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Forensic dentistry

USE OF ARTIFICIAL INTELLIGENCE IN FORENSIC DENTISTRY: A REVIEW OF LITERATURE.

O uso de inteligência artificial na odontologia forense: revisão de literatura.

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ABSTRACT

Forensic dentistry is concerned with the appropriate management, examination, and representation of dental findings in the service of justice. Modern forensic dentistry uses AI to identify bodies and address bite marks and injuries. Dental remains analyzed with AI for facial reconstruction and age estimate revolutionize crime identification. This research examined literature related to the use of artificial intelligence (AI) in forensic odontology from January 2000 to June 2023. Relevant publications in English language were searched following PRISMA guidelines in PubMed, LILACS, SciELO, and Open Grey databases. After screening for title, abstract, and full-text relevance, 67 papers were chosen for the study from an initial total of 1037 results. The results were classified according to the sub specialty in forensic dentistry, it was found that the majority of the articles (46.27% - n = 31) were related to dental age estimation, only about 8.96 % (n = 6) were related to sex estimation using artificial intelligence, 20.89% (n = 14) related to human identification, 11.94% (n = 8) related to dental implant system identification and 14.93% (n = 10) related to individual tooth identification. A steep incline was observed in the number of publications related to artificial intelligence from 2016 onwards. Dental AI is changing radiography, orthodontics, endodontics, prosthodontics, and maxillofacial surgery. AI helps forensic odontologists estimate age and gender from dental information. A comprehensive AI-powered care system will transform dental identification using computer programs, machine learning, and improving forensic dentistry's speed and accuracy.

KEYWORDS

Forensic odontology; Artificial intelligence; Deep learning; Machine learning.

INTRODUCTION

"Forensic dentistry" is concerned with the appropriate management, examination, and representation of dental findings in the service of justice[1]. One of the hardest problems that humanity has ever confronted is human identity. The primary focus of a forensic odontologist is identification through the detection of distinctive characteristics found in each

person's oral anatomy[2]. Identification of the deceased is possible through comparison of *antemortem* and *postmortem* documents. Forensic odontology has recently become a new hope in the field of crime investigation due to its numerous applications in the identification of human remains through dental records at crime scenes, such as those involving domestic violence, bite marks and physical injuries, age and gender determination of the living and deceased, and expert witness testimony in court to produce forensic dental evidence[3]. Because teeth have various qualitative and quantitative characteristics, dental identification is an important forensic practice. Dental identification is very useful in cases where teeth are the only components of a human corpse that have survived, such as fires, mass graves, plane accidents, or natural disasters like floods and avalanches[4]. Teeth cannot be easily broken down because they are the toughest tissue.

The procedures of forensic odontology have evolved alongside civilization. Dental tissues can frequently reveal the age, gender, and ethnicity of a person who may be a victim or suspect[5]. Dental traits are regularly analysed by the medicolegal department to identify human bodies that have been carbonised, disfigured, skeletonized, or are rotting. Some of the data used to support forensic odontology tasks include dental records, patient records, cast models, intraoral pictures, periapical radiographs, interproximal and panoramic radiographs, and postero-anterior skull radiographs. However, there are times when the victim under evaluation does not have clinical evidence proving relevant odontologic characteristics. As a result, professionals in the field of human identification now look for information from other sources, such as photographs of people's faces, videos, or grins that highlight distinguishing characteristics[6].

The primary fields of practice—civil, criminal, and research—support forensic dentistry's widely accepted categorization. The civil field deals with large-scale disasters such as train, aeroplane, and earthquake accidents that necessitate the identification of victims in various degrees of physical devastation. The criminal field handles the identification of individuals from dental remains alone in situations of homicide, rape, or suicide utilising procedures such as bite mark analysis, palatal rugoscopy, and cheiloscopy. Finally, the research topic is used to the education of medical and dental professionals in forensic odontology[7].

“ARTIFICIAL INTELLIGENCE”(AI) IS DEFINED AS A MACHINE CAPACITY THAT DEMONSTRATES A FORM OF ITS OWN INTELLIGENCE.

The goal here was to create machines that can learn. They can address difficulties by analysing data. Machine learning is a subset of AI that relies on algorithms to forecast outcomes based on data. The goal of machine learning is to enable machines to learn from data in order to solve problems without human intervention[8]. The term artificial intelligence in science describes a group of core technologies that allow computer systems

to do tasks that are like those performed by humans. Digital technology has become even more common in dentistry. Additionally, orthodontic analysis programmes and prosthodontic software with computer-aided (CAD-CAM) design have been developed[9].

Applications of artificial intelligence in forensic odontology are facial reconstruction, age estimation, gender determination, cheiloscopy, bite marks, 3D printing, personal identification[10]. The intelligent analysis of metadata from complicated data sets is an absolute necessity for digital forensics. As a result, artificial intelligence is a development in digital science that addresses a number of challenging issues that are currently affecting the society[11]. People's lives are becoming steadily infused with artificial intelligence, to the point that it is getting harder to find any context in which it doesn't exist in some way. It acts as a broader field, integrating a variety of approaches and procedures meant to generate intelligent machines that can conduct operations that normally call for human intelligence, like speech recognition, natural language processing, visual perception, and decision-making[12].

The aim of this study is to analyze and review literature related to use of artificial intelligence in forensic odontology from January 2000 till August 2023 and identify the increasing trend of artificial intelligence in dental forensics.

METHODOLOGY

This systematic review was carried out to review the use of artificial intelligence in forensic odontology. Selection of studies was based on relevance to use artificial intelligence (AI) in areas related to aspects of forensic odontology published from January 2000 till August 2023. Original articles published in English language were considered for the study. Articles or studies not related to various aspects of forensic odontology (i.e. dental age estimation, dental identification, bitemarks etc.); review type articles; those not published in English language were excluded from the study.

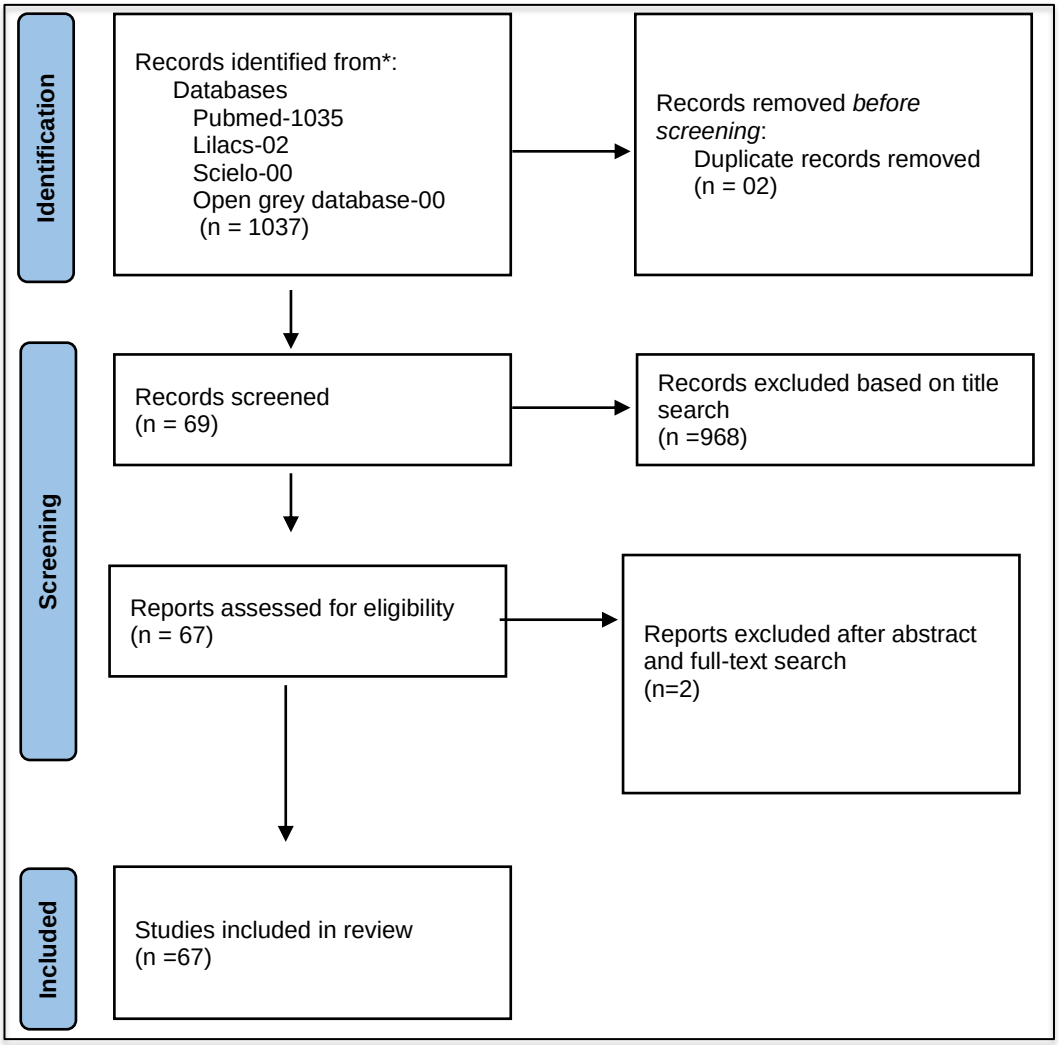
This systematic review followed PRISMA guidelines for reviews. A Boolean search string was formed to be used across all selected research and grey literature databases using specific keywords. The search string formed was, `Forensic AND (odontology OR dentistry OR dental) OR (Dental age OR Bitemark OR Bitemarks OR Dental identification) AND (Artificial intelligence OR AI)'. The following databases were used to perform the search for this review; PubMed; LILACS; SciELO; and Open Grey. Initial search was performed on 08/09/2023. Selection of relevant studies was done according to the inclusion and exclusion criteria after removing duplicates using Endnote software (version X9). A title search was initially performed to scrutinize the relevant search results across all databases, followed by an abstract and full-text search respectively to further scrutinize the results.

RESULTS

After the initial search using the search string formed, following number of results were produced ranging from January 2000 till August 2023; PubMed:

1035, LILACS: 2, SciELO**:** 0 and open grey database**:** 0. All the search results were transferred to Endnote citation manager software (version X9) to check for duplicates, therefore, 2 duplicates were excluded. The 1035 results found were then screened according to the inclusion and exclusion criteria based on the titles of the results, therefore, 69 out of the total were selected. These selected results were further screened based on their abstracts and full-text manuscripts for relevancy and an additional 2 articles were excluded from the study. After the title search followed by abstract and full text search, a total of 67 articles were selected to be part of our study. The process was explained following PRISMA guidelines in fig 1 below.

Figure 1- Identification of studies according to PRISMA guidelines



The studies included were summarized in a tabulated form according to their year of publication, journal, relevancy to forensic odontology and results as shown in table 1.

Table 1 - Summary of the studies included.

Publication title	Year of publication	Journal of publication	Which aspect of Forensic odontology was tested?	Conclusion Was AI intervention a success?
1.Transfer Learning Based Automatic Human Identification using Dental Traits- An Aid to Forensic Odontology.	2020	Journal of forensic legal medicine	Human identification	This approach outperforms the classic approach
2. Towards fully automated third molar development staging in panoramic radiographs	2020	International Journal of Legal Medicine	Age estimation	Promising results. Less time consuming than manual staging
3. Machine learning for identification of dental implant systems based on shape - A descriptive study	2021	Journal of Indian Prosthodontic Society	Identification of dental implant	Promising results to be used on a bigger sample
4. Automatic sex estimation using deep convolutional neural network based on orthopantomogram images	2023	Forensic Science International	Sex estimation	High accuracy results
5. Artificial Intelligence as a Decision-Making Tool in Forensic Dentistry: A Pilot Study with I3M	2023	International Journal of Environmental and Research Public Health	Age estimation	High accuracy results
6. Dental age estimation of Malaysian Indian children and adolescents: applicability of Chaillet and Demirjian's modified method using artificial neural network	2022	Annals of Human Biology	Age estimation using	Accurate method for dental age was established
7. Collaborative deep learning model for tooth segmentation and identification using panoramic radiographs	2022	Computers in Biology Medicine	Tooth identification	High accuracy observed
8. Dental biometrics: alignment and matching of dental radiographs	2005	IEEE Transactions on Pattern Analysis Machine Intelligence	Human identification	High accuracy was observed
9. Automatic detection of teeth and dental treatment patterns on dental panoramic radiographs using deep neural networks	2022	Forensic Sciences Research	Teeth identification	High accuracy
10. Intelligent dental identification system (IDIS) in forensic medicine	2006	Forensic Science International	Dental identification	Results of this study indicate that IDIS can be used to support dental identification
11. Individual tooth detection and identification from dental panoramic X-ray images via point-wise localization and distance regularization	2021	Artificial Intelligence in Medicine	Teeth identification	High accuracy observed
12. Automated Identification of Dental Implants Using Artificial Intelligence.	2021	International Journal of Oral and Maxillofacial Implants	Implant system identification	Precise method with good results
13. An automated technique to stage lower third molar development on panoramic radiographs for age estimation: a pilot study	2013	Journal of Forensic Odontostomatology	Age estimation	Results similar to manual method
14. Deep learning for automated detection and numbering of permanent teeth on panoramic images	2022	Dentomaxillofac Radiology	Individual teeth identification	High accuracy
15. Semi-supervised automatic dental age and sex estimation using a hybrid transformer model	2023	International Journal of Legal Medicine	Age and sex estimation	Better results than normal manual approach
16. Automatic human identification from panoramic dental radiographs using the convolutional neural network	2020	Forensic Science International	Human identification	High accuracy observed
17. Diagnostic performance of convolutional neural networks for dental sexual dimorphism	2022	Scientific Reports	Sex identification	Shows high classification accuracy and positive outcomes
18. Comparison of different machine learning approaches to predict dental age using Demirjian's staging approach	2021	International Journal of Legal Medicine	Age estimation	Machine learning is more accurate than most of the staging methods
19. Transformer based tooth classification from cone-beam computed tomography for dental charting	2022	Computers in Biology and Medicine	Teeth identification	This network outperforms others

20. Performance of a convolutional neural network algorithm for tooth detection and numbering on periapical radiographs	2022	Dentomaxillofacial Radiology	Teeth identification	Potentially accurate and efficient
21. Accurate age classification using manual method and deep convolutional neural network based on orthopantomogram images	2021	International Journal of Legal Medicine	Age estimation	This method can surpass humans in age classification
22. With or without human interference for precise age estimation based on machine learning	2022	International Journal of Legal Medicine	Dental age estimation	Without human interference, deep learning performs much better
23. Forensic Odontology: Automatic Identification of Persons Comparing Antemortem and Postmortem Panoramic Radiographs Using Computer Vision.	2018	RöFo : Fortschritte auf dem Gebiete der Röntgenstrahlen und der Nuklearmedizin	Human identification	The method used is suitable even without characteristics
24. Artificial intelligence in oral and maxillofacial radiology: what is currently possible	2021	Dentomaxillofacial Radiology	Teeth identification	The role of AI in OMF radiology is promising
25. Artificial Intelligence in Identifying Dental Implant Systems on Radiographs	2023	International Journal of Periodontics and Restorative Dentistry	Dental implant system	High accuracy achieved
26. Artificial intelligence system for automatic deciduous tooth detection and numbering in panoramic radiographs	2021	Dentomaxillofacial Radiology	teeth identification	AI plays a valuable role in forensic identification.
27. Age-group determination of living individuals using first molar images based on artificial intelligence	2021	Scientific Reports	Dental age estimation	The AI based on age group is very helpful
28. A fully automated method of human identification based on dental panoramic radiographs using a convolutional neural network	2022	Dentomaxillofacial Radiology	Human identification	This model is expected to be fast and accurate
29. Age Group Classification of Dental Radiography without Precise Age Information Using Convolutional Neural Networks	2023	Healthcare (Basel, Switzerland)	Dental age estimation	It shows promise for forensics and clinical application
30. Deep learning for preliminary profiling of panoramic images	2023	Oral Radiology	Human identification	Deep learning aids in preliminary profiling in radiographic interpretation
31. Identification of 130 Dental Implant Types Using Ensemble Deep Learning.	2023	International Journal of Oral and Maxillofacial Implants	Identification of dental implants	High accuracy as compared to other models
32. LCANet: Learnable Connected Attention Network for Human Identification Using Dental Images	2021	IEEE Transactions on Medical Imaging	Human identification	High accuracy was observed
33. Efficacy of deep convolutional neural network algorithm for the identification and classification of dental implant systems, using panoramic and periapical radiographs: A pilot study	2020	Medicine (Baltimore)	Identification of dental implant	Deep CNNs excel in dental implant classification
34. Age group prediction with panoramic radio morphometric parameters using machine learning algorithms	2022	Scientific Reports	Dental age estimation	Deep CNN architecture is useful for the identification and classification of dental implant system
35. Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification	2004	Journal of Forensic Odontostomatology	Human identification	High success rate
36. Personal identification with orthopantomography using simple convolutional neural networks: a preliminary study	2020	Scientific Reports	Human identification	CNNs enhance dental personal identification accuracy
37. Effect of Lower Third Molar Segmentations on Automated Tooth Development Staging using a Convolutional Neural Network	2020	Journal of Forensic Science	age estimation	It can optimize dental stage allocation for age estimation

38. Classification of teeth in cone-beam CT using deep convolutional neural network	2007	Computers in Biology and Medicine	Teeth identification	This method is beneficial for obtaining high accuracy and automatic filling of dental charts
39. Age Estimation using Panoramic Radiographs by Transfer Learning	2022	The Chinese Journal of Dental Research	dental age estimation	Transfer learning models can be used in different age estimation groups in radiographs
40. Tooth detection and classification on panoramic radiographs for automatic dental chart filing: improved classification by multi-sized input data	2021	Oral Radiology	Teeth identification	Useful in automatic filing of dental charts for forensic identification
41. AI-based computer-aided diagnosis for panoramic radiographs: Quantitative analysis of mandibular cortical morphology in relation to age and gender	2022	Journal of Stomatology and Oral Maxillofacial Surgery	Age and Sex identification	AI-CAD could be a useful tool for the quantitative analysis of mandibular cortical morphology
42. Identification of Dental Implant Systems Using a Large-Scale Multicenter Data Set	2023	Journal of Dental Research	Identification of dental implants	Deep learning can be used for identification of different dental implant systems
43. Applying artificial intelligence to assess the impact of orthognathic treatment on facial attractiveness and estimated age	2019	International Journal of Oral and Maxillofacial Surgery	Dental age estimation	AI might be considered to score facial attractiveness and apparent age in orthognathic patients
44. Identifying and tracking disaster victims: state-of-the-art technology review	2008	Family and Community Health	Human identification	Helps in improving disaster victim tracking with technology
45. Age Assessment through Root Lengths of Mandibular Second and Third Permanent Molars Using Machine Learning and Artificial Neural Networks	2023	Journal of Imaging	Dental age estimation	Machine Learning and Deep Learning effectively predict age using molar root lengths
46. A brief introduction to concepts and applications of artificial intelligence in dental imaging	2021	Oral Radiology	Human identification	AI transforms dental imaging, advancing diagnostics and more
47. Age determination on panoramic radiographs using the Kvaal method with the aid of artificial intelligence	2023	Dentomaxillofacial Radiology	Dental age estimation	The use of machine learning on panoramic radiographs can improve age estimation
48. Estimating sex and age from a face: a forensic approach using machine learning based on photo-anthropometric indexes of the Brazilian population	2020	International Journal of Legal Medicine	Dental age and sex estimation	High accuracy seen
49. Texture-Based Neural Network Model for Biometric Dental Applications	2022	Journal of Personalized Medicine	Human identification	CNN shows promising accuracy for dental biometrics application
50. Machine Learning Techniques for Human Age and Gender Identification Based on Teeth X-Ray Images	2022	Journal of Healthcare Engineering	Age and sex estimation	High accuracy achieved
51. Dental age assessment based on CBCT images using machine learning algorithms	2022	Forensic Science international	Dental age estimation	Machine learning, especially Random Forest, excels in CBCT-based dental age estimation

52. Hybrid HCNN-KNN Model Enhances Age Estimation Accuracy in Orthopantomography	2022	Frontiers in Public Health	Dental age estimation	This model significantly improves OPG-based age estimation accuracy
53. Machine learning assisted Cameriere method for dental age estimation	2021	BMC Oral Health	Dental age estimation	More accurate in estimating dental age than other methods
54. Evaluation of a machine learning algorithms for predicting the dental age of adolescent based on different preprocessing methods	2022	Frontiers in Public Health	Dental age estimation	More accurate
55. Automatic forensic identification using 3D sphenoid sinus segmentation and deep characterization	2020	Medical and Biological Engineering and Computing	Human identification	100 percent accuracy is seen
56. Identification of dental implants using deep learning-pilot study	2020	International Journal of Implant Dentistry	Identification of dental implants	Implants can be seen on radiographs and help in better treatment of patients
57. Human Remains Identification Using Micro-CT, Chemometric and AI Methods in Forensic Experimental Reconstruction of Dental Patterns after Concentrated Sulphuric Acid Significant Impact	2022	Molecules (Basel, Switzerland)	Human identification	It can solve problems for human identification using 3D and 2D patterns
58. Dental age estimation and different predictive ability of various tooth types in the Czech population: data mining methods	2013	Anthropologischer Anzeiger	Dental age estimation	GAME is a promising tool for age-interval estimation studies as they can provide reliable predictive models
59. Deep Neural Networks for Chronological Age Estimation from OPG Images	2020	IEEE Transactions on Medical Imaging	Dental age estimation	It is used to automatically predict the chronological age of a subject accurately
60. A population-based study to assess two convolutional neural networks for dental age estimation.	2023	BMC Oral Health	Dental age estimation	This study shows better and promising results
61. Efficacy of machine learning assisted dental age assessment in local population	2022	Legal Medicine (Tokyo)	Dental age assessment	More accurate study was observed
62. The Application of Artificial-Intelligence-Assisted Dental Age Assessment in Children with Growth Delay	2022	Journal of Personalized Medicine	Dental age assessment	This study overcame many limitations
63. Robust automated teeth identification from dental radiographs using deep learning	2023	Journal of Dentistry	Teeth identification	High performance level obtained
64. An artificial intelligence proposal to automatic teeth detection and numbering in dental bite-wing radiographs	2021	Acta odontologica Scandinavica	Dental identification	The CNN result shows promising results and helps in clinical settings to save time
65. Tooth and Bone Parameters in the Assessment of the Chronological Age of Children and Adolescents Using Neural Modelling Methods	2021	Sensors (Basel)	Dental age estimation	The accuracy ranges upto 99 percent
66. Robust Estimation of the Chronological Age of Children and Adolescents Using Tooth Geometry Indicators and POD-GP	2021	International Journal of Environmental Research and Public Health	Age estimation	Higher accuracy achieved
67. Deep Learning Neural Modelling as a Precise Method in the Assessment of the Chronological Age of Children and Adolescents Using Tooth and Bone Parameters	2022	Sensors (Basel)	Dental age identification	Verified more accurate deep neural network

The results were further classified according to their relevancy with various subtopics in forensic odontology (age estimation, sex estimation, human identification, dental implants identification system, individual tooth identification respectively) to analyze which of the subtopic had been tested the most using artificial intelligence methods. It was found that out of the total (n = 67) majority of the articles (46.27% - n = 31) were related to dental age estimation, only about 8.96 % (n = 6) were related to sex estimation using artificial intelligence, 20.89% (n = 14) related to human identification, 11.94% (n = 8) related to dental implant system identification and 14.93% (n = 10) related to individual tooth identification. The analysis was summarized in figure 2.

To check the emerging trends of the use of artificial intelligence in dental forensics the results were analyzed according to their respective year of publication by making a line graph explaining how the numbers have increased over time. As seen in figure 3, there can be seen a steep incline in artificial intelligence related studies from 2016 onwards.

DISCUSSION

This extensive research is designed to investigate and evaluate the published works that have been published between January 2000 and August 2023, with a particular emphasis on the application of artificial intelligence (AI) in the field of forensic dentistry. The objective of this research is to provide a thorough understanding of the increasing role that artificial intelligence plays in advancing forensic procedures within the dentistry domain. This will be accomplished by diving into a wide range of scholarly sources.

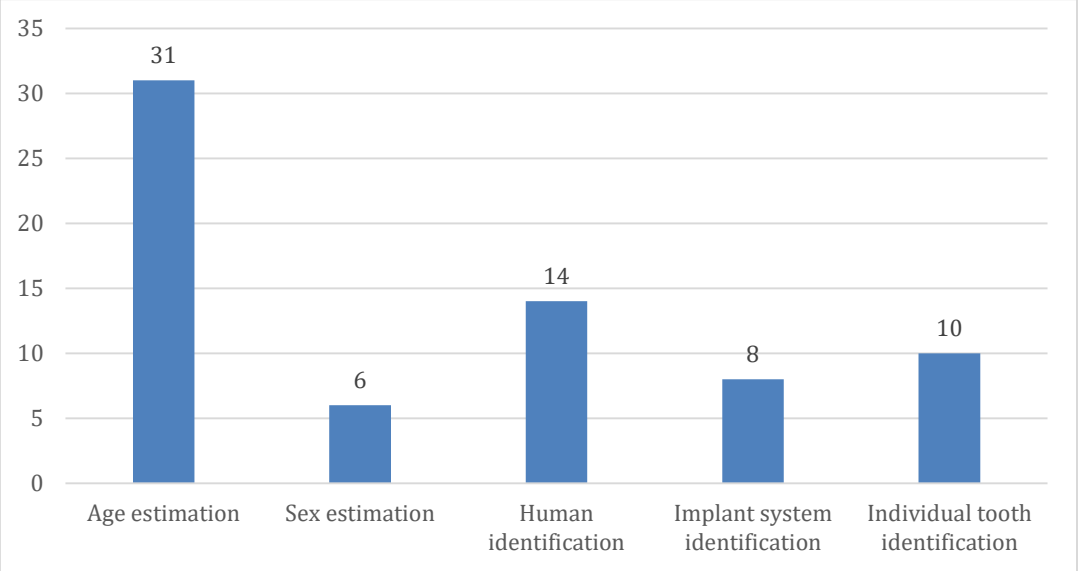


Figure 2. Classification of forensic odontology in relation to how many articles they are mentioned in.

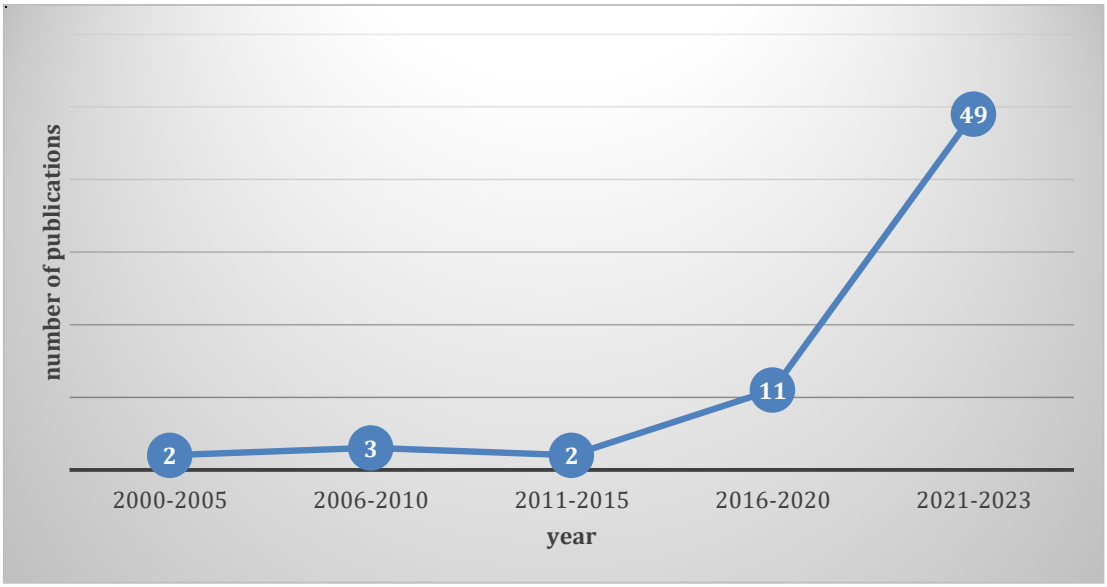


Figure 3. Number of publications published starting from the year 2000-2023.

AI in dentistry

AI in dentistry is growing as digitized workflows and large data train neural networks. Clinicians still consider AI a fad with dubious credibility. The COVID-19 pandemic may have caused an unusual increase in Scopus, Web of Science, and PubMed publications from 2019-2021. AI is mostly employed in dental radiology, but 3D image processing has spread to orthodontics, maxillo-facial surgery treatment planning, and restorative dentistry.

AI now influences dental education and wants to reorganize dentistry. When a patient's medical history, including vices like smoking and excessive alcohol consumption, is communicated to their dentist, it plays an important role in determining whether the patient is at elevated risk for dental disorders due to their genes or lifestyle choices. These aren't the only ways the software makes the dentist's job easier; voice recognition and interactive elements also contribute. Artificial intelligence software can record all relevant information and communicate it to the dentist[13].

AI in orthodontics

AI is mostly utilized in orthodontics to forecast ageing and facial growth, as well as pre-treatment AI monitoring, growth/aging predictions, and virtual treatment planning. Robotics and AI will rule the orthodontic industry in the future, not braces. Radiographs and photographs taken during orthodontic treatment can now be analyzed by AI systems to aid in diagnosis, treatment planning, and progress monitoring. Dental impressions have been replaced with digital ones due to the usage of intraoral scanners and cameras. Predicting tooth movements and treatment results is done using algorithms and AI software. Improving case acceptance is possible through the integration of personalised aligner-based orthodontics with modern technology[14].

AI in endodontics

Endodontics is one subspecialty of dentistry that has grown at an astounding rate. Research on the most accurate way to diagnose caries has been conducted. Pulse oximetry, electric pulp testing, and laser dopplemetry are just a few ways that artificial intelligence has improved tooth vitality testing, which is a crucial part of treatment planning. Both ultrasonics and operating microscopes have enhanced the quality of treatment and made a difference in challenging cases[15]. Artificial intelligence has the potential to improve dental care by analyzing radiographs to detect cavities. Record infinite images, including radiographs, caries images, parameters of restorative materials, expert opinions, and case scenarios. Once images have been scanned and radiographed, the system will analyze them and recommend treatments based on what is currently known or what is found online. For endodontic therapy to be effective, it is necessary to identify the root canal morphology, auxiliary canals, and working length. A separate study found that AI had a 96.6% success rate in detecting vertical root fractures[16]. Micro endodontic robots could provide patients with reliable root canal therapy that is safe, accurate, and precise. Nano diagnostic tools have the potential to identify cellular and molecular cancers at an early stage. To sense and manipulate human tissue, navigate it, and gather energy, dental nano-robots may employ specialized motility techniques. This may suggest that AI has clinical potential and that dentistry could benefit from its appropriate implementation[17].

AI in prosthodontics

Manufacturing prosthesis is an extremely complicated operation. Precise and hard labor are required for both the patient and the dentist. To meet the increasing demand, technology has simplified the fabrication of prosthesis. Aesthetic prosthesis that takes the patient's preferred color scheme, shape of face, and other personal details can be more easily created with the use of AI. In dentistry, digital impressions and CAD/CAM technology have been utilized since 1980. Digital impression recording helped decrease mistakes in the manufacturing of impressions. A lot of dentists are starting to use CAD/CAM systems. Dental restorations such as veneers, crowns, and laminates can be created using either direct or indirect CAD/CAM processes. New dental restorations made using CAD/CAM technology have a perfect fit and perform admirably beyond aesthetics[15]. The development of AI has simplified the process of addressing patient requests and creating cosmetic prosthesis. With the use of AI, the patient may virtually try on a prosthesis, adjust it until they are satisfied, and then have the prosthetic manufactured to their exact specifications.

AI in maxillofacial surgery

Preserving the important structures around to the tiniest detail before the actual surgery with improved intra-operative accuracy is one of the ways that artificial intelligence software applications have helped in the planning of surgical procedures as well. Image guided surgery is one example of a progressively more

advanced clinical application. This type of surgery allows for more precise surgical resection, which in turn reduces the need for revision surgeries. The enormous application of artificial intelligence in oral and maxillofacial surgery is occurring concurrently with the development of robotic surgery, which recreates human body motion and human intelligence via the use of computer programmes. Using a face detector and a CNN (Convolutional Neural Networks) that is specifically designed for the purpose, it presents a fresh approach to the field of dentistry for evaluating facial beauty[18].

AI in dental radiology

Dental radiology is the main specialization for AI use, and AI-focused dental papers have grown exponentially. Artificial intelligence's capacity to learn is what gives it its competitive edge. It can detect subtle abnormalities that a human eye might miss when used with imaging technologies like computed tomography and magnetic resonance imaging. With an increasing focus on diagnostic records pertaining to digital three-dimensional (3D) scans and cone beam computed tomography, artificial intelligence is slowly making its way into the realm of radiology within the dental profession. It is possible to build an AI to aid in rapid diagnosis and treatment planning by compiling and computing vast amounts of data. Radiographs can help pinpoint small apical foramina, which improves the reliability of working length calculations. The Caries Detector is a useful tool for identifying and characterizing caries in its early stages[13]. Using Deep Convolutional Neural Network (DCNN) based diagnostic systems on panoramic radiographs, Lee et al. demonstrated highly encouraging outcomes with AI models for osteoporosis detection[19].

AI in forensic odontology

The field of forensic odontology is still relatively new, although it has made noteworthy progress in the dental field so far. A dentist's testimony can be crucial in situations involving serious crimes, sexual assault, child abuse, and natural disasters. In instances where the sole evidence consists of dental remains, they are compelled to ensure that the victims and their families receive justice. Artificial intelligence has proven to be quite useful in this field. The ability to ascertain the gender or age of an unknown subject automatically and efficiently with minimal human involvement is a major strength of this technology. Estimating a person's age has long been an important part of forensic odontology.

Methods for calculating human age from facial pictures have been the subject of a deluge of research in recent years. However, information about the use of AI for dental age assessment is scarce. To determine a person's dental age, one must know their eruption time and the order in which their teeth will come in. Radiographs reveal the many phases of a tooth's growth. Radiographic methods of age assessment are commonly utilized due to the availability of easily retrievable data and before and after treatment records. With the advent of AI, several programming neural networks

have been developed that can train computers to automatically estimate ages[14].

In a previous review study by Khanagar et al 43 research publications were considered relevant to the use of AI in dentistry ranging from 2000 till 2020, after analysis a steep incline was seen in publications between 2018 (n = 7) and 2019 (n = 20)[8]. Another review conducted by Khanagar et al ranging from the year 2000 up till 2020 showed that only 8 publications were found related to AI and forensic odontology, further analysis of results according to sub specialty showed that 50% (n = 4) of the results were related to dental age estimation followed by sex estimation (n = 2), mandibular morphology (n = 1), and identification of bitemarks (n = 1)[20]. A review by Norhasmira Mohammad revealed 28 papers relevant to the topic over a span of 12 years ranging from 2000 till 2022, when classified according to the various fields in forensic odontology, it was seen that the most results were related to dental age estimation (47%) followed by sex estimation (32%), dental comparison (14%) and bitemarks analysis (7%)[21]. A study done by Thurzo et al to analyze literature related to artificial intelligence in the field of dentistry from the year 2011 till 2021 revealed that there were a considerable number of 1497 publications across the searched databases. Only 2.21% (n = 11) studies were found to be related to the field of forensic odontology[22]. In contrast, this study is more elaborate and is based on 69 research publication studies done over the past 23 years, the results vary from the previous review studies as most the publication 71% (n = 49) were published between the years 2021-2023 (figure 3). Like the previous studies, this study also revealed that the most publications were related to dental age estimation, as per figure 2, 44.92% (n = 31). To summarize, there has been an increasing interest in the field of forensic odontology for the use of artificial intelligence.

Future of AI in dentistry

Future call for an AI-powered comprehensive care system that will lead path for ground-breaking research and development, superior patient care, and innovative decision-support tools. Since accurate treatment processes and real-time information exchange are essential, AI will remain deeply intertwined with the dental field. Furthermore, because to these advancements, healthcare practitioners, patients, hospitals, and researchers will all be able to share large data pertaining to patients' health and gain insights that enhance patient care[23].

Groundbreaking future research could emerge from the convergence of artificial intelligence (AI) and forensic dentistry. Artificial intelligence (AI) has the potential to revolutionize dental identification by using sophisticated algorithms to compare dental records with unidentified human remains in a more efficient and accurate manner. Faster and more accurate identification is possible with the help of machine learning models trained on massive databases of dental records and photos. The examination of bite marks, an important part of forensic dentistry, can also be assisted by AI. The credibility of

forensic evidence can be enhanced by using technologies that can precisely examine bite marks on victims and compare them with dental impressions of perpetrators. The use of artificial intelligence in conjunction with 3D imaging techniques for forensic odontology is another potential subject for future study. To help identify people when conventional methods fail, AI algorithms can analyze dental components more precisely and help recreate facial features from dental records. In addition, studies can investigate the legal and ethical aspects of using AI in forensic dentistry, making sure it is used in a responsible and open way for criminal investigations. Ongoing multidisciplinary collaboration between computer scientists, forensic professionals, and legal experts is necessary to maximize the benefits of AI while resolving its accompanying issues in the ever-changing world of AI and its potential impact on forensic dentistry.

CONCLUSION

As a conclusion, it was noted that there has been an increasing interest of authors in publishing articles related to the use of AI in forensic odontology. A substantial increase in literature was observed from 2020 to 2021-23. In the future we might see even more literature about AI in forensic odontology.

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RESUMO

A Odontologia Forense se preocupa com o gerenciamento, exame e representação apropriados de achados odontológicos a serviço da Justiça. A Odontologia Forense moderna usa IA para identificar corpos e tratar marcas de mordidas e ferimentos. Restos dentários analisados com IA para reconstrução facial e estimativa de idade revolucionam a identificação de crimes. Esta pesquisa examinou a literatura relacionada ao uso de inteligência artificial (IA) em odontologia forense de janeiro de 2000 a junho de 2023. Publicações relevantes em inglês foram pesquisadas seguindo as diretrizes PRISMA nas bases de dados PubMed, LILACS, SciELO e Open Grey. Após a triagem de título, resumo e relevância do texto completo, 67 artigos foram escolhidos para o estudo de um total inicial de 1.037 resultados. Os resultados foram classificados de acordo com a subespecialidade em odontologia forense, foi descoberto que a maioria dos artigos (46,27% - n = 31) estava relacionada à estimativa da idade dentária, apenas cerca de 8,96% (n = 6) estava relacionado à estimativa do sexo usando inteligência artificial, 20,89% (n = 14) relacionados à identificação humana, 11,94% (n = 8) relacionados à identificação do sistema de implante dentário e 14,93% (n = 10) relacionados à identificação individual dos dentes. Uma inclinação acentuada foi observada no número de publicações relacionadas à inteligência artificial a partir de 2016. A IA odontológica está mudando a radiografia, a ortodontia, a endodontia, a prótese e a cirurgia maxilofacial. A IA ajuda os odontologistas forenses a estimar a idade e o sexo a partir de informações odontológicas. Um sistema de atendimento abrangente com tecnologia de IA transformará a identificação odontológica usando programas de computador, aprendizado de máquina e melhorando a velocidade e a precisão da odontologia forense.

PALAVRAS-CHAVE

Odontologia legal; Inteligência artificial; Aprendizado profundo; Aprendizado de máquina.

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