Review Article

Artificial intelligence in forensic odontology: A review

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A R T I C L E   I N F O

A B S T R A C T

Artificial Intelligence (AI) is a technology that allows computers to replicate human behaviour and outperform human decision-making in solving complex tasks, either independently or with minimal human involvement. AI technologies, including machine learning and deep neural networks, significantly enhance the accuracy and efficiency of analyzing dental evidence, such as radiographs and bite marks, facilitating reliable identification of individuals, even in complex cases like mass disasters or decomposed remains. Additionally, AI aids in estimating age and determining sex by analyzing dental and skeletal features. The automation of image analysis tasks reduces human error and accelerates identification processes. Furthermore, AI supports the creation of 3D models for facial reconstruction, improving investigative efforts to visualize unidentified remains. Overall, the integration of AI in forensic odontology enhances investigative capabilities, providing valuable tools for law enforcement and contributing to the pursuit of justice. This review article explores the transformative role of Artificial Intelligence (AI) in forensic odontology, highlighting its applications in dental identification, age and sex estimation, bite mark analysis, facial reconstruction, and dental databases

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1. Introduction

Artificial Intelligence (AI) is revolutionizing various fields, and dentistry is no exception. The integration of AI technologies in dental practices is transforming how clinicians diagnose, plan treatment, and enhance patient care. Artificial Intelligence (AI) is broadly defined as a technology that allows computers to replicate human behaviour and outperform human decision-making in solving complex tasks, either independently or with minimal human involvement. AI systems leverage machine learning, deep learning, and data analytics to assist in a range of applications, from radiographic interpretation to predictive analytics for treatment outcomes.[1] The components of Artificial Intelligence (AI) encompass a range of technologies and methodologies that enable machines to perform tasks that typically require human intelligence. Key components include machine learning, which allows systems to learn from data and improve over time; natural language processing (NLP), enabling machines to understand and interpret human language; computer vision, which equips AI to analyze and interpret visual information from the world; and robotics, which combines AI with physical machines to perform automated tasks. Additionally, expert systems utilize databases of knowledge to make decisions in specific domains, while

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neural networks mimic the human brain's structure to recognize patterns and make predictions. Together, these components form the foundation of AI, facilitating advancements across various fields, including healthcare, finance, and, notably, dentistry.[2] Forensic odontology is a branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings as defined by FDI.[3] Artificial Intelligence (AI) is becoming increasingly important in forensic odontology, significantly improving the precision and effectiveness of dental evidence analysis reducing human error, labour and time. By employing advanced algorithms and machine learning techniques, AI facilitates the identification of individuals through dental records, aids in age and sex estimation, and improves bite mark analysis. This integration not only streamlines forensic investigations but also supports law enforcement in solving complex cases, ultimately contributing to justice and public safety.

2. Applications of Artificial Intelligence in Forensic Odontology

Artificial Intelligence technologies used in forensic odontology include a range of tools such as deep neural networks, artificial neural networks, machine learning, and sophisticated computer technologies.

These systems enhance the analysis of dental records, bite marks, and other dental evidence, allowing for more accurate identification and classification. Deep neural networks are particularly effective in recognizing complex patterns in data, while artificial neural networks simulate human cognitive processes to improve decision-making. Machine learning algorithms can analyze vast datasets to identify trends and insights, and computer technology facilitates the integration of these AI tools into forensic investigations. Together, these technologies significantly improve the efficiency and accuracy of forensic analyses in dentistry, aiding in criminal investigations and legal proceedings.[4]

3. Artificial Intelligence in Dental Identification

Dental identification plays a crucial role in dental identification, as teeth are unique to each person and serve as a reliable means of identification. Each tooth exhibits distinct characteristics in size and shape, along with specific patterns of grooves and ridges that aid in this process.[5] In forensic science, dental identification is particularly valuable for recognizing human remains when other identification methods are unavailable, such as in mass disasters or when bodies are decomposed or mutilated. The process involves comparing dental records—such as radiographs, dental charts, and models—with the teeth of the remains to establish a match.[6] Artificial Intelligence

(AI) can accurately identify individual tooth types on radiographs with high precision and reliability. Recent research also suggests that AI may recognize various dental implants on these images. Furthermore, AI assists forensic dentists in analyzing dental images, such as X-rays, to match individuals based on their unique dental and jaw characteristics.[6,7]

4. Artificial Intelligence in Age & Sex Estimation

A key objective of forensic work is to estimate an individual's age to create their biological profile. This information is crucial in criminal investigations and disaster situations, where skeletal remains may be fragmented and challenging to identify.[8] Artificial Intelligence can estimate age by analyzing various features of an individual, including images of their face, teeth, or bones.[9] The AI system is trained to recognize patterns and characteristics associated with different age groups, enabling it to provide age estimates for unknown individuals. In the context of dental age estimation, AI can evaluate dental images, such as X-rays, to determine age based on tooth development and wear. Similarly, for skeletal age estimation, AI can analyze skeletal images from X-rays or CT scans to estimate age by examining the development and degeneration of bones.[10,11]

AI can also assist in sex determination by analyzing various features of an individual, including images of the face, teeth, and bones.[12] The system can be trained to identify patterns and characteristics associated with different sexes, enabling it to determine the sex of an unknown individual. Artificial Intelligence and artificial neural networks can analyze dental images, such as X-rays, to ascertain a person's sex based on the size, shape, and development of their teeth and jaws.[13] Additionally, AI can evaluate skeletal images, including X-rays or CT scans, to determine sex by examining the size, shape, and development of bones.[14] Furthermore, AI can analyze facial images, such as photographs, to identify sex based on features like wrinkles, skin texture, and other facial characteristics.[15]

5. Artificial Intelligence in Bite Mark Analysis

Bite mark analysis focuses on examining and comparing human bite marks found on skin, food, or other surfaces. AI can enhance images of bite marks, aiding forensic dentists in their analysis by making it easier to identify patterns and features. It can analyze and match bite marks, serving as evidence in criminal cases. By comparing bite marks found on a victim or object with a suspect's dental records, individuals can be classified as suspects or ruled out. Additionally, AI can automate tasks such as analyzing dental images, which enhances the speed and accuracy of the identification process while minimizing human error and reducing the need for manual labour. It can help predict

the likelihood of specific dental conditions and diseases by analyzing patient data, thereby contributing to more effective prevention and treatment strategies.[16]

6. Artificial Intelligence in Facial Reconstruction

Facial reconstruction is a process where AI can play a crucial role by generating 3D models of teeth and jaws. This technology aids forensic experts in reconstructing the facial features of unidentified remains. By analyzing dental structures, AI can provide detailed representations that contribute to creating an accurate likeness of an individual. These 3D models can assist in investigative efforts by enhancing the ability to visualize and identify unknown persons, ultimately supporting law enforcement in solving cases involving unidentified remains.[17]

7. Artificial Intelligence in Storing Dental Databases

Dental databases can leverage Artificial Intelligence to efficiently search and match dental records, facilitating the identification of individuals. By analyzing and comparing various dental characteristics, AI can streamline the process of cross-referencing records, enhancing the accuracy and speed of identifying missing persons or suspects in forensic investigations.[18]

8. Conclusion

In conclusion, the integration of Artificial Intelligence in forensic odontology is transforming the field by enhancing the accuracy and efficiency of dental identification, age and sex estimation, bite mark analysis, facial reconstruction, and the management of dental databases. AI technologies, including machine learning and deep neural networks, enable the precise analysis of dental records and images, facilitating the identification of individuals, even in complex cases involving decomposed or fragmented remains. By automating processes and improving data analysis, AI not only aids in criminal investigations but also contributes to better patient care in dentistry. As this technology continues to evolve, its applications will further support forensic professionals in their pursuit of justice.

9. Source of Funding

None.

10. Conflict of Interest

None.

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