Content available at: https://www.ipinnovative.com/open-access-journals

IP International Journal of Maxillofacial Imaging

Journal homepage: https://www.ijmi.in/

Review Article

Artificial intelligence in forensic odontology: A review

Backiyalakshmi A[1], Divya V C[1]*

[1]*Dept. of Oral Medicine and Radiology, SRM Kattankulathur Dental College and Hospital, Kanchipuram, Tamil Nadu, India*

ARTICLE INFO

Article history:
Received 11-04-2024
Accepted 30-04-2024
Available online 14-05-2024

Keywords:
Artificial intelligence
Machine learning
Forensic odontology
Convolutional neural networks

ABSTRACT

Over the past few decades, there have been numerous technological breakthroughs that have been incorporated into our daily lives. Artificial intelligence (AI) is a branch of engineering science that studies computers' computational comprehension and capacity to emulate the human brain in order to display intelligent behavior and carry out tasks with ease. It has started to make an impact on the medical and dental fields as well. The use of virtual reality in dentistry has made a variety of tasks possible, including data collection and even virtual surgery. Presently AI is making significant enhancements in forensic dentistry as well by improving the methods and process of individual identification. This review highlights the role of artificial intelligence in forensic odontology.

1. Introduction

The formal definition of artificial intelligence (AI) dates back to the 1950s, when it was described as a machine's capacity to carry out a task that would have previously needed human intelligence. When he organized the first academic meeting on the topic in 1956, John McCarthy is credited with coining the phrase artificial intelligence.[1] Now a days, artificial intelligence (AI) permeates many aspects of our daily life, including computer games, automated public [transit, personal assistants (like ChatGPT, Alexa, and Google Assistant), and flying.

Artificial intelligence is known as the ability of machines to display a degree of self-awareness.[2] The goal was to create machines that could learn from data in order to address issues.AI includes machine learning, which uses algorithms to forecast results based on a dataset. Machine learning aims to enable computers to learn from data so they can solve problems on their own without the need for human intervention. Predictive modeling, fraud detection, and recommendation systems are examples of machine learning use cases. A class of algorithms known as neural networks uses artificial neurons to compute signals. Neural network design aims to produce neural networks with similar functions to the human brain. A subset of machine learning known as "deep learning" analyzes input data by employing a deep neural network with several computational layers. Building a neural network with automatic pattern recognition is the aim of deep learning in order to enhance feature identification.[3] These networks are inspired by the structure of the human brain. Deep learning algorithms are capable of producing predictions or judgments by automatically recognizing and extracting features from unprocessed input such as text, audio, and image files. Artificial intelligence has been utilized for a long time in the dental and medical industries. It is used in radiology in medicine to diagnose and treat a variety of illnesses and ailments.[4] Artificial intelligence has garnered significant attention in the dental specialties of orthodontics, endodontics, prosthodontics, restorative

* *Corresponding author*.
E-mail address: divyav@srmist.edu.in (Divya V C).

https://doi.org/10.18231/j.ijmi.2024.002

dentistry, periodontics, and oral and maxillofacial surgery, oral medicine and radiology in recent times. Artificial intelligence has not yet found a more widespread practical use in forensic dentistry and medicine. The purpose of this review is to present the current state of artificial intelligence applications in forensic dentistry. Even though the majority of applications are still in the development stage, research shows encouraging results. In order to adapt to a changing healthcare landscape, dentists will increasingly need to understand the fundamental concepts and applications of artificial intelligence in dentistry.[5] By evaluating the architecture of the oral cavity, the dental specialty known as forensic odontology (FO) assists in the identification of a person. For the purpose of identifying a person after a mass tragedy or accidental remains, it mostly relates to medical-legal considerations. Lip prints, radiography, teeth, jawbones, and palate rugae are regarded as trustworthy means of identifying a person in FO. Models can be trained and used for medical and dental diagnostics, as well as decision-making and problem-solving. These models' main benefit is that they offer logic for clinical decision-making and have shown to be a breakthrough in the provision of trustworthy data for decision-making.[6]

1.1.

1.1.1. Application of AI in dentistry

Artificial Intelligence (AI) has mostly been applied in dentistry to improve diagnosis accuracy and efficiency. This is crucial for optimizing treatment outcomes and providing patients with high-quality care. Traditional dental procedures are being modernized by AI. Automation of software applications that simplify dental diagnostics and data management is frequently accomplished through the use of AI-based technologies.[7] The application of CNN algorithms for the identification and diagnosis of dental caries on periapical radiographs was reported by Lee et al,[8] in their study, which showed that AI technology in the detection of dental caries has displayed outstanding results. The application's outcome showed remarkably strong performance. CNNs were used to detect sjögren's syndrome (SjS) on CT scans, according to a study by Hiraiwa et al.[9] The results were compared to radiologists' performance and shown a higher diagnostic performance. Murata et al.[10] used the deep learning method in a different investigation to diagnose maxillary sinusitis on panoramic radiography. This system performed fairly well in diagnostics. By utilizing lateral cephalometric radiographs and an AI expert system, Jung et al.,[11] demonstrated 92% accuracy in making permanent tooth extraction decisions. The findings of the two investigations imply that the AI modes were successful and precise in anticipating the requirement for extraction. In clinical practice, these models can be employed as a decision-making aid. According to Thanathornwong's study,[12] an AI model based on a Bayesian network (BN) was highly accurate in determining whether orthodontic treatment was necessary. In Root canal Treatment, the precision of the working length measurement is the primary determinant of the outcome of a root canal procedure.[13] The main factor influencing endodontic success is the dentist's capacity to meticulously clean and shape the anatomic complexities of the root canal system. When estimating the working length, Saghiri et al,[14] used an artificial neural network (ANN) approach and demonstrated remarkable accuracy of 96%, which is higher than the accuracy of endodontists with professional training. A prevalent intraoral pathology and the sixth most common type of inflammatory disease is periodontal disease (PD), which can manifest in both acute and chronic forms. According to reports, periodontal disease is the most common cause of adult tooth loss. It destroys all periodontal supporting tissues, including the gingiva, alveolar bone, and periodontal ligaments surrounding the tooth. According to Lee et al,[15] the CAD system, which uses a deep convolutional neural network (CNN) algorithm, is used to identify and forecast teeth that have periodontal health issues. The results showed a mean prediction accuracy of 78.9%, which was pretty acceptable. Cancers have been identified using AI technology. According to a study by Xu et al.[16] convolutional neural networks have undergone revolutionary development and refining that has boosted their capacity for automated cancer diagnosis.

2. Application of Artificial Intelligence in Forensic Dentistry

Though it is a relatively recent field, forensic odontology has greatly advanced dentistry.[2] When it comes to identifying persons for legal matters such as mass tragedies, criminal activity, sexual assault, and child abuse, dentists are crucial. Especially when the dental remains are the only piece of evidence, they have a moral obligation to bring the victims and their families justice. Excellent outcomes have been obtained from the application of AI technology in this industry. Deep neural networks, artificial neural networks, machine learning, and computer technology are examples of artificial intelligence-based technologies utilized in forensic dentistry.[17]

3. Facial Reconstruction

Reconstructing a person's face from bone remains that are unknown to them is known as forensic facial reconstruction.[18] A CT scan or a laser video camera interfaced with a computer is used in the computerized facial reconstruction process. Artificial neural networks determine a person's sex 95% of the time based on skeletal anatomy. When applied to the sex estimate of skeletal remains, artificial intelligence techniques will remove human bias, require no specialized knowledge, and yield

quick findings.For the purpose of reconstructing the face from unidentified remains, artificial intelligence can be utilized to generate 3D representations of the jaws and teeth.[19]

4. Age Estimation

Several machine learning methods significantly increase the accuracy of dental age assessment. A number of programming neural networks have been developed since the development of artificial intelligence to enable computers to automatically determine age.[20] Selecting the right process depends on a number of aspects, including the material available for analysis, the time and facilities available, and the expert's experience, of course. It is impossible to apply a perfect, all-encompassing technique for estimating age.

5. Gender Determination

In forensic, sex determination needs to be done extremely carefully and accurately to guarantee that the results are accurate and unaffected by bias or mistake.[4] Sex determination is used in many contexts, including criminal investigations, where identifying a victim or suspect based on their sexual orientation can aid in identification; mass catastrophe victim identification; and cases involving missing persons. Artificial intelligence can determine a person's sex by examining a variety of personal characteristics, including pictures of their teeth, bones, and face.[21] The study conducted by Oura and colleagues on the use of deep learning to knee radiograph sex estimation achieved the best testing accuracy of 90.3%. Artificial intelligence may be educated to identify patterns and characteristics linked to distinct sexes, and it can then utilize this understanding to ascertain an individual's sex.[22] Dental scans, such as x-rays, can be analyzed by artificial intelligence and artificial neural networks to establish a person's sex based on the size, form, and development of their teeth and jaws.[23] Artificial intelligence can identify a person's sex by analyzing pictures of their face, such as photos, and taking note of wrinkles, skin tone, and other characteristics.[24] Based on the form of the upper posterior tooth crown, Bianchi et al. created a semi-automated approach for sex estimation. Determining a person's sex is a difficult procedure that mostly uses dental data. Other techniques including skeletal sexing, facial sexing, and predictive models should also be employed to improve accuracy and dependability. The accuracy of artificial intelligence-based sex determination varies depending on the particular use case and the caliber of the data used to train the system. This technology is currently in its early stages of development.

6. Application of Artificial Intelligence in Dental Identification

Since each person's teeth are unique and offer a trustworthy means of identifying a person, tooth identification is crucial to dental identification and certain ridge and groove patterns that serve as identifying.[25] Artificial Intelligence can assist with tooth recognition in a number of ways.[26]

1. **Image analysis**: Forensic dentists can identify and match people based on their teeth and jaws by using artificial intelligence to analyze dental photographs, such as x-rays.
2. **Dental databases**: Dental records can be searched for and matched using artificial intelligence, which can be used to identify specific persons.
3. **Automation**: Using artificial intelligence to automate some operations, like dental image processing, can greatly reduce the amount of manual labor required and increase the identification process' speed and accuracy.
4. **Predictive analytics**: By using a patient's data to estimate the risk of specific dental illnesses and ailments, artificial intelligence can aid in treatment and prevention.
5. **Reconstruction of the face**: 3D models of the jaws and teeth made by artificial intelligence can be used to rebuild the face of unexplained remains.

7. Application of Artificial Intelligence in the Detection of Bite Perpetrators

Bite mark analysis is a branch of forensic science that looks at and contrasts bite marks left by humans on food, skin, and other objects.[27] Finding out who created the bite mark and producing evidence that can be used in court are the two main objectives of bite mark analysis.[28] Usually, the bite mark analysis entails collecting and storing the bite mark, studying and recording it, contrasting it with known dental impressions or records, and interpreting and analyzing the findings.[29] There are various methods in which artificial intelligence might support bite mark analysis (30).Artificial intelligence has the potential to improve bite mark photos, which will facilitate forensic dentists' analysis and identification of features and patterns.Bite marks are evidence in criminal cases that can be analyzed and matched by artificial intelligence. By matching bite marks discovered on a victim or object with a suspect's dental records, a person can be categorized as a suspect or ruled out. Mechanization AI is capable of automating certain jobs, such as image analysis for dentistry. This can decrease the likelihood of human error and the necessity for manual labor while also improving the identification process's speed and accuracy.

8. Advantages

1. Artificial intelligence can speed up and improve the accuracy of forensic dentists' analysis of massive dental data sets, including imaging and patient records.
2. Dental image processing can be automated by artificial intelligence. This can decrease the need for manual labor and improve identification speed and accuracy.
3. Analyze dental images to assist forensic dentists in estimating the age and gender of individuals.
4. 3D dental and jaw models that can help with unidentified remains' face reconstruction.
5. Examine and compare bite marks, which may be utilized as proof in legal matters.
6. Aid in the database search and matching of dental information, which can be used to identify specific people.

9. Disadvantages

1. Automating certain jobs, such patient data analysis and dental imaging analysis, can result in employment displacement.
2. Maintain and even magnify prejudice and discrimination in the training data. This may result in incorrect identification or estimation of an individual's age and gender, as well as incorrect recognition of bite marks.
3. Absence of responsibility and transparency. Artificial intelligence systems can be difficult to explain or hold accountable for their actions since it might be difficult to grasp how they arrive at those decisions. Their use as evidence in court becomes challenging due to all of this.
4. AI need a lot of patient data to operate, which raises privacy and security issues, particularly in light of the widespread use of electronic dentistry records.
5. The use of artificial intelligence in forensic dentistry will increase, raising more and more ethical concerns.The origin of the samples used to train artificial intelligence is the main ethical concern.
6. A lack of model flexibility; not all problems have the right data to learn from; data may reflect bias in real life; not all problems can be solved with mathematical analysis, which is the only output with machine learning applications; and other factors, such as privacy concerns, which AI might not be able to address in the same way as humans, must be "factored into decisions."

10. Conclusion

Forensic odontology is a subspecialty of dentistry that focuses on identifying a person primarily via evaluation of the distinctive features of the oral cavity. The remains, which mostly consist of teeth and jawbones, can be used to identify a person in FO. An important source of information for determining the victim's chronological age is the pattern of tooth eruptions. The victim's jawbone's size and shape can provide important information about the victim's gender. When determining a person's gender by skull bone analysis, the accuracy can reach 90%. Since radiographic procedures are straightforward, less invasive, and applicable to both live and deceased patients, radiographic gender estimation using jawbone radiographs is seen to be more feasible. During an inquiry, artificial intelligence enables specialists to process vast amounts of complex data much more quickly and efficiently and to do analysis at several levels. Machine learning has several advantages over human learning, including the ability to process vast volumes of data, identify weaker or more complicated patterns, and perform better in unpredictable circumstances. Additionally, because they are less prone to cognitive bias, machines can make decisions with greater consistency.

11. Source of Funding

None.

12. Conflict of Interest

None.

References

1. Mintz Y, Brodie R. Introduction to artificial intelligence in medicine. *Minim Invasive Ther Allied Technol*. 2019;28(2):73–81.
2. Khanaga SB, Al-Ehaideb A, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, et al. Developments, application, and performance of artificial intelligence in dentistry - A systematic review. *J Dent Sci*. 2021;16(1):508–22.
3. Akst J, Inspiring Innovation: The Scientist Exploring Life . A primer: artificial intelligence versus neural networks; 2019. Available from: https://www.the-scientist.com/artificial-intelligence-versus-neural-networks-65802.
4. Vodanović M, Subašić M, Milošević DP, Galić I, Brkić H. Artificial intelligence in forensic medicine and forensic dentistry. *J Forensic Odontostomatol*. 2023;41(2):30–41.
5. Pethani F. Promises and Perils of Artificial Intelligence in Dentistry. *Aust Dent J*. 2021;66(2):124–35.
6. Khanagar SB, Vishwanathaiah S, Naik S, Al-Kheraif A, Devangdivakar D, Sarode SC, et al. Application and performance of artificial intelligence technology in forensic odontology - A systematic review. *Leg Med (Tokyo)*. 2021;48:101826.
7. Titus TKL, Thyvalikakath TP, Spallek H, Torres-Urquidy MH, Hernandez P, Yuhaniak J, et al. Clinical Computing in General Dentistry. *J Am Med Inform Assoc*. 2006;13(3):344–52.
8. Lee JH, Kim DH, Seong-Nyumjeong SH, Choi. Detection and diagnosis of dental caries using a deep learning-based convolutional neural network algorithm. *Journal of Dentistry*. 2018;77:106–111.
9. Kise Y, Ikeda H, Fujii T, Fukuda M, Ariji Y, Fujita H, et al. Preliminary study on the application of deep learning system to diagnosis of Sjögren's syndrome on CT images. *Dentomaxillofac Radiol*. 2019;48(6):20190019.
10. Murata M, Ariji Y, Ohashi Y, Kawai T, Fukuda M, Funakoshi T, et al. Deep-learning classification using convolutional neural network for evaluation of maxillary sinusitis on panoramic radiography. *Oral Radiol*. 2019;35(3):301–7.

11. Jung SK, Kim TW. New approach for the diagnosis of extractions with neural network machine learning. *Am J Orthod Dentofacial Orthop*. 2016;149(1):127–33.
12. Thanathornwong B. Bayesian-based decision support system for assessing the needs for orthodontic treatment. *Healthc Inform Res*. 2018;24(1):22–8.
13. Baugh D, Wallace J. The role of apical instrumentation in root canal treatment: a review of the literature. *J Endod*. 2005;31(5):333–40.
14. Saghiri MA, Asgar K, Boukani KK, Lotfi M, Aghili H, Delvarani A, et al. A new approach for locating the minor apical foramen using an artificial neural network. *Int Endod J*. 2012;45(3):257–65.
15. Lee JH, Kim DH, Jeong SN, Choi SH. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. *J Periodontal Implant Sci*. 2018;48(2):114–23.
16. Xu B, Wang N, Chen T, Li M. Empirical Evaluation of Rectified Activations in Convolution Network; 2015. Available from: https://arxiv.org/abs/1505.00853. doi:10.48550/arXiv.1505.00853.
17. Mohammad N, Ahmad R, Kurniawan A, Mohdyusof Y. Applications of contemporary artificial intelligence technology in forensic odontology as primary forensic identifier: A scoping review. *Front Artif Intell*. 2022;5:1049584.
18. Boreak N. Effectiveness of Artificial Intelligence Applications Designed for Endodontic Diagnosis, Decision-making, and Prediction of Prognosis: A Systematic Review. *J Contemp Dent Pract*. 2020;21(8):926–34.
19. Pham CV, Lee SJ, Kim SY, Lee S, Kim SH, Kim HS. Age estimation based on 3D post-mortem computed tomography images of mandible and femur using convolutional neural networks. *PLoS One*. 2021;16(5):e0251388.
20. Ahmed N, Abbasi MS, Zuberi F, Qamar W, Halim MSB, Maqsood A. Artificial Intelligence Techniques: Analysis, Application, and Outcome in Dentistry-A Systematic Review. *Biomed Res Int*. 2021;2021:9751564.
21. Oliva A, Grassi S, Vetrugno G, Rossi R, Morte GD, Pinchi V, et al. Management of Medico-Legal Risks in Digital Health Era: A Scoping Review. *Front Med (Lausanne)*. 2021;8:821756.
22. Oliva G, Pinchi V, Bianchi I, Focardi M, Paganelli C, Zotti R. Three-Dimensional Dental Analysis for Sex Estimation in the Italian Population: A Pilot Study Based on a Geometric Morphometric and Artificial Neural Network Approach. *Healthcare (Basel)*. 2021;10(1):9.
23. Milošević D, Vodanović M, Galić I, Subašić M. Automated Sex Assessment of Individual Adult Tooth X- Ray Images. In: International Symposium on Image and Signal Processing and Analysis (ISPA). Zagreb, Croatia: IEEE; 2021. p. 72–7.
24. Bianchi I, Oliva G, Vitale G, Bellugi B, Bertana G, Focardi M, et al. A Semi-Automatic Method on a Small Italian Sample for Estimating Sex Based on the Shape of the Crown of the Maxillary Posterior Teeth. *Healthcare (Basel)*. 2023;11(6):845.
25. Saxena S, Sharma P, Gupta N. Experimental studies of forensic odontology to aid in the identification process. *J Forensic Dent Sci*. 2010;2(2):69–76.
26. Heinrich A, Güttler F, Wendt S, Schenkl S, Hubig M, Wagner R, et al. Forensic Odontology: Automatic Identification of Persons Comparing Antemortem and Postmortem Panoramic Radiographs Using Computer Vision. *Rofo*. 2018;190(12):1152–8.
27. Daniel MJ, Pazhani A. Accuracy of bite mark analysis from food substances: A comparative study. *J Forensic Dent Sci*. 2015;7(3):222–6.
28. Verma AK, Kumar S, Bhattacharya S. Identification of a person with the help of bite mark analysis. *J Oral Biol Craniofacial Res*. 2013;3(2):88–91.
29. Velden AVD, Spiessens M, Willems G. Bite mark analysis and comparison using image perception technology. *J Forensic Odontostomatol*. 2006;24(1):14–21.

Author biography

Backiyalakshmi A, Tutor

Divya V C, Associate Professor https://orcid.org/0000-0001-7042-6435

Cite this article: Backiyalakshmi A, Divya V C. Artificial intelligence in forensic odontology: A review. *IP Int J Maxillofac Imaging* 2024;10(1):6-10.