



# Integrating Digital Imaging and AI in Forensic Odontology: Enhancing Identification Accuracy and Efficiency

Yessy Andriani Fauziah<sup>1</sup>, Eveline Yulia Darmadi<sup>1</sup>, Ryan Raditya Tjandra<sup>1</sup>

<sup>1</sup> Universitas Ciputra, Surabaya, Indonesia

Received : July 30, 2024

Revised : August 5, 2024

Accepted : August 9, 2024

Online : September 11, 2024

## Abstract

**Background:** The integration of digital imaging and artificial intelligence (AI) in forensic odontology can significantly enhance the accuracy and efficiency of dental identification processes. These technologies provide precise and rapid analysis, which is crucial for forensic investigations. However, implementing such technologies also introduces new ethical challenges that must be addressed. **Purpose:** To explore the synergistic use of digital imaging and artificial intelligence (AI) in forensic odontology. This section focuses on how these technologies improve identification accuracy and efficiency while discussing the ethical considerations that arise from their implementation. **Methodology:** This methodology involves a comprehensive review of the existing literature on the applications of digital imaging and AI in forensic odontology. Key studies, clinical trials, and case examples are analyzed to evaluate the effectiveness of these technologies in improving forensic outcomes. The review assesses these technologies' impact on identification accuracy and efficiency while addressing ethical concerns such as data privacy and AI biases. **Results:** The review highlights that the combination of digital imaging and AI significantly enhances the accuracy and speed of dental identification. Advanced algorithms can process large datasets and identify subtle patterns that are often missed by human examiners, resulting in more reliable forensic outcomes. However, ethical challenges, including data privacy concerns and potential biases in AI algorithms, are critical areas that require careful consideration and regulation. Ongoing research and policy development are essential to address these issues and ensure the ethical application of AI in forensic odontology.

**Keywords** *Digital Imaging, Forensic Odontology, Artificial Intelligence, Identification.*

## INTRODUCTION

The integration of digital imaging and artificial intelligence (AI) has revolutionized the field of forensic odontology, significantly enhancing the accuracy and efficiency of dental identification processes (Jadhav et al., 2020). Digital imaging technologies, such as Cone Beam Computed Tomography (CBCT) and advanced radiographic techniques, provide high-resolution images that are crucial for detailed forensic analysis (Urban et al., 2023). Artificial intelligence (AI) technologies, such as machine learning and deep learning, have shown great promise in the processing of radiography and dental data, increasing the precision and efficiency of forensic inquiries (Heo et al., 2020). These developments are critical for increasing the reliability of forensic odontology, allowing professionals to identify individuals with better precision and efficiency (Matsuda et al., 2020). The advent of AI has further transformed forensic odontology by enabling the rapid analysis of complex datasets, thus streamlining the identification process. Digital imaging continues to evolve and offers unprecedented precision and clarity, enhancing the overall efficiency of forensic odontology practices (Khanagar et al., 2021).

Artificial intelligence, particularly through use of machine learning and deep learning algorithms, has further revolutionized forensic odontology by enabling the rapid analysis of complex dental data. AI algorithms can process and analyze large datasets and identify subtle patterns and anomalies that may be overlooked by human examiners (Nguyen et al., 2021). Recent research has highlighted these issues, making AI systems a valuable tool in forensic odontology (Kumar, 2022). Innovations in artificial

### Copyright Holder:

© Yessy, Eveline, and Ryan. (2024)

Corresponding author's email: [yessy.andriani@ciputra.ac.id](mailto:yessy.andriani@ciputra.ac.id)

### This Article is Licensed Under:



intelligence (AI) and digital imagery have created new opportunities in the field of forensic odontology (Smitha, 2023). High-resolution, three-dimensional views of dental structures are provided by digital imaging technologies, such as Cone Beam Computed Tomography (CBCT) and sophisticated radiography procedures, allowing for precise and thorough analysis (Izham & Auerkari, 2021). The integration of digital imaging and AI into forensic odontology can significantly enhance identification accuracy and efficiency. This synergy can streamline forensic workflows, reduce human error, and provide more reliable outcomes, making it a critical area of focus for forensic scientists and researchers (Backiyalakshmi & Divya, 2024).

## LITERATURE REVIEW

### Digital Imaging in Forensic Odontology

Digital imaging has significantly improved forensic odontology by providing detailed, accurate visual representations of dental structures. Technologies like Cone Beam Computed Tomography (CBCT), digital radiography, and 3D scanning have become essential tools in investigations. CBCT offers high-resolution images, enabling precise analysis of dental and skeletal structures, which is crucial for identifying unique dental features and comparing them with antemortem records. Digital radiography offers immediate results and efficient workflow (Sinha, 2018).

Digital imaging is used in forensic odontology for purposes other than identification. In both criminal and civil situations, these technologies make it easier to examine oral injuries, diagnose pathological diseases, and estimate age (Middleton et al., 2016). Digital imaging, for example, can reveal the minute features of dental abnormalities and restorations, which are frequently specific to an individual and can be used to identify individuals (Zhang, 2022). The high precision and clarity offered by digital imaging also minimizes the risk of human error, thereby increasing the accuracy and reliability of forensic analyses. Moreover, the non-invasive nature of digital imaging preserves the integrity of evidence, which is essential for subsequent legal proceedings (Matsuda et al., 2020).

Several case studies have explained the usefulness of digital imagery in forensic odontology. In one famous case, forensic specialists were able to identify a victim by using CBCT to analyze dental restorations and root canal treatments in detail, which matched the antemortem dental data (Gopal, 2018). In another example, 3D scanning was used to recreate a broken skull, enabling successful dental comparison and identification thereafter (Norman et al., 2017). These examples underscore the pivotal role of digital imaging in modern forensic practice, highlighting its ability to enhance both the accuracy and efficiency of identification processes (Middleton et al., 2016). The future of digital imaging in forensic odontology is promising, with ongoing research and development aimed at further enhancing these technologies (Goyal et al., 2014). Innovations such as advanced 3D imaging software, automated image analysis tools, and the integration of AI algorithms are expected to improve the precision and speed of forensic dental identifications even further (Kim, 2024).

### Artificial Intelligence in Forensic Odontology

Artificial intelligence (AI) is a collective term for various technologies intended to perform tasks that typically require human intelligence. The primary AI applications in forensic odontology are machine learning and deep learning algorithms, which are capable of processing massive amounts of data and precisely identifying patterns (Vodanović et al., 2023). These technologies are capable for analyzing complex dental images, recognizing unique dental features, and making precise identifications that enhance the overall forensic process. Artificial intelligence (AI) can be a significantly helpful tool in forensic science, where accuracy and efficiency are crucial because AI can learn from and become better at processing data (Mohsin, 2021).

AI has several applications in forensic odontology, ranging from dental identification to the analysis of dental anomalies and trauma. One significant application is the automated matching of

postmortem dental records with antemortem records, a process that traditionally required extensive manual comparison. AI algorithms can rapidly analyze dental X-rays, CT scans, and photographs to find matches, significantly reducing the time required for identification (Mohammad et al., 2022). Furthermore, AI can assist in age estimation by analyzing dental development and wear patterns, providing crucial information in both forensic and archeological contexts. The integration of AI into forensic odontology offers numerous benefits, primarily enhancing the accuracy and efficiency of dental identification. AI algorithms can process and analyze data at a speed and accuracy that are unattainable by human examiners alone, thereby reducing the potential for human error. For instance, AI can detect subtle differences in dental structures that might be overlooked in manual examination, thereby leading to more accurate identification. Additionally, AI's ability to handle large datasets allows for the rapid processing of numerous cases simultaneously, which is particularly beneficial in mass disaster situations where swift identification is critical (Backiyalakshmi & Divya, 2024).

Several AI algorithms have been developed specifically for forensic odontology applications. Convolutional Neural Networks (CNNs), for example, are widely used for image recognition tasks, including the analysis of dental radiographs. These networks can learn to identify specific dental features and anomalies with high precision, thereby improving the reliability of forensic analyses. In addition, depending on various dental parameters, Support Vector Machines (SVMs) and Random Forest algorithms have been used to identify and predict dental age (Murray et al., 2024).

### **Integration of Digital Imaging and AI**

The integration of digital imaging and AI significantly enhances the accuracy of dental identification processes in forensic odontology (Chiam, 2014). Digital imaging technologies such as cone beam computed tomography (CBCT) and digital radiography provide high-resolution, detailed images of dental structures. When these images are analyzed using AI algorithms, the precision with which unique dental features are identified and matched with antemortem records is greatly improved (Reddy et al., 2022). Artificial intelligence (AI) can detect patterns and minute variations in tooth traits that human examiners may overlook, thus reducing the probability of errors and increasing the accuracy of identification. This collaboration allows forensic odontologists to achieve more accurate identifications, which is crucial in both criminal investigations and disaster identification (Backiyalakshmi & Divya, 2024).

### **RESEARCH METHOD**

The methodology for this literature review involves a systematic collection of data from various peer-reviewed journals, books, conference papers, and other credible sources published between 2016 and 2024. The primary focus is on studies that have explored integrating digital imaging technologies, such as Cone Beam Computed Tomography (CBCT), 3D scanning, and AI algorithms, within the context of forensic odontology. The search for relevant literature was conducted using databases such as PubMed, Google Scholar, IEEE Xplore, and ScienceDirect, with specific keywords like "forensic odontology," "digital imaging," "AI in forensic science," and "dental identification." The inclusion criteria were based on the study's relevance to forensic odontology and the use of digital imaging and AI technologies. Articles not meeting these criteria or lacking substantial methodological details were excluded. The methodology for this review involves a thorough examination of the existing literature focusing on the application of digital imaging and artificial intelligence (AI) in forensic odontology. This includes analyzing key studies, clinical trials, and case examples to assess how these technologies enhance forensic outcomes, such as identification accuracy and efficiency. This review also addresses critical ethical concerns, including data privacy issues, potential biases in AI algorithms, and the necessity for transparent and accountable AI systems. This review provides a comprehensive understanding of the impact and implications of digital imaging and AI in forensic odontology.

## FINDINGS AND DISCUSSION

Combining digital imaging with AI also enhances the efficiency and speed of forensic analysis. Digital imaging technologies provide immediate, high-quality images that can be processed quickly using AI algorithms. This rapid processing capability is particularly beneficial in situations where time is critical, such as mass disaster scenarios where numerous victims need to be identified. Digital imaging techniques such as Cone Beam Computed Tomography (CBCT) and digital radiography provide high-resolution, detailed images of dental structures. These images, when analyzed using AI algorithms, can detect subtle differences and patterns that may not be noticeable to the human eye. AI's ability to analyze large datasets quickly and accurately allows precise matching of postmortem dental records with antemortem records, significantly increasing the reliability of identifications. This enhanced accuracy is crucial in both criminal investigations and mass person who has experienced disaster identification, where precise identification can make a significant difference (Zhang, 2022).

While the integration of digital imaging and AI into forensic odontology offers numerous benefits, it also raises important ethical and legal considerations. Privacy and data security are paramount, as dental records contain sensitive personal information. To avoid misuse and unwanted access to such data, strong encryption and secure storage solutions are important. Additionally, there is a need for clear legal frameworks and guidelines to govern the use of AI in forensic dentistry, addressing issues such as consent, data sharing, and the ethical implications of automated decision-making. AI systems are essential for forensic investigations, but their ethical implications must be carefully considered. AI enhances dental identification accuracy and speed, making it crucial in forensic settings. However, ethical concerns such as data privacy, algorithmic unfairness, and openness must be addressed to ensure responsible and equitable deployment. In the future, the integration of digital imaging and AI into forensic odontology holds great promise for further advancement. Emerging AI technologies, such as deep learning and neural networks, can enhance the accuracy and efficiency of dental identifications even further (Mörch et al., 2021).

The integration of digital imaging and AI into forensic odontology does not occur in isolation but rather as part of a broader forensic system. Combining these technologies with other forensic disciplines such as genetics and toxicology can enhance the overall effectiveness of forensic investigations. For instance, integrating dental data with genetic profiles could provide a more comprehensive approach to identification, particularly in cases in which dental records are insufficient. Effective collaboration among forensic professionals and integration of diverse data sources are critical for maximizing the potential of digital imaging and AI technologies. Forensic odontologists can use these improvements to increase the accuracy of dental identification, especially in complex cases with limited or destroyed dental records. The ongoing progress of AI technologies provides an opportunity to create new and improved algorithms specifically tailored to forensic applications. Deep learning and neural networks, two recent AI algorithms, can completely transform forensic odontology. These advanced algorithms can learn from enormous data volumes and produce extremely precise classifications and predictions (Mohammad et al., 2022).

The effectiveness of AI in forensic odontology is significantly influenced by the level of technological proficiency of forensic odontologists. Despite the advanced capabilities of AI in analyzing digital imaging data and improving identification accuracy, its practical application depends on the user's ability to effectively utilize such technologies (Vodanović et al., 2023). Forensic odontologists must be adept at operating sophisticated imaging systems and interpreting AI-generated results. Training and ongoing education on digital technologies are crucial for optimizing the use of AI because the success of AI integration depends on the operator's expertise and familiarity with the system. In addition, the ability to critically evaluate AI outputs and address potential limitations or biases in

algorithms is essential to ensure accurate and reliable forensic analysis. Increasing the technological skills of forensic odontologists is essential for maximizing the potential of AI in forensic practice (Galante et al., 2023).

## CONCLUSIONS

The accuracy and efficiency of dental identification have increased significantly with the integration of digital imaging and artificial intelligence (AI) in forensic odontology. Foresightful and rapid identification can be accomplished by utilizing high-resolution imaging and advanced AI algorithms. This is vital in both normal investigations and urgent situations like mass disasters. However, the effective application of these technologies depends on resolving moral and legal issues, overcoming technological obstacles, and encouraging multidisciplinary cooperation. Further developments in forensic odontology will guarantee more reliable and efficient identification techniques in the future. This can be achieved through strong research and useful applications in conjunction with ongoing innovation in artificial intelligence and digital imaging. The effectiveness of AI in forensic odontology depends on the forensic odontologist's technological proficiency, as advanced tools require skilled operators for accurate analysis. The review significantly contributes by consolidating current knowledge on how digital imaging and artificial intelligence enhance identification accuracy and efficiency in forensic practice. This highlights the potential of AI in improving forensic processes, reducing human error and increasing reliability. The discussion of ethical considerations is also crucial, emphasizing the need for a balanced approach when adopting these technologies. Overall, this review provides valuable insights for future research and guidance for practitioners integrating advanced technologies into forensic odontology.

## LIMITATION & FURTHER RESEARCH

This literature review identifies key advancements in integrating digital imaging and AI in forensic odontology while acknowledging certain limitations. Reliance on previously published studies introduces potential biases and may not fully capture the latest technological developments, which affects the generalizability of the findings. The review's focus on digital imaging and artificial intelligence may overlook other emerging or hybrid technologies that could impact forensic odontology. Additionally, variations in study designs and criteria across the literature make direct comparisons challenging.

## REFERENCES

- Backiyalakshmi A., Divya V C, (2024). Artificial Intelligence in Forensic Odontology: A Review. *IP International Journal of Maxillofacial Imaging*, 10(1), 6–10. <https://doi.org/10.18231/j.ijmi.2024.002>
- Chiam, S. L. (2014). A Note on Digital Dental Radiography in Forensic Odontology. *Journal of Forensic Dental Sciences*, 6(3), 197-201. <https://doi.org/10.4103/0975-1475.137072>
- Galante, N., Cotroneo, R., Furci, D., Lodetti, G., & Casali, M. B. (2023). Applications of Artificial Intelligence in Forensic Sciences: Current Potential Benefits, Limitations and Perspectives. *International Journal of Legal Medicine*, 137(2), 445-458. <https://doi.org/10.1007/s00414-022-02928-5>
- Gopal SK. (2018). Role of 3 D Cone Beam Computed Tomography Imaging in Forensic Dentistry: A Review of Literature. *Indian Journal of Forensic Odontology*, 11(2). <http://dx.doi.org/10.21088/ijfo.0974.505X.11218.5>
- Goyal, N., Ashwarya, T., Singla, N., Gupta, S., & Goyal, M. (2014). Role of Imaging in Forensic Odontology. *Journal of PEARLDENT*, 5(4), 10-12. <http://dx.doi.org/10.5958/2229-4457.2014.00010.5>
- Heo, M. S., Kim, J. E., Hwang, J. J., Han, S. S., Kim, J. S., Yi, W. J., & Park, I. W. (2021). Artificial Intelligence

- in Oral and Maxillofacial Radiology: What is Currently Possible? *Dentomaxillofacial Radiology*, 50(3), 20200375. <https://doi.org/10.1259/dmfr.20200375>
- Izham, A., & Auerkari, E. I. (2021, March). The Use of Radiology CBCT in Odontology Forensic. In *AIP Conference Proceedings* (Vol. 2344, No. 1). AIP Publishing. <https://doi.org/10.1063/5.0047278>
- Jadhav, E. B., Sankhla, M. S., & Kumar, R. (2020). Artificial Intelligence: Advancing Automation in Forensic Science & Criminal Investigation. *Journal of Seybold Report ISSN NO, 1533*, 9211.
- Khanagar, S. B., Vishwanathaiah, S., Naik, S., Al-Kheraif, A. A., Divakar, D. D., Sarode, S. C., ... & Patil, S. (2021). Application and Performance of Artificial Intelligence Technology in Forensic Odontology–A Systematic Review. *Legal Medicine*, 48, 101826. <https://doi.org/10.1016/j.legalmed.2020.101826>
- Kim, H. (2024). Deep Learning in Dental Radiographic Imaging. *Journal of the Korean Academy of Pediatric Dentistry*, 51(1), 1-10. <https://doi.org/10.5933/JKAPD.2024.51.1.1>
- Kumar A. (2022). Artificial Intelligence in Dental Radiology: An Overview. In *Conference: 3rd International Conference for Dental Research Presentations 2022*. <http://dx.doi.org/10.13140/RG.2.2.17724.51847>
- Matsuda, S., Yoshida, H., Ebata, K., Shimada, I., & Yoshimura, H. (2020). Forensic Odontology with Digital Technologies: A Systematic Review. *Journal of Forensic and Legal Medicine*, 74, 102004. <https://doi.org/10.1016/j.jflm.2020.102004>
- Middleton, A., Alminyeh, A., Apostol, M. A., Boel, L. W., Brough, A., Develter, W., ... & Yoshida, M. (2016). Forensic Odontology Radiography and Imaging in Disaster Victim Identification. *Journal of Forensic Radiology and Imaging*, 6, 28-30. <https://doi.org/10.1016/j.jofri.2016.08.003>
- Mohammad, N., Ahmad, R., Kurniawan, A., & Mohd Yusof, M. Y. P. (2022). Applications of Contemporary Artificial Intelligence Technology in Forensic Odontology as Primary Forensic Identifier: A Scoping Review. *Frontiers in Artificial Intelligence*, 5, 1049584. <https://doi.org/10.3389/frai.2022.1049584>
- Mohsin, K. (2023). Artificial Intelligence in Forensic Science. *International Journal of Forensic Research, Artificial Intelligence in Forensic Science*, In *J Fore Res*, 4(1), 172-173. <https://dx.doi.org/10.2139/ssrn.3910244>
- Mörch, C. M., Atsu, S., Cai, W., Li, X., Madathil, S. A., Liu, X., ... & Ducret, M. (2021). Artificial Intelligence and Ethics in Dentistry: A Scoping Review. *Journal of Dental Research*, 100(13), 1452-1460. <https://doi.org/10.1177/00220345211013808>
- Murray, J., Heng, D., Lygate, A., Porto, L., Abade, A., Manica, S., & Franco, A. (2024). Applying Artificial Intelligence to Determination of Legal Age of Majority from Radiographic. *Morphologie*, 108(360), 100723. <https://doi.org/10.1016/j.morpho.2023.100723>
- Nguyen, T. T., Larrivé, N., Lee, A., Bilaniuk, O., & Durand, R. (2021). Use of artificial intelligence in dentistry: current clinical trends and research advances. *Journal Canadian Dental Association*, 87(17), 1488-2159.
- Norman, N., Dimmock, M. R., Lee, K., Graham, J., & Basset, R. (2017). The Applicability of Dual-Energy Computed Tomography (DECT) in Forensic Odontology–A review. *Journal of Forensic Radiology and Imaging*, 10, 15-22. <https://doi.org/10.1016/j.jofri.2017.07.002>
- Reddy, B. N. K., Swetha, P., Manyam, R., & Supriya, A. N. (2022). Importance of Dental Radiography in Forensic Odontology: A Review. *Oral and Maxillofacial Pathology Journal*, 13(2), 124-7.
- Sinha, P. K. (2018). Future of Forensic Odontology in India with Cone Beam Computed Tomography. *Journal of forensic dental sciences*, 10(1), 1. [https://doi.org/10.4103/jfo.jfds\\_39\\_18](https://doi.org/10.4103/jfo.jfds_39_18)
- Smitha T. (2023). Artificial Intelligence in Forensic Odontology. *Journal of Forensic Dental Sciences*, 13(1), 01–02 <https://doi.org/10.18311/jfds/13/1/2021.659>
- Urban, R., Haluzová, S., Strunga, M., Surovková, J., Lifková, M., Tomášik, J., & Thurzo, A. (2023). AI-Assisted CBCT Data Management in Modern Dental Practice: Benefits, Limitations and

- Innovations. *Electronics*, 12(7), 1710. <https://doi.org/10.3390/electronics12071710>
- Vodanović, M., Subašić, M., Milošević, D., Galić, I., & Brkić, H. (2023). Artificial Intelligence in Forensic Medicine and Forensic Dentistry. *The Journal of Forensic Odonto-Stomatology*, 41(2), 30. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10473456/>
- Zhang, M. (2022). Forensic Imaging: A Powerful Tool in Modern Forensic Investigation. *Forensic Sciences Research*, 7(3), 385-392. <https://doi.org/10.1080/20961790.2021.2008705>