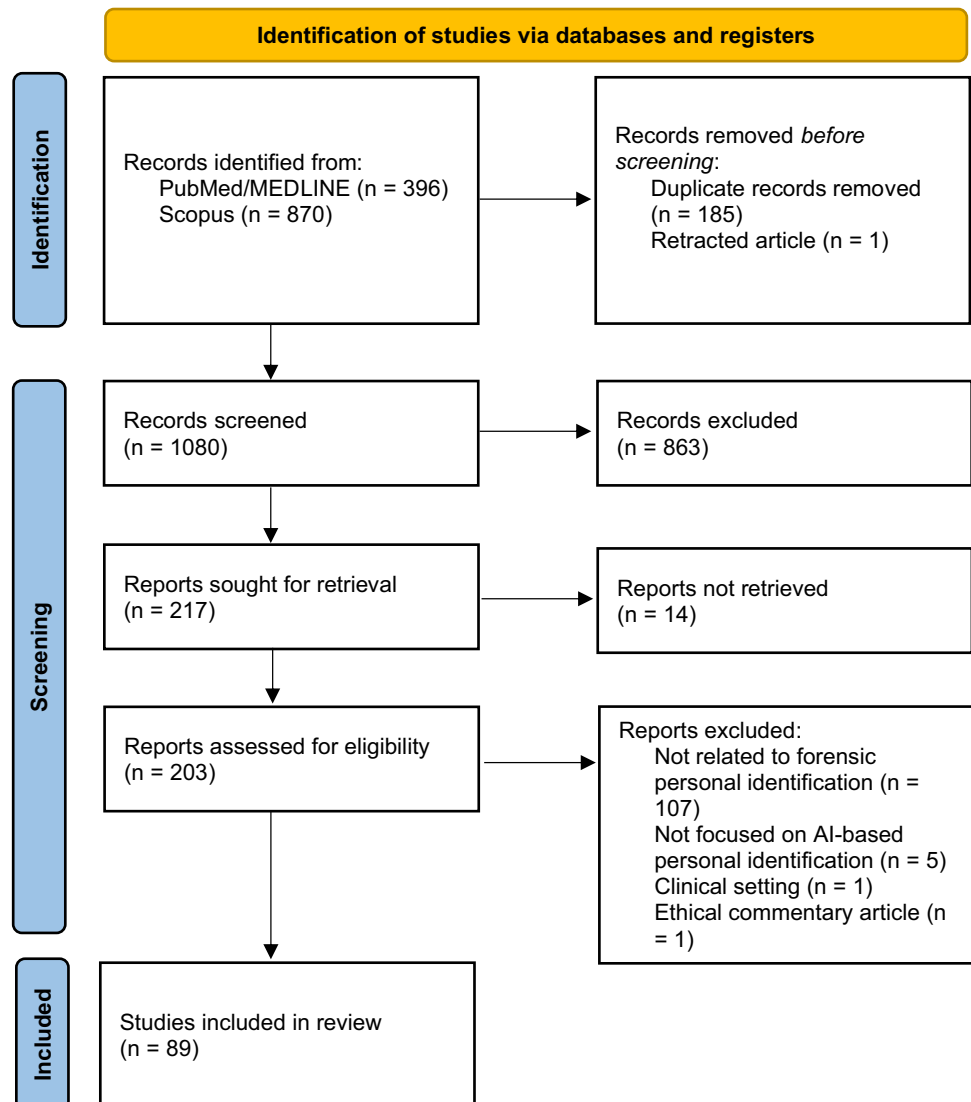


Table 1 Summary characteristics of the studies included in the systematic review ($n=89$)

Characteristic	Category	Studies n (%)
Forensic task	Sex estimation	56 (63.0)
	Human identification	14 (15.7)
	Ancestry estimation	9 (10.1)
	Multi-task prediction	6 (6.7)
	Kinship verification	4 (4.5)
Data type	Computed tomography-based datasets	34 (38.2)
	Conventional radiographs	21 (23.6)
	Dental panoramic radiographs	10 (11.2)
	Photographic skeletal images	12 (13.5)
	Other datasets	12 (13.5)
AI model category	Deep learning	47 (52.8)
	Traditional machine learning	28 (31.5)
	Hybrid approaches	14 (15.7)

common data types, reflecting their widespread use in forensic anthropology and forensic identification research.

AI approaches

A wide variety of AI models were employed across the included studies. The most commonly used algorithms included: Convolutional Neural Networks (CNNs); Artificial Neural Networks (ANNs); Random Forest (RF); Support Vector Machines (SVM); k-Nearest Neighbors (KNN); Logistic Regression (LR); Gradient Boosting and XGBoost models. Deep learning architectures such as ResNet, EfficientNet, GoogLeNet, and VGG-based networks were frequently used in studies involving medical imaging. Several studies also implemented ensemble learning approaches, combining multiple machine learning algorithms to improve predictive performance.

Imaging-based datasets were predominantly analyzed using deep learning architectures, particularly convolutional neural networks, whereas studies relying on morphometric or osteometric measurements more frequently employed traditional machine learning algorithms such as Random Forest or Support Vector Machines.

Forensic tasks and model performance

The majority of studies focused on sex estimation, which represented the most common forensic application across the literature. Other investigated tasks included human identification, ancestry or population affinity estimation, kinship verification, and multi-task prediction frameworks combining sex and age estimation.

Overall, AI approaches demonstrated high predictive performance across most forensic applications. In sex estimation studies, reported accuracies frequently exceeded

85–90%, with several deep learning models achieving accuracy values above 95%. The highest reported performances were observed in CT-based deep learning studies, particularly in pelvic and cranial analyses, where accuracies approached 100% in some datasets. Similarly, identification systems based on dental radiographs or biometric features showed high rank-based identification accuracy, often exceeding 90%. However, performance varied depending on the anatomical structure analyzed, dataset size, and population characteristics, highlighting the importance of population-specific validation.

Across studies reporting single-value accuracy metrics, the median accuracy was 91.4%, with an interquartile range from 88.9% to 95.0%. The distribution of accuracy values across studies is illustrated in Fig. 2. When stratified by model category, deep learning approaches showed slightly higher median accuracy values than traditional machine learning algorithms, although substantial overlap between distributions was observed (Fig. 3).

The heterogeneity of datasets, evaluation metrics, and methodological approaches limited the possibility of conducting a formal meta-analysis.

Geographical distribution of studies and population representation

The included studies demonstrated a broad geographical distribution, although a clear concentration of research activity was observed in specific regions. Most studies were conducted in Asia, particularly in China, Turkey, Japan, South Korea, and Thailand, which together accounted for the largest proportion of published datasets. A substantial number of studies also originated from Europe, including populations from France, Portugal, Italy, Greece, Spain, and Bulgaria. Additional contributions were reported from North America, South America, and Africa, although these regions were comparatively less represented.

Several studies used population-specific skeletal collections or hospital-based imaging datasets, often reflecting the demographic composition of the local population. Despite this geographic diversity, the overall distribution of datasets revealed uneven population representation, with a predominance of studies conducted on East Asian and Turkish populations. In contrast, African, South American, and multi-ancestry populations remain underrepresented.

Temporal trends in AI applications

An increasing trend in the application of AI to forensic anthropology and identification was observed over time. The earliest studies included in this review date back to 2012, when machine learning approaches were primarily applied

Distribution of accuracy values in AI-based sex estimation studies

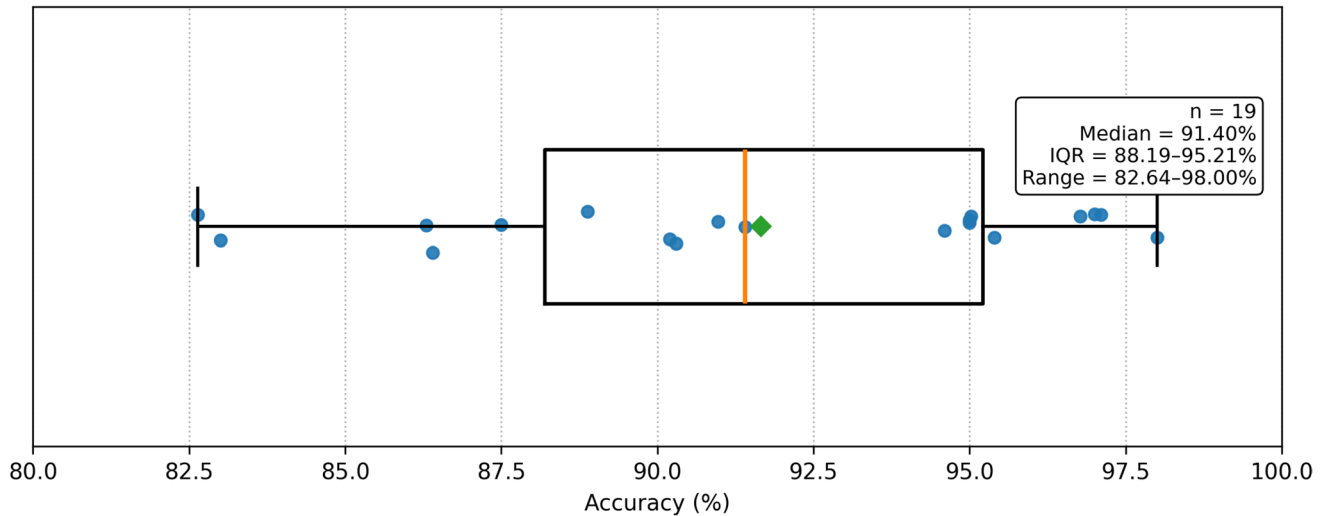


Fig. 2 Distribution of accuracy values reported in artificial intelligence models for sex estimation. Boxplot representing the distribution of reported accuracy values across studies providing explicit numeric accuracy outcomes. The central line represents the median, the box

indicates the interquartile range (IQR), and whiskers represent the minimum and maximum values. Individual points correspond to accuracy values reported by each included study

Accuracy comparison between machine learning and deep learning models

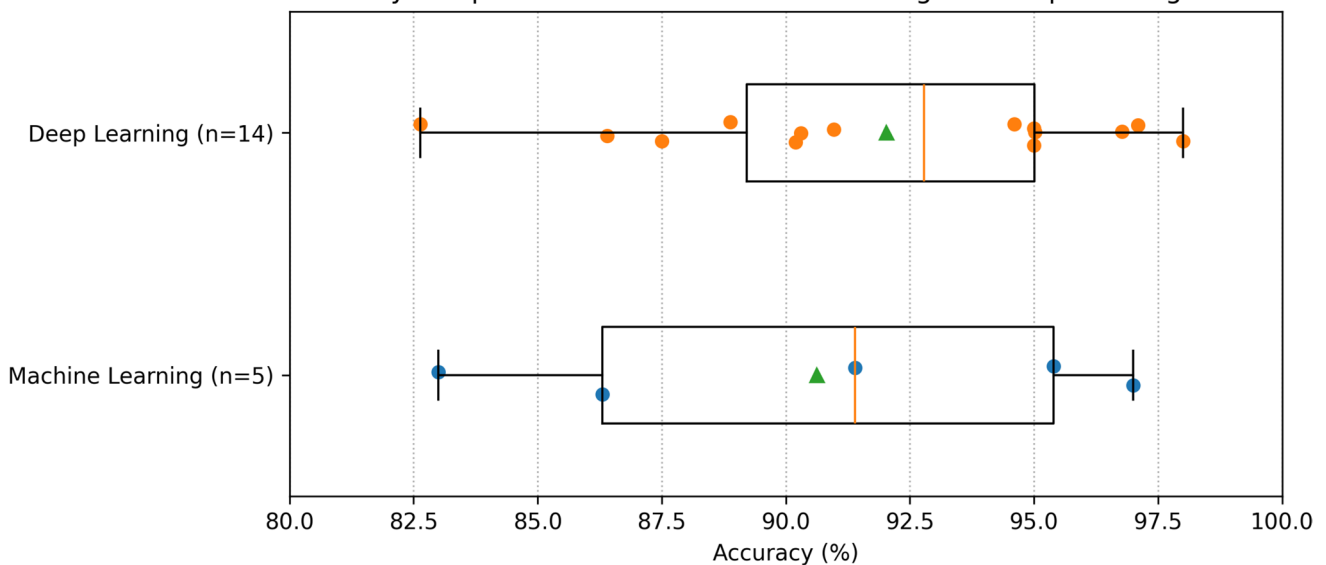


Fig. 3 Comparison of accuracy distributions between traditional machine learning and deep learning models used for sex estimation. Boxplots showing the distribution of reported accuracy values across studies using traditional machine learning algorithms ($n=5$) and deep

learning models ($n=14$). The central line represents the median, boxes indicate the interquartile range (IQR), and whiskers represent the minimum and maximum values. Individual points correspond to accuracy values reported by each included study

to biometric identification tasks, such as ear recognition or basic morphometric classification. Between 2015 and 2019, the number of publications gradually increased, with the introduction of more advanced machine learning techniques applied to skeletal morphometrics and radiological datasets. During this period, algorithms such as Support Vector Machines, Random Forest, and Artificial Neural Networks were commonly used. A marked increase in publications

was observed after 2020, coinciding with the rapid adoption of deep learning architectures and the growing availability of large medical imaging datasets. Recent studies published between 2023 and 2026 frequently incorporated advanced architectures, including ResNet, EfficientNet, Transformer-based networks, and hybrid deep learning frameworks, often achieving higher predictive performance than traditional machine learning approaches.

Overall, these trends indicate a clear shift from traditional morphometric statistical models toward data-driven AI methods, reflecting broader developments in medical imaging and computational anthropology.

Discussion

This systematic review analyzed the current evidence regarding the application of AI techniques in forensic personal identification. A total of 89 studies were included, covering a wide range of forensic tasks such as sex estimation, human identification, ancestry or population affinity estimation, and kinship verification [12–100]. Overall, the findings of this review indicate that AI-based approaches demonstrate high predictive performance across multiple forensic applications. In studies reporting single accuracy metrics, the median accuracy was approximately 91%, suggesting that AI methods may provide valuable support for forensic identification tasks. Sex estimation represented the most frequently investigated application, while deep learning approaches—particularly convolutional neural networks applied to radiological and photographic datasets—were the most commonly used model architectures. Despite these promising results, substantial heterogeneity was observed across datasets, methodological approaches, and evaluation metrics, highlighting the need for careful interpretation of reported performances.

One of the most consistent findings across the included studies was the high predictive performance achieved by AI models in sex estimation tasks. Many studies reported accuracy values exceeding 85–90%, with several deep learning models achieving performance above 95%, consistent with the overall accuracy distribution observed in the included studies (Fig. 2) and with individual studies reporting very high performance in CT-based skeletal analyses [56, 81, 92]. These results are consistent with the well-established sexual dimorphism of specific skeletal regions—particularly the pelvis and skull—which are widely used in forensic anthropology for biological sex estimation [2, 4, 101]. These anatomical differences provide biologically informative features that can be effectively captured by machine learning algorithms. AI-based approaches may therefore enhance traditional morphometric analyses by automatically identifying complex patterns within multidimensional datasets and by reducing potential observer-related variability.

In addition to metric and morphometric approaches, individual skeletal features and pathological variations may also contribute to forensic identification and anthropological reconstruction. Case-based investigations and historical osteological studies have demonstrated how specific skeletal traits, trauma patterns, or anatomical anomalies can

assist in reconstructing biological profiles and identifying human remains in both modern forensic contexts and historical investigations [102–104]. These traditional anthropological approaches remain essential in forensic practice and provide valuable reference frameworks for the development and validation of AI-based analytical models.

When comparing model categories, deep learning approaches tended to achieve slightly higher accuracy values than traditional machine learning algorithms. This trend was particularly evident in studies using imaging datasets, where convolutional neural networks demonstrated strong performance in tasks involving radiographs, computed tomography scans, and photographic skeletal images [25, 41, 92]. The ability of deep learning models to automatically extract hierarchical visual features from high-dimensional image data likely contributes to their improved performance in these contexts. However, the difference between deep learning and traditional machine learning models was not always substantial. In several studies relying on structured morphometric measurements, algorithms such as Random Forest, Support Vector Machines, or ensemble learning approaches performed comparably to deep learning models [14, 34, 47]. These findings suggest that the optimal modeling strategy may depend largely on the type and structure of the available data.

Another important observation emerging from this review is the prominent role of medical imaging datasets in AI-based forensic identification research. Computed tomography scans, conventional radiographs, and dental panoramic radiographs represented the most commonly used data sources across the included studies. The increasing availability of digital medical imaging, particularly post-mortem computed tomography (PMCT) in forensic practice, has likely facilitated the rapid adoption of AI-based analytical approaches [5, 7]. Imaging-based datasets offer several advantages, including high anatomical detail, standardized acquisition protocols, and the possibility of extracting large numbers of quantitative features from skeletal structures. As a result, AI-driven image analysis may represent one of the most promising directions for future developments in forensic identification.

Imaging-based approaches have long played a central role in forensic identification, particularly in facial comparison and age progression techniques used in missing persons investigations. These methods rely on the analysis of craniofacial morphology and growth patterns and have been extensively discussed in forensic medicine literature [105–113].

Despite the encouraging performance of AI models reported in the literature, several methodological and practical challenges remain. One of the most notable issues concerns the geographical and demographic distribution of the

datasets used for model development. A large proportion of the included studies were conducted on Asian populations, particularly in China, Turkey, Japan, and South Korea. European populations were also represented in several studies, whereas African and South American populations were considerably underrepresented. This imbalance raises important concerns regarding the generalizability of AI models across different populations. Skeletal morphology and biological traits may vary between populations due to genetic, environmental, and developmental factors [19, 49]. Consequently, models trained on population-specific datasets may not perform equally well when applied to individuals from different demographic backgrounds. Addressing this limitation will require the development of more diverse and multi-population datasets in future research.

Another challenge identified in this review relates to methodological heterogeneity across studies. The included studies differed substantially in terms of dataset size, anatomical structures analyzed, model architectures, and evaluation metrics. Sample sizes ranged from fewer than ten individuals in microbiome-based identification studies to more than two hundred thousand radiographic images in large dental datasets. Similarly, performance was reported using a variety of metrics, including accuracy, AUC, sensitivity, specificity, equal error rate, and rank-based identification measures. This heterogeneity limited the possibility of conducting a formal meta-analysis and complicates direct comparisons between studies. Standardization of reporting practices and evaluation metrics would therefore greatly facilitate future evidence synthesis in this rapidly evolving field.

In addition to dataset heterogeneity, several studies exhibited methodological limitations that are commonly encountered in AI-based predictive modeling. These include small training datasets, potential class imbalance, limited transparency regarding model development, and the absence of external validation. External validation using independent datasets is particularly important to assess the robustness and real-world applicability of predictive models. However, many studies relied exclusively on internal validation procedures such as cross-validation or hold-out testing within the same dataset. Without independent validation, reported performance metrics may overestimate the true predictive ability of the models when applied in forensic casework.

The findings of this review are broadly consistent with previous research highlighting the growing role of AI in forensic sciences [5–8]. Recent reviews in forensic medicine and forensic radiology have similarly emphasized the potential of AI-based approaches to assist experts in tasks such as skeletal analysis, dental comparison, and biometric identification. In this context, AI should not be considered a replacement for forensic expertise, but rather a

complementary tool capable of supporting expert decision-making and improving analytical efficiency. Integrating AI-based systems with expert interpretation may ultimately enhance both accuracy and reproducibility in forensic identification processes.

The integration of AI into forensic identification also raises important ethical and legal considerations. In medico-legal contexts, algorithmic outputs may influence judicial decisions, making transparency, interpretability, and methodological robustness essential requirements for AI-based systems [5–8]. The integration of complex “black-box” models may limit the ability of forensic experts to explain how specific predictions are generated, potentially creating challenges in legal settings where expert testimony must be clearly justified [114]. In addition, the use of population-specific datasets may introduce potential biases if models are applied to individuals from underrepresented demographic groups [5–8]. Ensuring transparency in model development, rigorous validation procedures, and adherence to emerging reporting guidelines for AI research will therefore be crucial for the responsible implementation of AI in forensic practice.

This review has several strengths. First, it provides a comprehensive synthesis of the available literature on AI-based forensic personal identification across multiple forensic disciplines, including anthropology, odontology, radiology, and biometrics. Second, the review was conducted in accordance with PRISMA guidelines and followed a predefined protocol registered on the Open Science Framework, which increases methodological transparency and reproducibility. Finally, the inclusion of a large number of studies allowed the identification of broad methodological trends and research patterns within the field.

Nevertheless, several limitations should be acknowledged. The review included only peer-reviewed studies published in English, which may introduce a degree of publication bias. In addition, the substantial heterogeneity in datasets, model architectures, and performance metrics prevented quantitative meta-analysis of the results. Finally, the rapidly evolving nature of AI research means that new methodological developments may emerge quickly after the completion of the literature search.

Future research should focus on several key priorities. The development of larger and more diverse datasets, including multi-population skeletal and radiological collections, will be essential to improve the generalizability of AI models. External validation using independent datasets should become a standard practice in the evaluation of forensic AI systems. Furthermore, the integration of explainable AI techniques may help improve transparency and interpretability, which are critical factors in medico-legal contexts where algorithmic decisions may be subject

to legal scrutiny. Ultimately, interdisciplinary collaboration between forensic scientists, data scientists, and clinicians will be crucial to ensure the responsible and effective implementation of AI technologies in forensic identification.

Conclusions

This systematic review provides a comprehensive overview of the current applications of AI in forensic personal identification. The findings indicate that AI-based approaches, particularly deep learning models applied to imaging datasets, have demonstrated high predictive performance across several forensic tasks, including sex estimation, human identification, ancestry estimation, and kinship analysis. The increasing availability of digital imaging data, such as computed tomography and radiographic datasets, has played a key role in facilitating the development of AI-driven analytical methods in forensic research.

Despite these promising results, important challenges remain. The predominance of population-specific datasets, methodological heterogeneity across studies, and the limited availability of externally validated models highlight the need for more standardized research protocols and multi-population datasets. In addition, ethical and legal considerations related to transparency, interpretability, and the potential forensic use of algorithmic outputs must be carefully addressed before widespread implementation in medico-legal practice.

Overall, AI should be considered a complementary tool capable of supporting forensic experts rather than replacing human expertise. Future research should focus on improving model transparency, expanding population diversity in training datasets, and developing standardized validation frameworks to ensure the reliability and forensic applicability of AI-based identification systems.

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Data Availability This study is a systematic review of previously published literature. No new datasets were generated during the current study. All data underlying the findings of this review are available in the published articles included in the review and in the supplementary

materials provided by the respective authors.

Declarations

Ethics approval and ethical standards This study is a systematic review of published literature and did not involve new human participants or biological samples. Therefore, approval from an institutional review board or ethics committee was not required.

Human ethics and consent to participate declaration Not applicable.

Clinical trial number Not applicable.

Competing interests The authors declare no competing interests.

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