

## Artificial Intelligence in Human Identification in Forensic Dentistry: A Narrative Literature Review

### *Inteligência Artificial na Identificação Humana em Odontologia Forense: Uma Revisão Narrativa da Literatura*

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#### Abstract

This study analyzes the application of Artificial Intelligence (AI) to human identification within forensic dentistry, a field in which computational tools have been progressively incorporated into the analysis of dental data and radiographic images. This study aimed to analyze the applications of artificial intelligence related to human identification in forensic dentistry, considering the reported performance of AI-based methods and their main benefits and limitations. A literature review was conducted based on the analysis of scientific articles published between 2015 and 2025. The search strategy used the terms “Artificial Intelligence”, “Machine Learning”, “Deep Learning”, “Forensic Dentistry”, “Forensic Odontology”, “Dental Forensics”, “Human Identification”, “Personal Identification”, “Age Estimation”, “Bite Mark Analysis”, “Diagnostic Imaging”, “Dental Radiography” in PubMed, SciELO, LILACS, and Google Scholar, the latter being used as a source of gray literature. Eleven studies were included, comprising literature reviews and retrospective studies. The main applications identified were related to age and sex estimation through the analysis of dental images, particularly panoramic radiographs, using deep learning models and convolutional neural networks. The studies reported promising performance of these methods; however, the findings were heterogeneous due to differences in study designs, populations, methodological approaches, and validation procedures. The findings indicate that artificial intelligence has potential to support methods related to human identification in forensic dentistry, particularly age and sex estimation. However, methodological heterogeneity among studies, population differences, and the need for further validation limit the generalizability of the findings and highlight the need for additional research before widespread application in forensic practice.

**Keywords:** Artificial Intelligence; Forensic Dentistry; Human Identification; Age Estimation.

#### Resumo

Este estudo analisa a aplicação da Inteligência Artificial (IA) na identificação humana no contexto da Odontologia Legal, área em que ferramentas computacionais vêm sendo progressivamente incorporadas à análise de dados odontológicos e imagens radiográficas. O objetivo deste trabalho foi analisar as aplicações da inteligência artificial relacionadas à identificação humana na Odontologia Legal, considerando o desempenho relatado dos métodos baseados em IA e seus principais benefícios e limitações. Realizou-se uma revisão de literatura baseada nos artigos publicados no período de 2015 a 2025. A estratégia de busca utilizou os termos: “Artificial Intelligence”, “Machine Learning”, “Deep Learning”, “Forensic Dentistry”, “Forensic Odontology”, “Dental Forensics”, “Human Identification”, “Personal Identification”, “Age Estimation”, “Bite Mark Analysis”, “Diagnostic Imaging”, “Dental Radiography”, nas bases de dados PubMed, SciELO, LILACS e Google Acadêmico (como fonte de literatura cinzenta). Foram incluídos 11 estudos, compostos por revisões de literatura e estudos retrospectivos. As principais aplicações identificadas concentraram-se na estimativa de idade e sexo por meio da análise de imagens odontológicas, especialmente radiografias panorâmicas, utilizando modelos de aprendizado profundo e redes neurais convolucionais. Os estudos relataram desempenho promissor desses métodos, embora os resultados tenham sido heterogêneos em razão das diferenças nos desenhos dos estudos, populações avaliadas, métodos empregados e processos de validação. Os achados indicam que a inteligência artificial apresenta potencial para auxiliar métodos relacionados à identificação humana na Odontologia Legal, especialmente na estimativa de idade e sexo. Entretanto, a heterogeneidade metodológica entre os estudos, as diferenças populacionais e a necessidade de maior validação limitam a generalização dos resultados e reforçam a necessidade de novas pesquisas antes de sua ampla aplicação no contexto pericial.

**Palavras-chave:** Inteligência Artificial; Odontologia Legal; Identificação Humana; Estimativa de Idade.

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## 1 INTRODUCTION

Forensic Dentistry is a branch of forensic science that applies dental knowledge to support legal investigations, playing a crucial role in human identification (Machado; Jassé; Arantes, 2024). This is especially relevant in scenarios where other methods are not viable, such as mass disasters or when bodies are in advanced stages of decomposition (Pessoa *et al.*, 2023). The analysis of dental structures, radiographs, and dental records allows for comparisons between ante-mortem and post-mortem data, facilitating the identification of individuals (Filho; Melani, 2022; Anees; Riaz; Franco, 2024).

With technological advances, Artificial Intelligence (AI) has been incorporated into various healthcare fields, including Dentistry (Vodanović *et al.*, 2023). AI refers to computational systems capable of performing tasks that typically require human intelligence, such as learning and reasoning (Alcântara *et al.*, 2024). In Dentistry, AI has been used to improve diagnostics, plan treatments, and interpret images with greater precision (Silva *et al.*, 2024; Kahm *et al.*, 2023).

In the context of Forensic Dentistry, the application of AI is still emerging but shows significant potential (Savegnago *et al.*, 2024). Recent studies demonstrate the use of machine learning - algorithms that “learn” from large dental datasets - and artificial neural networks in forensic applications involving dental radiograph analysis, age estimation, and bite mark analysis (Murray *et al.*, 2024; Hiyari; Pasic; Zukic, 2024). These technologies may contribute to improving the accuracy and efficiency of forensic analyses and reducing errors associated with manual evaluation (Khanagar *et al.*, 2021; Vodanović *et al.*, 2023).

However, challenges such as the need for standardization, ethical considerations, and scientific validation must still be overcome for the effective implementation of AI in forensic dental practice.

Although artificial intelligence has been increasingly investigated in forensic dentistry, the available literature encompasses different applications, methodological approaches, and forensic purposes, resulting in a heterogeneous body of evidence. Synthesizing the available literature may contribute to a broader understanding of how AI has been applied to human identification, as well as its reported benefits and limitations (Khanagar *et al.*, 2021; Vodanović *et al.*, 2023).

Therefore, this study aimed to analyze the applications of artificial intelligence related to human identification in forensic dentistry, considering the reported performance of AI-based methods and their main benefits and limitations. In this review, AI applications related to forensic human identification are considered broadly, including individual identification, age estimation, sex estimation, and other applications that may provide complementary information for forensic assessment.

## 2 METHODS

This narrative literature review was conducted to identify and synthesize published evidence regarding the application of artificial intelligence in forensic dentistry, with emphasis on human identification and related

forensic applications.

A literature search was conducted in PubMed, SciELO, LILACS, and Google Scholar. The search covered publications from 2015 to 2025 and used combinations of terms related to artificial intelligence, forensic dentistry, and human identification, including “Artificial Intelligence,” “Machine Learning,” “Deep Learning,” “Forensic Dentistry,” “Forensic Odontology,” “Human Identification,” “Age Estimation,” and “Dental Radiography.”

Studies were considered relevant when they addressed the use or potential use of artificial intelligence in forensic dentistry, particularly in human identification, age estimation, sex estimation, dental image analysis, or other related forensic applications. Studies that were unrelated to the topic or did not provide sufficient information for the purposes of this review were not considered.

The retrieved literature was screened for relevance, and the information considered most pertinent to the objectives of the review was organized in a Microsoft Excel® spreadsheet. The extracted information included publication year, country, study design, forensic application, AI method, main objective, and principal findings. The evidence was synthesized qualitatively, with emphasis on the main applications, reported performance, potential benefits, limitations, and challenges associated with the use of artificial intelligence in forensic dentistry.

Following full-text reading, relevant information from the included studies was extracted and organized for synthesis. The data collected included author and year of publication, country, study design, evaluated parameters, objective and methodology, and main results and conclusions, as summarized in Table 1.

Table 1 – Characteristics of the studies included in the literature review

| Author / Year                             | Country             | Design              | Evaluated Para-meter                          | Objective / Methodology                                                                                                                                                                                                                                  | Results / Conclusions                                                                                                                                                                                                                                                                                           |
|-------------------------------------------|---------------------|---------------------|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Anees, Riaz e Franco (2024)               | Pakistan            | Literature Re-view  | Sex and age es-timation, human identification | To examine the literature on the use of AI in forensic dentistry (2000–2023) via PubMed, LI-LACS, and SciELO searches.                                                                                                                                   | AI use in forensic dentistry is li-kely to increase, especially in hu-man identification and age/sex estimation.                                                                                                                                                                                                |
| Bui <i>et al.</i> (2023)                  | France              | Retrospective Study | Human Identifica-tion                         | To evaluate the technical fea-sibility of I3M-based decision-making using 456 radiographs from France and Uganda. Deep learning models (Mask R-CNN, U-Net) were compared with and without topological analysis.                                          | The most effective approach combined a U-Net algorithm with a topological method, demon-strating the technical feasibility of de-veloping a decision-support tool that replicates the I3M index for forensic experts.                                                                                           |
| Cacñahuaray-martínez <i>et al.</i> (2021) | Peru                | Literature Re-view  | Use of AI in Foren-sic Dentistry              | To review the application of AI across dental specialties via Pub-Med, Scopus, and Web of Sci-ence (2017–2021).                                                                                                                                          | AI shows promising results, of-ten matching or surpassing exp-ert performance while reducing human error.                                                                                                                                                                                                       |
| Hiyari, Pasic e Zu-kic (2024)             | Bosnia Her-zegovina | Retrospective Study | Sex and age esti-mation                       | To assess the performance of three convolutional neural networks (CNNs) for age and sex estimation using 3,716 orthopan-tomograms.                                                                                                                       | The CNN models showed high performance in age and sex esti-mation, supporting their potential use as auxiliary tools in forensic analysis based on dental radio-graphs.                                                                                                                                         |
| Kahm <i>et al.</i> (2023)                 | South Ko-rea        | Retrospective Study | Age estimation                                | To evaluate the accuracy of AI ap-plied to 27,877 panoramic dental images from ages 5 to 90. Mo-dels used: WideResNet, Dense-Net.                                                                                                                        | The ±3-year age classification showed satisfactory results, de-monstrating AI's efficacy for fo-rensic age estimation.                                                                                                                                                                                          |
| Khanagar <i>et al.</i> (2021)             | Saudi Ara-bia       | Systematic Review   | Sex/age estima-tion and bite mark analysis    | To evaluate the application and performance of AI in forensic odontology through comprehen-sive database search (2000–2020).                                                                                                                             | AI has been widely used in fo-rensic investigations with accu-racy comparable to trained hu-man examiners.                                                                                                                                                                                                      |
| Murray <i>et al.</i> (2024)               | Brazil              | Retrospective Study | Age estimation                                | To investigate the use of artificial intelligence for legal age assess-ment using 4,003 panoramic ra-diographs from individuals aged 8 to 22.9 years. A convolutional neural network was trained to es-timate chronological age from ra-diographic data. | The CNN achieved 87% ac-curacy for the evaluated age-classification task, indicating promising performance for AI-assisted legal age assessment based on panoramic radiographs. This result should be interpreted within the specific population, da-taset, and validation approach used in the original study. |
| Pereira <i>et al.</i> (2019)              | Brazil              | Literature Re-view  | Human Identifica-tion                         | To present an AI-based solution for managing and analyzing den-tal records.                                                                                                                                                                              | AI-enhanced systems can map similarities in radiographs and foster synergy between health-care and tech sectors.                                                                                                                                                                                                |
| Savegnago <i>et al.</i> (2024)            | Brazil              | Literature Re-view  | Use of AI in Foren-sic Dentistry              | To analyze methods used by fo-rensic dentistry in human identi-fication.                                                                                                                                                                                 | AI may contribute to greater pre-cision and efficiency in foren-sic dental analyses, but its use should remain complementary to professional expertise and not re-place expert judgment.                                                                                                                        |
| Singh, Singha e Kumar (2024)              | India               | Systematic Review   | Sex and age esti-mation                       | To assess the use of AI in foren-sic dentistry for sex and age de-termination.                                                                                                                                                                           | AI models performed comparably to human examiners; suitable for legal and disaster victim identi-fication.                                                                                                                                                                                                      |
| Vodanović <i>et al.</i> (2023)            | Croatia             | Literature Re-view  | Use of AI in Foren-sic Dentistry              | To highlight AI's applications in forensic and legal medicine based on literature from PubMed, Web of Science, and Scopus.                                                                                                                               | AI offers advantages (accuracy, automation, evidence quality), but ethical concerns—bias, pri-vacy, accountability—must be ad-dressed.                                                                                                                                                                          |

Source: Elaborated by the authors based on the literature review.

3 DISCUSSION

The studies included in this review describe different applications of artificial intelligence in forensic dental analysis that may contribute directly or indirectly to human identification. These applications involve the

analysis and comparison of dental images and records, pattern recognition, machine learning and deep learning techniques, and age and sex estimation (Bui *et al.*, 2023; Kahm *et al.*, 2023; Hiyari; Pasic; Zukic, 2024). The main applications identified are discussed in the following subsections.

### 3.1 Applications of AI in forensic dentistry

#### 3.1.1 AI-based analysis of dental radiographs and pattern recognition

The application of AI in the comparison of dental radiographs has shown promising potential for age estimation in both clinical and forensic contexts (Singh; Singha; Kumar, 2024; Mohammad *et al.*, 2024). Automated image analysis may contribute to more accurate assessments and support forensic decision-making (Barroso *et al.*, 2024). However, its implementation requires appropriate ethical considerations and scientific validation.

According to Kahm *et al.* (2023), deep learning models such as WideResNet and DenseNet showed satisfactory performance in age estimation using panoramic dental images. The analysis of full panoramic images demonstrated the potential of these models to use broader radiographic information for age-related assessment.

Pattern recognition algorithms applied to dental records, particularly panoramic images, may also identify characteristics related to biological traits such as sex and age (Hiyari; Pasic; Zukic, 2024). Image analysis allows the extraction of dental development characteristics, such as eruption and wear (Furtado *et al.*, 2024). These algorithms can identify such features and use them as relevant information for age-related assessment (Kahm *et al.*, 2023).

#### 3.1.2 Machine learning and neural networks in individual identification

The use of Convolutional Neural Networks (CNNs) is widely reported in studies on artificial intelligence applied to dental image analysis. In age estimation based on panoramic radiographs, CNNs are trained to identify complex patterns related to dental development, including root formation and tooth eruption (Kahm *et al.*, 2023)..

The application of CNNs to dental images has also been investigated for both age and sex estimation. Hiyari, Pasic e Zukic (2024) evaluated three convolutional neural network models using orthopantomograms, reporting promising performance for these forensic applications.

#### 3.1.3 AI in the assessment of dental findings associated with trauma or abuse

AI-based pattern recognition may assist in the analysis of radiographic and intraoral images for the identification of findings potentially related to trauma, such as fractures, injuries associated with physical aggression, and bite marks (Vodanović *et al.*, 2023). These tools may contribute to the detection of subtle image patterns that could support forensic assessment, although their use should be interpreted as an auxiliary resource

rather than a substitute for professional evaluation.

### 3.1.4 Deep learning for radiographic and intraoral image analysis

Deep learning, which simulates human brain processing, has been used to train systems capable of detecting complex patterns in radiographs and intraoral images, aiding in the identification of diseases, fractures, and dental alterations relevant in forensic contexts (Bui *et al.*, 2023; Savegnago *et al.*, 2024). Automated analysis may reduce the burden associated with repetitive manual assessment and may support the consistency of forensic evaluations (Kahm *et al.*, 2023; Vodanović *et al.*, 2023).

### 3.1.5 AI in age estimation based on dental characteristics

Age estimation is an important component in medico-legal contexts, particularly when chronological age needs to be inferred from biological characteristics (Prokurat *et al.*, 2024). In forensic dentistry, artificial intelligence has been applied to dental images to support age estimation, with promising results reported in different populations and methodological approaches (Murray *et al.*, 2024; Ghods *et al.*, 2023).

Hiyari, Pasic e Zukic (2024) reported that convolutional neural networks could estimate age and sex from orthopantomograms with high performance. Murray *et al.* (2024), using 4,003 digital panoramic radiographs, trained a convolutional neural network for chronological age estimation and reported an accuracy of 87% for the evaluated task.

### 3.1.6 AI-based forensic facial reconstruction using dental structures

AI-supported forensic facial reconstruction may contribute to the creation of three-dimensional facial representations using dental and craniofacial data (Mendes *et al.*, 2024). This approach may be particularly useful in complex forensic cases involving severe facial trauma, supporting human identification when conventional methods are limited (Cacñahuaray-martínez *et al.*, 2021).

## 3.2 Potential benefits and limitations

### 3.2.1 Benefits

Greater precision and speed in identification processes: The use of Convolutional Neural Networks (CNNs) has shown promising performance in age estimation, contributing to more efficient forensic analyses (Kahm *et al.*, 2023).

Reduction of human errors: AI may reduce the need for constant manual intervention, potentially decreasing workload and errors associated with manual analysis (Khanagar *et al.*, 2021).

Automation of repetitive processes: The automation of specific tasks, such as dental image analysis, may contribute to faster and more efficient forensic assessments (Vodanović *et al.*, 2023).

### 3.2.2 Limitations

Need for reliable and standardized databases: The effectiveness of AI models depends on the availability of extensive, reliable, and standardized datasets (Kahm *et al.*, 2023). The lack of diversity in these datasets may compromise the applicability of models across different populations.

Ethical and legal issues in the use of AI in forensic examinations: The use of AI in forensic dentistry raises ethical concerns related to privacy, algorithmic bias, and legal accountability (Cacñahuaray-martínez *et al.*, 2021; Khanagar *et al.*, 2021; Ghods *et al.*, 2023). Algorithmic transparency is an important aspect to consider for the responsible and legally acceptable use of AI-generated results (Kahm *et al.*, 2023).

Acceptance of the technology in legal and academic fields: Despite initial resistance, studies show growing academic interest and advances in the validation of AI for forensic applications (Cacñahuaray-martínez *et al.*, 2021; Khanagar *et al.*, 2021; Ghods *et al.*, 2023).

### 3.3 Future Perspectives

The use of advanced techniques, such as convolutional neural networks and deep learning, has expanded the possibilities for automated analysis of dental data in forensic dentistry (Cacñahuaray-martínez *et al.*, 2021). Applications involving age estimation and facial reconstruction represent areas of interest for the continued development of artificial intelligence in the field. In addition, the integration of AI with technologies such as 3D scanning, biometrics, and big data may contribute to improving the precision and efficiency of forensic processes (Pereira *et al.*, 2019; Anees; Riaz; Franco, 2024; Hiyari; Pasic; Zukic, 2024; Barroso *et al.*, 2024). The incorporation of AI into forensic dental practice may also contribute to faster and more accurate analyses, task automation, and greater efficiency in forensic procedures (Vodanović *et al.*, 2023). However, the advancement of these applications depends on further validation and the development of broader and more diverse databases, which are important for training and evaluating algorithms across different populations and forensic conditions. Professional training and continuing education are also relevant to ensure the appropriate interpretation and use of these technologies in forensic practice.

### 3.4 Limitations of the Review

This review has some limitations. The literature identified was heterogeneous regarding study designs, populations, sample sizes, AI models, forensic applications, and validation procedures, limiting direct comparison among studies. In addition, the relatively small number of studies specifically addressing AI applications in forensic dentistry reflects the emerging nature of this field. The inclusion of different types of publications, including primary studies and literature reviews, also limits the comparability of the available evidence. Therefore, the findings should be interpreted as a narrative synthesis of the current literature rather than as definitive estimates of the performance of artificial intelligence in forensic dentistry.

## 4 FINAL CONSIDERATIONS

The findings of this review reinforce the importance of Forensic Dentistry in human identification, particularly in situations in which conventional identification methods may be limited, such as mass disasters or cases involving advanced post-mortem changes. In these contexts, dental characteristics and records may provide valuable information for forensic analysis.

The incorporation of Artificial Intelligence (AI) into forensic dental analysis has expanded the possibilities for processing and interpreting dental data, particularly through radiographic analysis, pattern recognition, and age and sex estimation. The studies reviewed indicate that AI-based methods may contribute to greater efficiency and support forensic decision-making, although the reported performance varies according to the methodology, population, and type of data evaluated.

Deep learning approaches, including convolutional neural networks, have shown promising results in the analysis of dental images and age-related characteristics. However, the available evidence does not yet support the unrestricted generalization of these results to all populations or forensic contexts, highlighting the importance of further validation and the development of more diverse datasets.

The use of AI in Forensic Dentistry also involves ethical and legal challenges related to data privacy, algorithmic transparency, accountability, and the interpretation of AI-assisted results. Therefore, these technologies should be considered supportive tools for forensic professionals rather than substitutes for expert judgment. Professional training and continuing education remain important for their appropriate and responsible use in forensic practice.

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