

ROLE OF VARIOUS STAKEHOLDERS IN APPLICATION OF ARTIFICIAL INTELLIGENCE TO FORENSIC ODONTOLOGY- A POTENTIAL PERSPECTIVE

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ABSTRACT

Globally, an advance of field of technology that is rapidly growing is Artificial intelligence (AI). It is a breakthrough in digital science and deals with several complex difficulties that currently exist. The meta-analysis of the metaknowledge available can be simplified in a very short time and an understandable language. AI may, therefore, have a significant role to play in Forensic Odontology (FO). FO involves the examination, evaluation, management, and presentation of dental evidence in criminal or civil proceedings, all in the interest of justice. It is a vital part of forensic science that plays a fundamental role in the identification of individuals, alive or dead. Digital forensics has effectively and reliably replaced traditional forensic investigations in terms of acquiring, analyzing, and reporting evidence. The application of digital forensic investigation is very useful in mass disasters, personal identification, age estimation, and communication with other forensic odontologists. Various stakeholders may be able to contribute towards the widespread and effective use of AI in forensic dentistry including general dental practitioners, dental radiologists, forensic odontologists, general pathologist, oral pathologist, biomedical engineer, data scientists and government statutory bodies. Thus, the purpose of this paper is to attempt at having an overview of the probable role of various stakeholders in the future application of AI to FO.

Key words: Artificial intelligence, Forensic odontology, Forensic science, Digitisation

Introduction

Forensic Odontology (FO) involves the examination, evaluation, management, and presentation of dental evidence in criminal or civil proceedings, all in the interest of justice [1]. Forensic odontology is a vital part of forensic science that plays a fundamental role in the identification of individuals alive or dead [2, 3]. Digital forensics has effectively and reliably replaced traditional forensic investigations in terms of acquiring, analyzing, and reporting evidence. The application of digital forensic investigation is very useful in mass disasters, personal identification, age estimation, and communication with other forensic odontologists [4]. Digital forensics requires the intelligent analysis of the metaknowledge from complex data sets. Therefore, Artificial Intelligence (AI) is a breakthrough in digital science and deals with several complex difficulties that currently exist. Various stakeholders may be able to contribute towards the widespread and effective use of AI in forensic dentistry. Thus, the purpose of this paper is to discuss the probable role of various stakeholders for the future application prospects of AI in forensic odontology.

Main Body

Artificial Intelligence

Globally, an advance of field of technology that is rapidly growing is Artificial intelligence (AI). Since the inception of dentistry, exceptional achievements have been witnessed. Hence, every stakeholder should be acquainted with this technology as the future of forensic dentistry lies in the application and AI implementation. Meta analysis of the complex data from various sources can be translated into an understandable language in a very short span [5]. The relationship between prevention, disease process, biologic behavior of the disease, treatment, and patient outcome can be primarily analyzed through AI applications in healthcare systems. AI technologies have already made their way into digital forensic science. Sophisticated algorithms are used today for e-discovery document review, cyber-crime detection and DNA sequence matching. Therefore, AI may also have an essential part in forensic odontology.

In 1954, John McCarthy coined the term artificial intelligence, which is defined as 'a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behavior, and with the creation of artifacts that exhibit such behavior' [6].

Types of AI of relevance to healthcare [7]:

1. Machine Learning- Neural networks and deep learning.

2. Natural Language Processing (NLP)- Statistical and Semantic NLP.
3. Rule-based expert systems
4. Physical Robots
5. Robotic process automation.

Stakeholders in the Application of Artificial Intelligence to Forensic Odontology

Several stakeholders may contribute to the future application of artificial intelligence in forensic odontology (**Figures 1 and 2**).

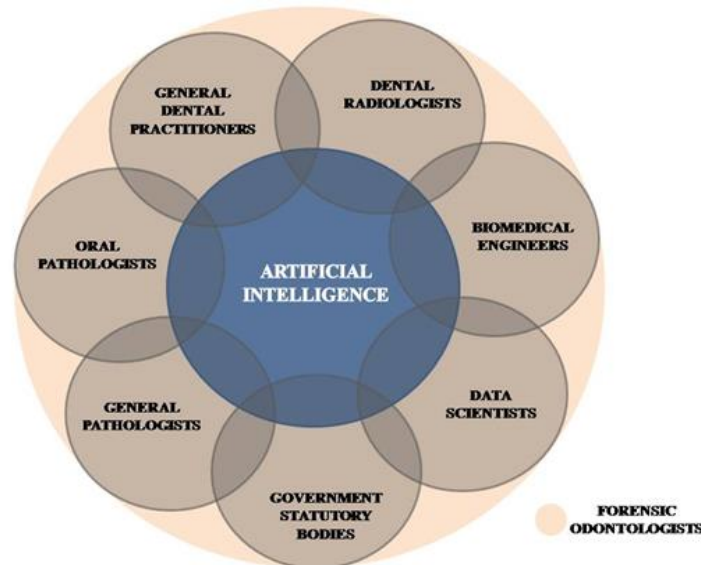


Figure 1. Various Stakeholders contributing in Forensic Odontology fortified with Artificial Intelligence

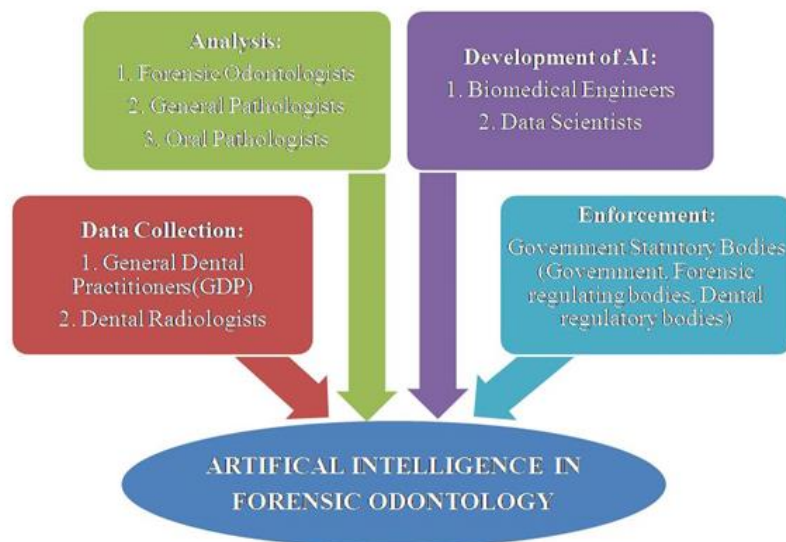


Figure 2. Contribution of various stakeholders in Forensic Odontology for application of AI

Role of various stakeholders in the application of artificial intelligence to forensic odontology

General dental practitioners

Dental hard tissues are known to be resistant to pressure, humidity, and high temperatures changes, which in the identification process, makes them a very reliable source [8]. The role of General Dental Practitioners (GDP) is thus

unprecedented. GDPs collect dental records in various formats. Complete digital dental records should be maintained by all GDP's in a unified format which will enable personal identification of victims by comparison of antemortem and post-mortem data, especially in disaster victim identification (DVI). Reproduction of detailed dental conditions and a large volume of information which are easy to upload on the internet website is now constructed, on a

cost-effective basis, using dental data and actual oral digital images, with the recently developed new style of dental chart called the Digital Dental Chart (DDC) [9]. Thus, all GDP's should electronically store data in the DDC which, in the future, through artificial intelligence, will be a rapid and useful resource in personal identification.

In the future, it is expected that various relevant algorithms, constructed via AI, will be developed and designed specifically for dental use. This automated intelligent workflow system will help in conducting an overall analysis of the patient by integrating patient's demographic data, 2D/3D diagnostic images, clinical findings, medical history, and/or intraoral/facial scans. This may help build a real-time database for future use in forensics.

Dental radiologists

Digitization has revolutionized forensic investigations and therefore, all dental radiological data should be available in readily accessible and quickly interpretable digital format which will enable radiologists to have Satellite communication of the digital transmission of images without loss of image details [10]. Complex dental x rays with artificial intelligence can produce more accurate results with less noisy images. AI provides added advantage in determining the minutest deviations from normality that could have gone unnoticed on visual examination [11]. In a study conducted by researchers, it was shown that Convolutional Neural Network (CNN)-based system enables detection and numbering of teeth on orthopantomograms for the automated dental charting purposes which besides saving time also improvises the completeness of electronic-based data [12]. Based on this convolutional neural network, tooth types can be automatically classified on CBCT images through the development of a deep learning algorithm [13]. Deep learning algorithms are shown to enhance the CT image resolution and lower the noise levels.

Forensic odontologist

Facial reconstruction

Forensic facial approximation /reconstruction involves recreation of an individual's face of unknown identity from their skeletal remains through an integration of osteology, anatomy, artistry, and anthropology. It is a method used in the forensic field when a crime involves unidentified remains. A laser video camera interfaced with a computer or with CT scanning is used in the Computerized facial reconstruction method. Artificial neural networks are used for sex determination from skeletal structures, with 95% accuracy. Artificial intelligence methods will eliminate human bias, require no special expertise and provide rapid results when used for sex estimation of skeletal remains [14].

Bite mark analysis

Bite marks on human tissues can be observed in various brutal incidents such as child abuse, sexual abuse, and offenses involving physical violence. Bite mark analysis is done in several ways including digital photography with visible light and infrared / UV light, intraoral 3D optical scanners, computer-assisted overlays, or Dental Print 3D software [4]. AI can develop trained networks that can give a reasonable matching accuracy by selecting some specific features of the bite marks which are obtained and analyzed on a given model. If bite marks are obtained as antemortem records and stored in a database, then via algorithms developed through AI, they can be matched with postmortem records and be a useful source of positive identification. For eg: In the case of a mass disaster, such as an air crash, if the bite marks can be obtained before the travel, this information might be useful to identify the passengers [15].

Cheiloscopy

Lip prints are unique to individuals. Cheiloscopy is the study of lip prints and is widely used as an identification method for forensic investigations. Human lips are an emerging biometric modality. A novel biometric system based only on lip contours and new lip geometrical measurements, in contrast to other methods like the texture of the lip surface, is employed using a Probabilistic Neural Network for lip based biometric verification [16].

Age estimation

Age estimation is one of the essential factors in human identification. It plays a pioneering role in the identification of unknown corpses and skeletal remains at crime scenes, in accidents and mass disasters cases as teeth are the hardest structures in the human body, which usually survive post-mortem destruction. Thus, they have an essential part in comparative as well as reconstructive identification. Several machine learning algorithms improve the accuracy of dental age estimation. With the advent of artificial intelligence, several programming neural networks can train computers to automatically estimate age [17].

3D printing

3D printing is widely used in forensic odontology in bite mark analysis, sex determination, cheiloscopy, age estimation, facial reconstruction, palatoscopy, tongue print pattern analysis, and in illustrating patterns of bone injury [4]. When AI is combined with 3D printing technologies it increases the performance of a 3D printer by facilitating automated production and reducing the risk of error.

Gender determination

Gender estimation is an important aspect of personal identification and thus, has an immense forensic relevance. Previously used models- discriminant analysis and logistic regression can be replaced by algorithms created through an artificial neural network. Hence, the application of this technique in the field of forensic odontology is promising to owe to its ease of use and having minimal human errors due to automation [18].

Personal identification

Using appropriate techniques, forensic personal identification is a fundamental scientific discipline used in the identification of the living, recently deceased, and compromised human remains. In crime scene investigations, it is often used as a tool. Personal Identification System, based on Meta-Heuristic Algorithm, reported an identification percentage of 97.7% when using Dental Panoramic Radiograph [19].

General pathologist

The scalpel-free autopsy can be performed by imagistic modalities instead of the conventional autopsy. This is called- Virtual Autopsy / Virtopsy. It is a non-invasive technique. There can be a virtual biobank created to which machine learning is applied. Several algorithms can be formulated, by building a model from sample inputs, which will make data-driven predictions or decisions [20].

Oral pathologist

Artificial intelligence and deep learning are invaluable in digital pathology. The histopathological diagnosis can show

inter-and intra-observer variability. Thus, the use of AI in the field of oral pathology is indispensable for obtaining consistent, reliable, and more accurate diagnoses. Oral pathologists should use Forensic comparison microscopes to compare two images when slides are placed side by side and capturing the images digitally so that they can be simultaneously seen. The findings can be then interpreted by AI [21].

Biomedical engineer

The development of forensic biorobots by biomedical engineers has played a pioneering role in the automation of the DNA sampling process. Thus forensic scientists can concentrate on the analysis and interpretation of processed data. BioRobot M 48 is found to be very effective in DNA extractions [4]. Application of the same in forensic odontology along with formulating algorithms for analysis will speed up the DNA profiling process besides reducing human errors.

Data sciences

A Data scientist's role combines database management, data wrangling, statistical analysis, visualization, and predictive modeling on structured and unstructured data. In recent years data science has been increasingly in-cooperated in predictive, preventive, and forensic medicine. **Figure 3** illustrates a general pipeline of the potential phases of involvement of data science with medical domain experts for the development of predictive data models and AI technology [22].

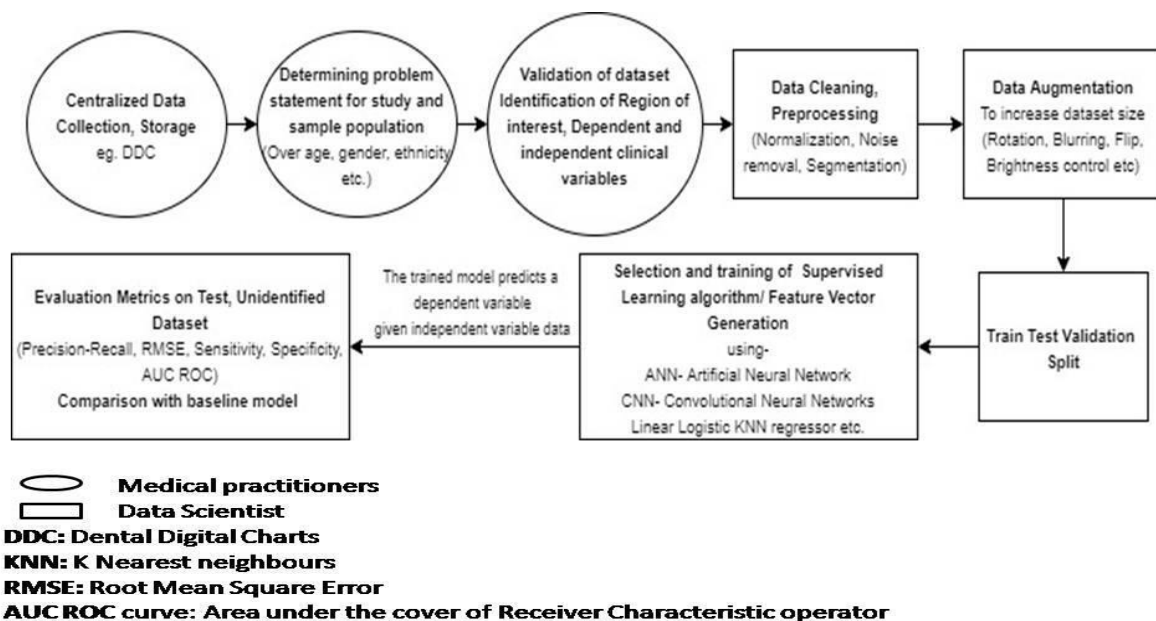


Figure 3. Potential phases of involvement of data science in various medical domains.

The dental records collected should be in a standardized format through a common coding system. Thus, like the Japan Dental Association Oral Examination Standard code (JDAOES), a code should be formulated to unify the display of the dental records [23]. Hence, model projects should be created. The use of Electronic Health Records (EHR) that share medical/dental health information among relevant persons should be encouraged by the Government. The patient information can then be readily stored and browsed through cloud technology thus creating cloud-based electronic health records, with standard data format, for ready reference. However, legal maintenance is required for the protection of personal information. Funds should be directed towards the development of diagnostic technology using AI. Various regulatory bodies like the Dental Councils, Dental Associations, and Forensic odontology associations should come together and lay down policies that will uplift the technology-based scientific world.

Several limitations encompass the stakeholders which one should try to overcome. These are enlisted in **Table 1**.

Table 1. Limitations of Stakeholders in Artificial Intelligence

Sr. No	Stakeholder	Limitations
1.	General Dental Practitioners	-Lack of standardized format for data collection. -Lack of adequate knowledge of AI and its use in FO.
2.	Forensic Odontologist	-Limited number of forensic odontologists available -Limited resources
3.	Dental Radiologist	-Insufficient digitization of available records -Inadequate application of AI to digitized records.
4.	General Pathologist	-Lack of armamentarium for performing technology-based autopsy for forensic studies.
5.	Oral Pathologists	-Limited emphasis on forensic odontology training amongst specialists.
6.	Biomedical Engineers	-Lack of integration amongst science and technology for evolution in the field of biotechnology.
7.	Government Statutory bodies	-Lack of coherence amongst various other stakeholders. -Limited resources and political considerations before bringing in reforms.

Conclusion

Artificial Intelligence is the best device to store, evaluate and use product data collected for forensic evidence in legal cases. It can create and provide a repository of digital forensic investigations. Various algorithmic models, for this

purpose, can be formulated and modified so that all the related stakeholders can contribute to the field of forensic odontology in the best possible manner. Most importantly, if there is an interdisciplinary integrated approach amongst all stakeholders, AI can be a boon in Forensic Odontology that will enhance the efficacy of the final output. However, it should be borne in mind that artificial intelligence is the innovation of mankind and only assists in performing tasks efficiently. It can by no means replace the intellect of humans or enslave mankind.

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