Artificial Intelligence In Dentistry : A recent trending concept

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ABSTRACT

Artificial intelligence (AI) is the branch of computer science dedicated to edifice systems that are capable of performing human tasks. AI tries to solve problems and learn like humans. AI is not a new term; the concept of AI can be dated back to 1950. The term artificial intelligence was coined by a mathematician John McCarthy in 1956 and was called as "Father of Artificial Intelligence". But the field of AI has experienced remarkable development and growth over the past few decades. Owing to the rapid development of three keystones of current AI technology are - huge data (coming through digital devices), computational power and AI algorithm in the past two decades. In dentistry, AI has been adopted in almost all dental disciplines, to provide health care benefits such as decreasing postoperative complications, increasing quality of life, improving decision-making and decreasing the number of unnecessary procedures. This chapter aims to explain the current applications and future estimates of AI in dentistry, which is one of the most current topics of recent times.

Keywords : artificial intelligence, data collection, machine learning, neural networks, dentistry

I. INTRODUCTION

Artificial intelligence (AI) is a fast-moving technology that enables machines to perform tasks previously exclusive to humans[1] such as reasoning, learning, and self-development. The initial question was asked by Alan Turing in 1950 as “Can machine think?” and then the word was first used by John McCarthy as "Artificial Intelligence”. The complexity of neural networks in a functional human brain has always been a topic of interest to many researchers in different fields.[2] With the development of science over time, many advanced technology products have emerged that imitate the functions of the human brain, but it is still not possible to fully simulate the human brain today (Figure 1). Despite the many difficulties experienced, AI has gained great importance in all areas of life with its irrepressible progress.[3]

AI studies basically aim to imitate the cognitive processes of human intelligence by using machines and software-type algorithms to manage possible problems and complex tasks solved by human mind and skill. The sub-branches of AI are symbolic Preparing datasets for AI requires large amounts of data to be processed to improve accuracy. The experts must invest time and effort in making data suitable for effective learning.[2]

It is essential to be aware of key elements of AI systems in society today[4] -

1. Machine learning uses algorithms to anticipate outcomes from a set of data. The goal is to make it easier for machines without human intervention to learn from data and solve problem.

2. Neural networks compute signals using artificial neurons which operates similar to human brain.

3. Deep learning with multiple computational layers builds a neural network that automatically recognises patterns in order to improve feature detection.

4. Data science is the process of analysing data and extracting useful information from it.

5. Big data provides users with accurate information by assessing a vast set of data that has been continually growing for years at the right time.

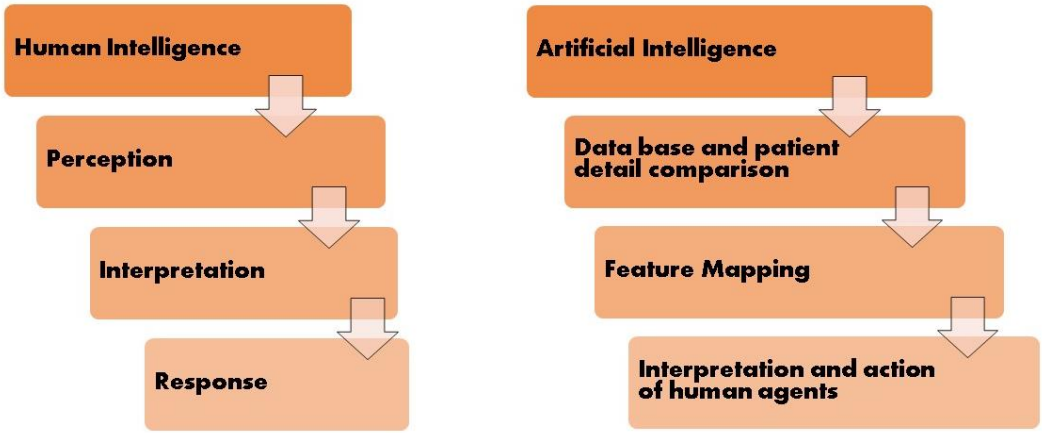
In medicine and dentistry, one of the most commonly used subclasses of ANN is the convolutional neural network (CNN) (Figure 2). A CNN uses a special neuron connection architecture and the mathematical operation, convolution, to process digital signals such as sound, image and video. CNNs use a window to scan a small neighbourhood of inputs at a time, from left to right and top to bottom, to analyse a wider image or signal. They are extremely well adapted to the task of image classification and are the most used algorithm for image recognition.[5]

Clinical-Decision-Support-System (CDSS) is one of the any computer system designed to help healthcare professionals make clinical choices through managing clinical data or medical knowledge. Most CDSS have four basic components[6]:

1. Knowledge Base (KB) : Contains the data for comparison for the clinical condition.
2. Working Memory (WM): In this, collected patient data may be stored in a database or may exist in the form of a message.
3. Inference Engine (IE) : is the main part of any such system, uses data from KB and compares with patient details in WM and final conclusions can be made regarding certain conditions.

4. Explanation Module (EM) : This is the last component of CDSS. This section is responsible for composing justifications for the conclusions drawn by the IE.

Since dentistry is one of the zones where technology is most widely used, it is a very open area for developments in technology and the adaptation of AI applications. In recent years, AI applications have been extensively used in dentistry, ranging from the diagnosis of caries to dental implant construction. With the rapid developments in the field, AI studies, have started to radically change the sectors,



will inevitably transform dentistry. The purpose of this chapter is to review the current and potential uses of AI applications in dentistry, to discuss the opportunities it will offer to improve oral and dental health of the community.

Figure 1 : Human and Artificial intelligence. Human intelligence is characterized by perception, interpretation and biological response. In contrast, artificial intelligence does not actually replace human responses, but largely supports human interpretation and action.

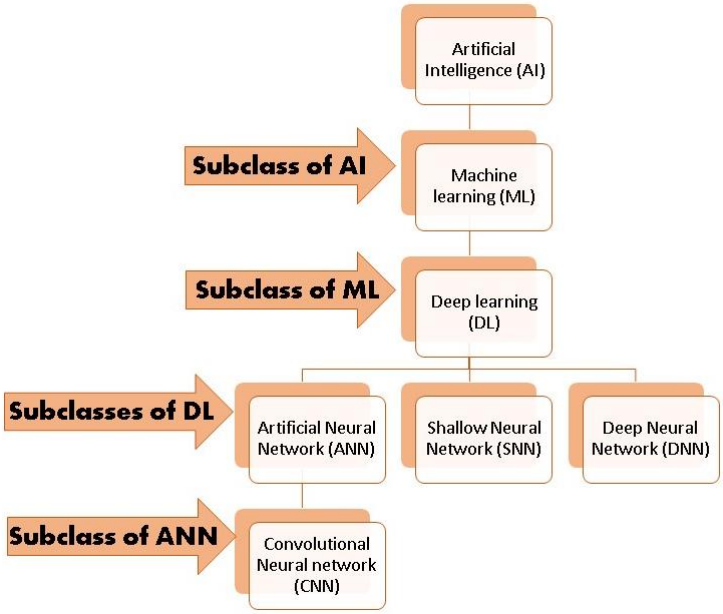


Figure 2 : Sub-classes of AI used most commonly in medicine and dentistry.

II. HISTORY OF AI

Back then, in 1950 there was no term to interpret AI. Turing mathematically investigated the feasibility of AI and explored how to construct intelligent machines and assess machine intelligence. He proposed that humans solve problems and make decisions by utilising available information and inference, machines also can do the same thing. So, he proposed setting a test as to whether a machine can achieve human-level intelligence. This test is known as the Turing Test. It lies on the following lines: Assuming a human evaluator could distinguish natural language communications between a human test taker and a machine. It is given that a human evaluator knows that the conversation is between a human and a machine, and the human evaluator, human test taker and machine are separated from one another. The conversation between the human test taker and the machine is limited to plain text, i.e., keyboard input, instead of speech. This is to make the test only focus on the machine's ability to answer the questions logically instead of testing its speech

interpretation ability. If the human evaluator cannot distinguish the human test taker and the machine, the machine can be viewed as having passed the Turing Test, and such a machine is said to have "machine intelligence".[7]

Later, in 1955, the term AI was first proposed in a workshop named "Dartmouth Summer Research Project on Artificial Intelligence" led by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon. However, the concept was only on paper. Certain restrictions stopped researchers from developing real AI machines in the 1950s. Firstly, computers before 1949 lacked a fundamental prerequisite for AI tasks: there was no storage function, which means the codes could not be stored, they could only be executed. Secondly, computers were costly at that time. Lastly, funding sources had conservative attitudes towards this new field back then.[8]

From 1957 to 1974, the AI field was fast-growing because of the growth of computer power, its accessibility, and AI algorithms. Later AI development slowed down due to insufficient practical applications and research funding reduction in the mid-1970s and late 1980s In the 1980s, it developed through two paths: ML and expert systems. ML finds the solution by learning and summarizing the experience by itself, while expert systems need human experts to input all possible situations and solutions in advance.[9]

Two important time points in computer vision are 2012 and 2017. In 2012, a graphics processing unit (GPU)-implemented deep learning (DL) network with eight layers was developed. The work won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) and achieved a classification top-5 error of 15.3%. The error rate was more than 10.8% lower than the runner-up. In 2017, SE-NET further lowered the top-5 error to 2.25%, surpassing the human top-5 error (5.1%).[10]

Later famous AI examples include Deep Blue—a chess-playing expert system in 1997; 20 years later in 2017, Google's AlphaGo, a DL program and now recently in late 2022, OpenAI launched ChatGPT (Chat Generative Pre-trained Transformer), it is a text-generation model that can generate human-like responses based on text input, the model received extensive discussion since its launch. These examples used different AI approaches to operate.[7]

By now, AI encompasses a range of applications. These include computer vision (for example face recognition by smartphones or security cameras, autonomous driving), natural language processing (voice assistants or chatbots that can systematize and link both structured and unstructured text and similar tools), robotics, virtual reality and simulation systems (for example in manufacturing or surgery but also drug development), and decision-making support (for example in medical symptom checkers). AI is abundant in our everyday world and with exponential growth of data, hardware capacities, and new software architectures has led to astonishing dynamics in many of the fields.[11]

III. APPLICATIONS OF AI IN DENTISTRY

In dentistry examination of the mouth, teeth, jaws and other oral structures are examined to assess the condition and related pathologies. The patient's complaint, medical history, digital radiography images, and, when necessary, intraoral/extraoral photographs are recorded. Oral diseases such as dental caries, gingival diseases, inflammatory conditions, cysts, and tumors are commonly evaluated with these instruments. Then a conclusive diagnosis is given by establishing a relationship between clinical, systemic, radiological and histopathological findings.[2]

Correct diagnosis is very important for a successful treatment. Using AI technologies in the health field can reduce human-related errors, reduce the time for diagnosis and the need for experts. In this sense, there are many AI techniques to diagnose or to solve the problems. The potential of AI can be studied in specific to different branches in dentistry and clinical practice, to facilitate faster adoption of AI techniques, and to provide a reference to future studies.[12]

A. Oral Diagnosis and Maxillofacial Radiology

Dentistry examines the conditions and pathologies of the mouth, teeth, jaws & surrounding structures through different imaging techniques like intraoral radiographs, panoramic, cephalometric and advanced imaging technique, and cone beam computed tomography (CBCT). These are collected for diagnosis, treatment planning, and treatment evaluation purposes. In the imaging of maxilla and mandible jaw bones, all existing teeth and the supporting tissues, panoramic radiographs are the most widely used radiological diagnostic tools. Due to the complex anatomical structure of the region, displaying it in 2D may cause superpositions and may cause improper and incomplete interpretations.[2]

Due to many pre-treatment radiographs taken in dentistry, offers a huge dataset and rich resource for scientific / medical research, especially for use in AI development work. Many AI studies can help the dentist in accurate and rapid diagnosis in radiological examinations. However, since the same standardization cannot always be achieved in radiological images and due to the complexities and errors in the images, AI cannot fully replace human intelligence in the interpretation of radiographs.[2]

Due to the high number of cysts and tumors in the maxillofacial region and their similar radiological appearance, it may be difficult to make a differential diagnosis of these lesions. Many AI based systems have made it possible to make more accurate radiological preliminary diagnosis. Automatic Segmental analysis of cysts and tumors gives reliable results to differentiate these pathologies.[12]

The application of AI is also appreciated in the detection and classification of suspiciously changed mucosa experiencing premalignant and malignant alterations. Even little changes at the single-pixel level which could escape the human eye are picked up. AI may be able to correctly identify a large population's genetic inclination towards oral cancer.[13] ML algorithm can detect a lymph node in head and neck image as normal or abnormal.

AI in patient management system can assist in managing regular appointments. It can also be used to alert the patients and dentists about check-ups whenever any genetic or lifestyle information indicates increased susceptibility to dental diseases.[14]

B. Oral & Maxillofacial Pathology

Oral and Maxillofacial Pathology (OMFP) is a specialty for histopathologically examining pathological conditions and diagnosing diseases. An algorithm that can perform epithelial segmentation in digital micrographs of hematoxylin eosin-stained samples of odontogenic cysts are developed. Later, a fully automated algorithm that can define the difference of epithelial layers of four different odontogenic cysts by using a support vector machine (SVM) and logistic regression was developed. This helped in classification of cysts. CNN models and DL are being introduced to distinguish the cysts accurately.[15]

A CNN model has been developed to distinguish normal tissues from pathological tissues using auto-fluorescent and white light images obtained by intraoral scanning devices of malignancies and dysplasias in the oral region. By expanding this dataset and adding more pathologies, automatic detection of pathologies in the oral region using AI can help clinicians more. Hyperspectral images, in which the DL algorithm are being used, for the early detection of oral cancers which showed 91.4% accuracy. Using different AI models intra oral squamous cell carcinoma can be detected by photographic images, shape, texture & color featured in the hispathological images and positron emission tomography/CT mages that detect lesions larger than 1 cm and have a high metabolism. Few ML based techniques can also detect the survival of the individuals with related pathologies.[16,17]

C. Oral & Maxillofacial Surgery

It is the branch of dentistry that treats and rehabilitates pathological conditions, trauma, and developmental anomalies in the mouth, teeth, jaws and other supporting structures. Impacted third molar tooth extraction is one of the most common surgical procedures. One of the most common postoperative complications in third molar surgery is facial swelling. With the help of dataset related to patient's age, gender, medical and dental status, the relationship of the third molar with the second molar and ramus, the degree of impaction in the bone, the type of incision, the removal of the tooth in single or multiple pieces, the duration of the procedure, etc. an artificial neural network model was developed to predict the probability of facial swelling after extraction.[18]

The greatest application of artificial intelligence in oral surgery is the development of robotic surgery. Successful clinical application in image guided surgery in craniofacial area including oral implant surgery, removal of tumor and foreign bodies, biopsy and TMJ surgery. Comparative studies between manual freehand procedures and AI guided procedures in oral implant surgery indicate significantly more accuracy even if performed by experienced surgeons. Shorter operation time, safer manipulation around delicate structures and higher intra operative accuracy has been also been reported. Image guidance allows more thorough surgical resection potentially decreasing need for revision procedures.[19]

D. Conservative and Endodontics

It is a branch of dentistry that treats structure and deformities caused by dental hard tissue and pulp & periapical diseases with protective, restorative, and aesthetic methods. AI makes detection of all pathologies easy in radiographs as it is already explained in earlier section. Although the diagnostic performance of the designed CNN algorithm is not bad, the sensitivity and specificity tests indicate that it is not yet reliable enough to be used in clinical practice.[20]

In endodontics areas such as anatomical variations of root canals, canal shaping techniques, and materials used in treatments are some of the topics that are researched and continue to be developed. Detection of accessory canals, root morphology, canal orifice, canal apical foramen and working length are the most common and important structures to be identified in this branch. Among all the above mentioned, correct determination of working length is very important for successful root canal treatment results. An AI model using ANN has been successfully used to determine the working length accurately.[21]

E. Periodontics

Periodontal diseases are an important public health problem due to their high prevalence and may lead to the loss of teeth.AI models for diagnosis of diseases occurring in the gingiva and surrounding tissues along with related microbiota, in the classification of periodontal diseases & halitosis, in the detection of plaque with fluorescent imaging have been developed. A CNN model developed to identify periodontal bone loss is very accurate when compared to routine methods. This also detected automatic alveolar bone loss areas and could measure the degree of alveolar bone loss. Later a DL-based CNN model for the automatic detection of periodontally weakened premolar and molar teeth.[22]

AI model, trained by fluorescent biomarkers and experts, has been shown to detect the presence and location of dental plaque in intraoral photographs. Thus, they have developed an AI model that can help plaque control with intraoral images and provide early periodontal disease detection without various plaque imaging methods or experts. Another automatic AI model that can distinguish healthy and inflamed gums from fluorescent images obtained using intraoral cameras has also been developed.[23]

F. Prosthodontics

This branch of dentistry deals with dental treatments related to loss of substance in natural teeth, missing teeth, and oral and maxillofacial tissue defects and are restored with artificial materials. Computer-aided design/computer-aided manufacturing (CAD/CAM) is a technique in which computer skills are used to design and produce prosthetic parts. In recent years, CAD/CAM has been widely used to produce fixed prosthetic restorations. Smart software tools are needed to optimize the digital digits of CAD/CAM systems.[24]

AI assisted developments help in tooth classification and segmentation planning through 3D models. Thus, easily obtained in clinical applications, the plaster model can be included in an automated process. Though implants have gained popularity, removable prostheses still remain the primary way of treatment. Depending on the design, patients may have discomfort, aesthetic problems, and, more importantly, problems such as not using the prosthesis which led to the development of a clinical decision support model to design removable prostheses.[25]

G. Paediatric dentistry

In paediatric dentistry, faster and more effective diagnoses enable patients to cooperate better and increase the success rate. DL method in the automatic detection and numbering of milk teeth. The deep CNN algorithm YOLOv4 to detect permanent dental germs has been developed. CNN algorithms have also been developed to detect and classify impacted milk molars. AI models have been able to detect the developmental anomalies related to teeth in early stages reducing the future dental complications. The proposed model has performed well and has the potential for clinical use and to detect all dentition periods.[26]

H. Orthodontics

Accurate diagnosis is very important in orthodontic applications aiming to correct the irregularities in the teeth, the relationships of the jaws with each other, malocclusions, and the positions of the jaw bones on the facial skeleton. Malocclusions are common, and this is a serious public health problem in developed countries. DL methods, you-only-view-forget version 3 (YOLOv3), and single-shot multibox detector (SSD) AI methods, the accuracy of YOLOv3 was found to be higher than SSD. AI model that automatically determines skeletal classification and eliminates the landmark detection process was developed. An algorithm has been developed to automatically detect 20 cephalometric points on the images obtained with CBCT. Determination of bone age with high accuracy in the CNN model have been developed and stated that this system is a much faster and more efficient decision support system than traditional methods. An AI model has been developed to define the effect of orthognathic treatment on facial attraction and visible age.[27]

IV. CONCLUSION

In short, although there are both technical and ethical difficulties in artificial intelligence, the fact that it is a very open field for development and progress makes artificial intelligence worth researching. The risks are especially high in the health field. There are great concerns about data protection, data security, and the transfer of critical medical decisions to computers. However, artificial intelligence has the potential to revolutionize both healthcare and dentistry. In the upcoming period, it seems inevitable that artificial intelligence and dentists must work together in cooperation. It is becoming a necessity of the age for dentists to follow current developments and integrate them into their clinical lives. On the other hand, the support of dentists is absolutely needed in order to carry the achieved developments further.

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