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Review Article

AI in forensic odontology – A new era

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Abstract

The development of robotic technologies that are able to simulate the way the human brain works has produced ground-breaking advancements in the field of dentistry. A great number of technological advancements have been made over the course of the last few decades, and these advancements have been interwoven into our everyday life. A subfield of engineering science called artificial intelligence (AI) examines how computers can understand computation and mimic the human brain to exhibit intelligent behaviour and complete jobs with ease. It also started to have an effect on the dental and medical industries. Data collecting and virtual surgery are only two of the many activities made feasible by the applications of virtual truth in dentistry. By advancing the techniques and procedure of individual identification, artificial intelligence is currently significantly boosting forensic dentistry as well. This review emphasize the significance of artificial intelligence in forensic odontology.

Keywords: Forensic odontology, Artificial intelligence, Machine learning, Deep learning, Convolution neural network

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1. Introduction

Artificial intelligence (AI) was first described formally in the 1950s as the ability of a machine to perform an activity that previously would have needed human intelligence. John McCarthy is regarded for having first used the term artificial intelligence in 1956 when he arranged the first scholarly conference on the subject.[1]Artificial intelligence (AI) has become a ubiquitous presence in many facets of our everyday lives, such as personal assistants (such as ChatGPT, Alexa, and Google Assistant), computer games, public transit and aviation.

Artificial intelligence refers to the capability of machines to exhibit a certain level of self-analysis.[2] The idea was to build machines that could solve problems by learning from data. Machine learning is a branch of artificial intelligence that makes predictions about outcomes using algorithms and data. The goal of machine learning is to make it possible for computers to learn from data so they can solve issues without assistance from humans. Predictive modelling, recommendation systems, and fraud detection are examples of machine learning applications. Neural networks are a class of algorithms that process signals by using created neurons. The aim of neural network design is to develop neural networks that carry out tasks that are comparable to those of the human brain. "Deep learning" is a subfield of machine learning that analyses incoming data using a deep neural network with multiple layers of computing. Deep learning seeks to develop a neural network with autonomous pattern recognition to improve identification of feature.[3] The human brain's structure served as the model for these networks. Algorithms for deep learning can automatically recognise and extract features from unprocessed data, including text, audio, and image data, to provide predictions or judgements. For many years, the dental and medical fields have made use of artificial intelligence. It is employed in radiology and medicine to identify and manage a range of diseases and conditions.[4] The dental specialities of orthodontics, endodontics, prosthodontics, restorative dentistry,

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periodontics, oral and maxillofacial surgery, oral medicine, and radiology have all recently shown a great deal of interest in artificial intelligence. The practical application of artificial intelligence in forensic dentistry and medicine is still relatively new. This article's goal is to give a summary of the current state of artificial intelligence applications in forensic dentistry. Studies reveal promising outcomes, despite the fact that most applications are still in the development stage. In order to adjust to a changing healthcare environment, it will be more and more important for dentists to comprehend the basic ideas and uses of artificial intelligence in dentistry.[5] By examining the structure of the oral cavity, the dental speciality known as forensic odontology (FO) assists in identifying people. Identifying a person after a significant accident or accidental remains primarily involves medical-legal considerations. Lip prints, radiography, teeth, jawbones, and palate rugae are the most trustworthy methods of identifying a person in forensic odontology. These models have proven to be a breakthrough in the provision of trustworthy data for decision-making, and their main benefits are that they offer clinical decision-making logic.[6]

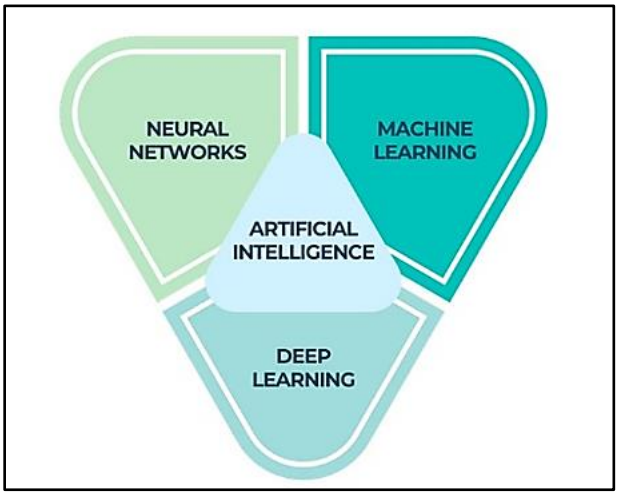

Figure 1: Venn diagram for artificial intelligence

2. Discussion

2.1. Application of Artificial Intelligence in dentistry:

The primary application of artificial intelligence (AI) in dentistry has been to improve diagnostic accuracy and efficacy. In order to maximise therapy results and give patients top-notch care, this is essential. Artificial Intelligence is modernising traditional dental practices. Using AI-based technology to automate software programs that streamline dental diagnostics and data administration is a common practice.[7] According to Lee et al.'s work, which used CNN algorithms to use periapical radiographs to detect and diagnose dental caries, AI technology has demonstrated exceptional leads to the identification of dental cavities.[8] The results of the application that was shown exceptionally good performance. In one study, Hiraiwa et al employed CNNs to identify Sjögren's syndrome (SjS) on Computed tomography images.[9] Higher diagnostic interpretation was demonstrated when the results were compared to radiologist's interpretation. Maxillary sinusitis was identified using panoramic radiography Murata et al.[10] The diagnostic performance of this system was reasonably good. Jung et al.[11] showed 92% precision in deciding whether to extract a permanent tooth by using An AI expert system and lateral cephalometric radiographs. According to the findings of the two studies, the AI modes were successful and accurate in anticipating when extraction would be necessary. These models can be used to help make decisions in clinical practice. Thanathornwong's study[12] found that an AI model based on a Bayesian network (BN) was highly accurate in determining whether orthodontic treatment was necessary. The main factor that determines how well a root canal operation goes is how precisely the working length is measured.[13] The ability of the dentist to thoroughly clean and shape the complex anatomy of the root canal system is the main factor influencing endodontic success. Using an artificial neural network (ANN) technique, Saghiri et al.[14] estimated the working length with an impressive 96% accuracy rate, surpassing the precision of professionally trained endodontists. Periodontal disease (PD), the sixth most frequent inflammatory disease and a common intraoral pathology, can appear in both acute and chronic forms. The most common reason for losing teeth in adults, according to statistics, is periodontal disease. The tooth's surrounding periodontal ligaments, gingiva, and alveolar bone are all destroyed along with all other periodontal supporting tissues. The system of CAD, which employs a deep convolutional neural network (CNN) algorithm, is used to detect and predict teeth with periodontal health problems, claim Lee et al. (2015).[15] The findings revealed a 78.9% mean prediction accuracy, which was quite respectable. Artificial intelligence has been used to detect cancer. As per a study conducted by Xu and colleagues[16] convolutional neural networks have experienced revolutionary advancement and improvement that has increased their automated cancer diagnosis capabilities.

2.2. Application of artificial intelligence in forensic odontology

Forensic odontology is a relatively new science, yet it has significantly improved dentistry.[2] Dentists are essential in identifying people for legal issues such mass murders, criminal activities, sexual assault, and child abuse. They have a moral duty to provide justice to the victims and their families, particularly in cases where the dental remains are the only piece of evidence. The implementation of AI technology in this sector has produced excellent results. Artificial intelligence-based technologies used in forensic dentistry include deep neural networks, artificial neural networks, machine learning, and computer technology.[17]

2.3. Facial reconstruction

Forensic facial reconstruction is the process of reconstructing a person's face from bone fragments that they are not aware

of.[18]In the computerised facial reconstruction procedure, a CT scan or a laser video camera connected to a computer is employed. Artificial neural networks can determine a person's sex 95% of the time based on bone architecture. When applied to the sex assessment of skeletal remains, artificial intelligence techniques will remove human bias, require no specialised knowledge, and yield quick results. Rebuilding the face from unidentified remains can be accomplished by using artificial intelligence to generate 3D models of the jaws and teeth.[19] (**Figure 2**)

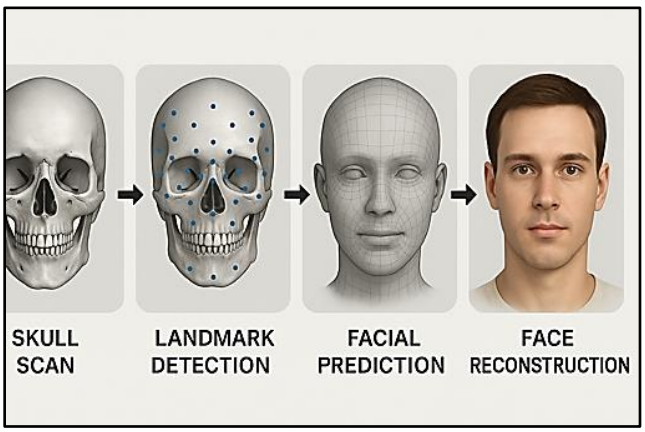

Figure 2: Four-step AI-based facial reconstruction process

2.4. Age estimation

By automating age calculations through neural network programming, machine learning techniques—including artificial intelligence—have greatly improved the accuracy of dental age determination.[20] The selection of a process is influenced by various factors including available resources, time, facilities, and specialist experience, making an accurate method for calculating age challenging.

Important Modalities for AI-Based Face Image Age.

2.4.1. Facial Images

1. Most common modality.
2. Utilizes facial features like wrinkles, skin texture, and bone structure.
3. Common models: CNNs, VGGNet, ResNet, MobileNet.
4. Datasets: MORPH, FG-NET, UTKFace, IMDB-WIKI.

2.4.2. Dental radiographs

1. Particularly useful in forensic odontology.
2. AI analyzes tooth development and eruption patterns (e.g., panoramic radiographs).
3. Techniques: CNNs, radiomic features, transfer learning.

2.4.3. Skeletal radiographs

1. Hand/wrist X-rays for children/adolescents (e.g., using Greulich & Pyle Atlas).
2. AI models analyze ossification centres and bone maturation.

2.5.4. Voice and speech patterns

1. Age-related changes in vocal cords and pitch are analyzed.
2. Often used in security and human-computer interaction.

2.5.5. Gait analysis

1. Analyzes walking patterns via video.
2. Used for age group classification.

2.5.6. Other biometric signals

Includes iris patterns, retinal scans, and fingerprint ridge densities.

2.6. AI techniques used

Table 1: Describes about the AI techniques used

Technique	Description
Convolutional Neural Networks (CNNs)	Extract spatial features from images (e.g., facial, dental).
Recurrent Neural Networks (RNNs)	Beneficial for time-series data, such as voice.
Support Vector Machines (SVMs)	Frequently combined with handcrafted elements.
Random Forests & XGBoost	Applied when features are structured/tabular.
Transfer Learning	Age-specific datasets were used to refine pre-trained models..

2.5. Gender determination

To ensure that the results are precise and unaffected by bias or error, forensic sex determination calls for a great deal of attention to detail and accuracy.[4] Identifying a victim or suspect based on their sexual orientation can help with identification in a variety of situations, such as mass disaster victim identification, missing persons cases, and criminal investigations. Images of a person's face, teeth, and bones are among the personal characteristics that artificial intelligence can use to determine their gender.[21] The study by Oura and colleagues yielded the highest testing accuracy of 90.3% when estimating the sex of knee radiographs using deep learning. The sex of an individual can be ascertained by training artificial intelligence to recognise characteristics and patterns associated with the sexes.[22.] Based on the size, shape, and development of a person's jaws and teeth, artificial intelligence and artificial neural networks can determine a person's gender using data from dental scans, including x-rays.[23] Artificial intelligence can determine a person's gender by examining images of their face, including photographs, and noting features like creases and tone of skin. In order to estimate gender, Bianchi et al. created a semi-automated technique based on the upper posterior tooth crown's shape to estimate gender. The process of identifying a person's sex is

challenging and mostly relies on dental information.[24] To increase accuracy and reliability, additional methods such as skeletal sexing, facial sexing, and prediction models ought to be used. Depending on the specific use case and the quality of the data used to train the system, artificial intelligence's sex determination accuracy varies. The development of this technology is still in its infancy.

2.6. Application of artificial intelligence in dental identification

Since each person's teeth are unique and offer a trustworthy means of identifying them, tooth identification is crucial to dental identification and particular ridge and groove patterns that serve as identifying markers.[25] In many ways, artificial intelligence can help with teeth recognition.[26]

1. **Image analysis:** Forensic dentists use artificial intelligence to analyse dental images, including x-rays, in order to identify and match individuals based on their teeth and jaws.
2. **Dental databases:** Artificial intelligence can look up and compare dental data, which enables the identification of particular people.
3. **Automation:** Artificial intelligence can be used to automate certain processes, such as dental image processing, which can greatly reduce the amount of manual labour needed while improving the identification process's speed and accuracy.
4. **Predictive analytics:** By assessing the risk of specific dental conditions using patient data, artificial intelligence can support in both prevention and treatment.
5. **Facial remodeling:** The face of unexplained remains can be recreated using 3D reconstructions of the jaws and teeth produced by artificial intelligence.

2.7. Application of artificial intelligence in the detection of bite perpetrators

A branch of forensic science called "bite mark analysis" looks at and contrasts bite marks left by people on food, skin, and other objects.[27] Finding the bite mark's creator and producing evidence that can be used in court are the two main objectives of bite mark analysis.[28] In order to analyse a bite mark, one must usually collect and preserve the mark, examine and record it, compare it to known dental records or impressions, and then interpret and analyse the findings.[29] Bite mark analysis could benefit from artificial intelligence in a variety of ways. Artificial intelligence has the potential to improve bite mark photos, which would facilitate forensic dentists' analysis and identification of patterns and characteristics. Artificial intelligence can analyse and compare bite marks as evidence in criminal cases.

Different application of AI in bite marks analysis are as follows:[4]

1. **Enhancement of images and recognition of patterns:** Bite mark photos can be improved by AI algorithms, which makes it simpler for forensic specialists to examine and spot unique patterns and characteristics. AI helps identify possible matches or exclusions by comparing bite marks discovered on victims or objects with suspects' dental records.
2. **Analysis automation**: AI reduces manual labour, minimises human error, speeds up the identification process, and automates tasks like dental image analysis.
3. **Photogrammetry and 3D modelling:** AI makes it easier to create 3D models of bite marks using open-source photogrammetry software and smartphone cameras. This strategy provides an affordable and easily accessible way to conduct in-depth analysis, particularly in environments with limited resources.

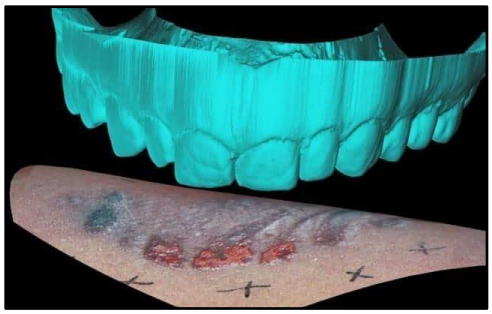

Figure 3: 3D Scanning of bite marks using artec space spider

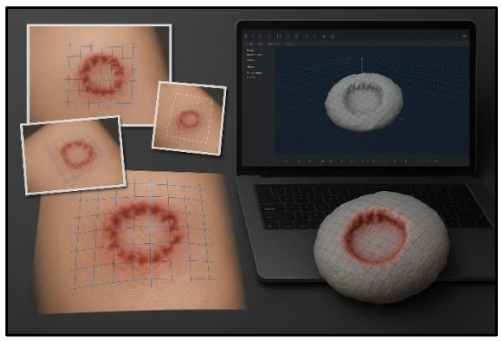

Figure 4: 3D Reconstruction of bite marks using photogram

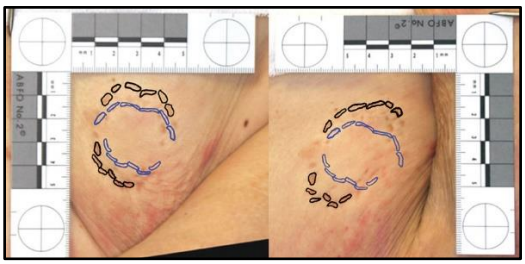

Figure 5: Variability in bite mark appearance due to body positioning using AI algorithm

3. Conclusion

The field of dentistry known as "forensic odontology" uses distinctive features of the oral cavity, mainly the teeth and

jawbones, to identify people. It has 90% accuracy in determining gender, age, and the size and shape of skull bones. Artificial intelligence makes it possible to analyse complex material at multiple levels more quickly and effectively, while jawbone radiographs are useful, minimally invasive, and pertinent for both living and defunct patients. Processing large data sets, identifying complex patterns, and performing better in unpredictable situations are all areas where machine learning surpasses human learning. It also lessens cognitive bias.

4. Source of Funding

None.

5. Conflict of Interest

None.

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