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DENTISTRY AND ARTIFICIAL INTELLIGENCE

Dental Science

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ABSTRACT

Over the last two decades, the field of artificial intelligence (AI) has seen spectacular development and growth. AI applications are expanding into areas that were previously thought to be reserved for human experts, thanks to recent advances in digitised data acquisition, machine learning, and computing infrastructure. When used in medicine and dentistry, AI has the power to dramatically improve patient care and transform the industry. All dental specialties, including operative dentistry, periodontics, orthodontics, oral and maxillofacial surgery, and prosthodontics, have adopted AI. The majority of AI applications in dentistry focus on diagnosis based on radiographic or optical images, with other tasks being less applicable due to data availability, data uniformity, and computational power for handling 3D data. Furthermore, artificial intelligence (AI) is widely used in dental laboratories and is becoming increasingly important in dental education. The following article discusses current and future AI applications in clinical dentistry.

KEYWORDS

Dentistry Focus, Healthcare Field, Dentistry Clinical Practices, Digitalised Data Acquisition, Digital Dentistry.

INTRODUCTION

What is Artificial Intelligence?

Artificial intelligence (AI) is a broad term that refers to computer systems that can simulate human intelligence and perform in a human-like manner. Algorithms enable AI to perform human tasks such as visual and speech recognition, language processing, and decision making. Machine learning, a subfield of AI, is the study of algorithms that can educate and improve themselves by analysing an input, which is typically a large amount of relevant data.

The main drivers of the AI revolution are two key facts.: a) recent developments in AI and computing architecture that provide the necessary computational power, [1] and b) the capacity to gather a lot of data (big data). The computer will automatically learn chess if you feed it a long list of chess games. [2] Before the advent of cutting-edge machine learning algorithms, that was in 1996. Nearly two decades later, algorithms existed that could play the strategy game GO, which is much more difficult than chess. [3] Besides that, AI recently outperformed poker experts. [4]

The latter is regarded as a turning point in AI history because it is the first instance in which AI has outperformed human reasoning and intelligence in a scenario involving numerous non-linear interactions and insufficient information, which calls for the use of game theory. The ability of AI to collect data, analyse it, identify patterns, learn from it, and extract an output without human intervention is what makes it superior. It rapidly generates its own logic by employing artificial neural networks that are similar to biological neural networks, resulting in increased performance, subjectivity, and automation.

Machine learning (ML) is a subset of artificial intelligence (AI) in which systems learn to perform intelligent tasks without prior knowledge or hand-crafted rules. Instead, the systems identify patterns in examples from a large dataset without the need for human intervention. This is accomplished by specifying a goal and optimising the system's tunable functions to achieve it. An ML algorithm gains experience in this process, known as training, by being exposed to random examples and gradually adjusting the "tunables" towards the correct answer. As a result, the algorithm discovers patterns that can be applied to new images. This method is analogous to an adult showing a child several photos of cats. Eventually, the child learns the patterns involved in recognising a cat and identifying one in new images.

Deep learning (DL) is a sub-branch of machine learning in which systems attempt to learn not only a pattern, but also a hierarchy of composable patterns that build on one another. Combining and stacking patterns results in a "deep" system that is far more powerful than a simple, "shallow" one. A child, for example, does not recognise a cat in a single, indivisible step of pattern-matching; rather, the child first notices the object's edges, a specific grouping of which defines a textured outline with simple shapes such as eyes and ears. Larger groups emerge among these components, such as heads and legs, and a specific grouping of these defines the entire cat.

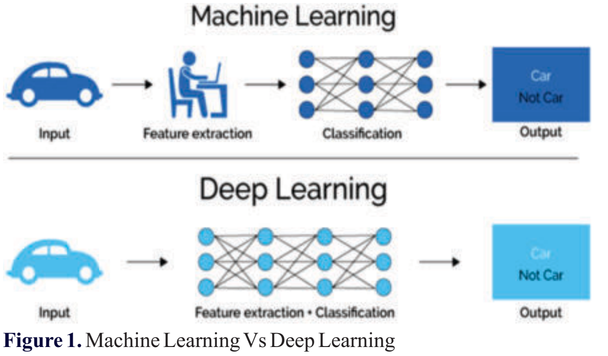

Figure 1. Machine Learning Vs Deep Learning

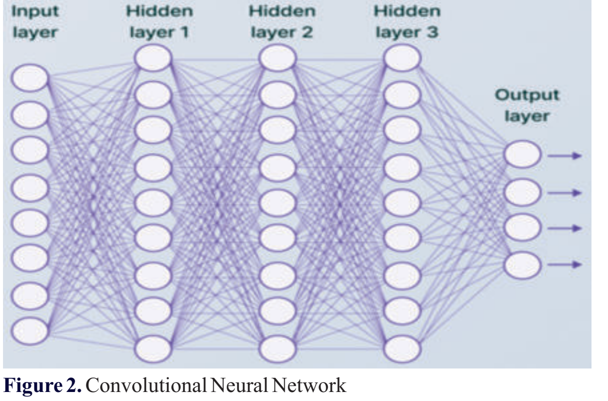

Figure 2. Convolutional Neural Network

The convolutional neural network is one of the most commonly used subclasses of ANN in medicine and dentistry (CNN). To process digital signals such as sound, image, and video, a CNN employs a unique neuron connection architecture and the mathematical operation convolution. CNNs use a sliding 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 the most commonly used image recognition algorithm because they are extremely well adapted to the task of image classification. [5]

Application In Dentistry Practise.

In essence, dental artificial intelligence applications have the capacity to identify significant relationships in data sets, enabling use in diagnosis, treatment, and even result prediction before any procedure. Artificial intelligence is already being used to read cephalometric, CT, and MRI scans and assist physicians and dentists with research. AI has the potential to reduce dentists' overall workload. Helping the patient become more productive will lead to developing stronger patient relationships.

1. **Radiology**

Research on a variety of AI-related topics is being conducted in the field of OMF radiology. Hwang et al. reviewed English-language artificial intelligence studies in the dental field using the PubMed, Scopus, and IEEE Xplore databases. Of the 25 articles they found, 12 were about teeth, 2 were about dental tissues, and 2 were about osteoporosis. They discovered that CNN served as the main network component. Over time, more training data sets and papers have been published in various fields of dentistry. [6] Nagi et al, In their analysis of the clinical applications and performance of intelligence systems in dental and maxillofacial radiology. They gave an overview of the fundamental concepts underlying fuzzy logic, artificial intelligence, machine learning, deep learning, neural network training, and learning programmes. They also presented future prospects for radiomics, imaging biobanks, and hybrid intelligence.[7]

In the area of OMF radiology, artificial intelligence has been used to study a number of diseases, including those affecting the maxillary sinus, temporomandibular joints, osteosclerosis, dental caries, and periodontal disease. Artificial intelligence studies must take into account the fact that the learning process necessitates refined data based on exact readings from OMF radiologists. However, because observers' levels of knowledge and experience vary, dental caries can be diagnosed with varying degrees of accuracy. As a result, the precision of annotation data determines the overall capability of artificial intelligence systems. Researchers investigating automatic readings using artificial intelligence must use refined data to produce reasonable results (i.e., readings from experienced OMF radiologists). [8]

Dental image analysis has been used for a number of tasks, including the segmentation or localization of teeth, the evaluation of bone quality (osteoporosis), the estimation of bone age from hand-wrist radiographs, and the localization of cephalometric landmarks. [6,9]. A system that uses both 3D CBCT images and 2D images has been developed, and deep learning systems based on CNN structures have been used in the dental industry.[6]

Deep learning has been applied to the detection and classification of teeth in CBCT and panoramic images. [10,11] Automated CAD outputs can help dentists by reducing charting times and assisting with clinical decisions by automatically populating digital patient records when teeth are classified using such systems. [10,12]

Radiographic imaging is very useful in dentistry for making diagnoses and ensuring that treatment is carried out properly. In implant, orthodontic, and oral surgery, radiographic images are quantitatively analysed as part of the treatment planning process. Artificial intelligence is very helpful in these fields. Because OMF radiologists are experts who understand the fundamentals of radiographic imaging and have the skills to read radiographs and interpret them in terms of various diseases, they continue to play a significant role in the research into artificial intelligence. One of the most promising areas for dental advancement is OMF radiology.

2. **Orthodontics**

To enhance the user experience, orthodontic treatment and appliances must be patient-centred. [13] This is one of the biggest problems in modern orthodontics because the aligners will not be ideal due to mechanical constraints if the conventional bracket device is not ideal due to aesthetic and comfort-related issues. Therefore, it still takes a lot of work to create a device design that takes into account all of these factors.

Cephalometric landmark identification and analysis, face analysis, tooth and mandible segmentation, bone age determination, prediction of orthognathic surgery, and temporomandibular bone segmentation are the main uses of AI [14,15,16]. Orthodontic diagnosis is a labour-intensive process that involves a patient's dynamic examination, the review and analysis of images and radiographic recordings, and model analyses. This intricate assessment process among orthodontists may lead to different treatment strategies. The orthodontic diagnosis must therefore be automated in order to increase efficiency, consistency, and precision [17].

ANNs have a great deal of potential to support clinical decision-making. To provide patients with predictable results during orthodontic treatments, it is crucial to carefully plan treatments. The inclusion of tooth extractions in the orthodontic treatment plan is common, though. Before beginning any irreversible procedures, it is crucial to make the best clinical decision possible. In patients with malocclusion, an ANN was used to help determine whether tooth extraction was necessary prior to orthodontic treatment. [18,19] The four built ANNs demonstrated an accuracy of 80-93% in determining whether extractions were required to treat patients' malocclusions while taking into account a number of clinical indices. [18,19]

3. **Periodontics**

A complex inflammatory disease with multiple concurrent and interactive causes is periodontal disease. They are among the most prevalent oral conditions affecting people today. According to Lee et al. [20], the disease will eventually progress to the point where adult patients lose their teeth. Numerous studies have been conducted to determine whether AI technology can be used to detect and forecast periodontal diseases.

According to Lee et al. [21], CAD systems based on deep convolutional neural network (CNN) algorithms are used to diagnose and predict the teeth whose periodontal health is compromised. The accuracy of PCT diagnosis using the CNN algorithm was found to be 76.7-81.0%, while the accuracy of predicting the need for extraction was 73.4-82.8%. Premolars were more accurately identified as PCTs than molars (accuracies were 82.8% and 73.4%, respectively), which was the apparent difference in accuracy between tooth types. Premolars typically have a single root, whereas molars typically have two or three roots, making the anatomy of molars more complex for a CNN to understand.

Yauney et al. [22] reported that AI can be used for automated diagnoses and can also be useful for screenings for other diseases. They used an AI-based system based on CNNs to correlate poor periodontal health with systemic health outcomes.

Leukocytes, interleukins, and IgG antibody titres were used by Papantanopoulos and colleagues [23] to use an ANN to distinguish between aggressive and chronic periodontitis in patients. In classifying patients as having aggressive or chronic periodontitis, the one ANN was 90–98% accurate. An ANN with inputs for monocyte, eosinophil, neutrophil, and CD4+/CD8+ T-cell ratio produced the best overall prediction. According to the study's findings, ANNs can be used to accurately distinguish between aggressive and chronic periodontitis using relatively easy-to-obtain parameters, like leukocyte counts in peripheral blood.

4. **Endodontics**

Periapical lesions:

In a study by Orhan et al., it was determined whether the DL system accurately detected periapical pathosis using an AI system. The pathosis was then volumetrically measured on CBCT images using both manual and AI systems. The researchers came to the conclusion that AI systems were 92.8% accurate at detecting periapical lesions and were comparable to manual segmentation methods. [24]

Cariology-

The area under the receiver operating characteristic (ROC) curve for occlusal and proximal lesions, respectively, generated by a CNN-based AI system trained on a semantic segmentation method was found to be 83.6% and 85.6%, indicating excellent discriminating ability between the presence or absence of carious lesions. [25]

With its potential applications in the diagnosis, prognosis, and prediction of treatment outcomes, experimental research on the applications of AI in the field of endodontics has opened new vistas. The use of AI as a great ally for dentists can be achieved by overcoming limitations in data acquisition, interpretation, computational power, and moral concerns. Additionally, it appears that dental professionals are hesitant to implement AI in their clinical practises because they are dubious about the idea that it can substitute for clinicians, despite the fact that it is well-established that nothing can replace the human brain or intelligence. AI can be used as an additional tool to improve clinical practise. To support its use and strengthen its applications in the field of endodontics and dentistry in general, more research is necessary.

5. **Oral And Maxillofacial Pathology**

It is crucial to identify various mucosal lesions early in order to determine whether they are benign or malignant. Malignant lesions necessitate surgical resection. However, some of the lesions exhibit similar behaviours, necessitating the use of biopsy slides and radiographs for the diagnosis. By using a microscope to examine the morphology of stained specimens on glass slides, pathologists can identify disease. [26]

For pathologists, it is laborious work that requires a lot of effort. Only about 20% of the biopsies that need to be examined are discovered to be malignancies. As a result, AI may be an effective tool to support pathologists in their work.

Ameloblastomas and keratocystic odontogenic tumours, 2 significant maxillary tumours with similar radiologic appearance but different clinical characteristics, were distinguished in one study using a CNN algorithm. [27] The algorithm's specificity and accuracy of diagnosis were 81.8% and 83.3%, respectively, which were comparable to clinical specialists' 81.1% and 83.2% values. The difference in diagnostic time, however, was more noticeable: specialists took an average of 23.1 minutes to make a diagnosis, whereas the CNN made the same determination in 38s. [27]

6. **Oral And Maxillofacial Surgery**

In the following ways, AL will have a significant impact on the field of oral and maxillofacial surgery. In order to treat maxillofacial cysts, benign tumours, and malignant tumours, AL is helpful in early screening, accurate diagnosis, proper treatment, preventing morbidity, and accurately predicting treatment-associated toxicity. Second, AL algorithms hold great promise for the reconstruction of facial defects because they have been extremely successful in virtual surgical planning. Third, AL has been regarded as a helpful tool in orthognathic surgery for determining a precise diagnosis, assessing the need for surgery, and projecting the results of the procedure. Finally, AL models have shown great promise for assisting implant planning, assessing implant performance, enhancing implant designs, and identifying dental implants. However, it is still essential to assess the repeatability, accuracy, and reliability of AL in the medical field. Ongoing research should concentrate on enhancing the usability of algorithms for various diseases. Additionally, there is a pressing need to create standards for many ethical problems, such as data security, privacy protection, and legal and regulatory issues. Despite these drawbacks, clinicians still regard AL as a potent tool. We think that this review could give readers in-depth knowledge about the use of AL in oral and maxillofacial surgery and assist clinicians in facilitating clinical practises.

7. **Prosthodontics**

When a patient has clinical issues related to missing or inadequate teeth, oral and maxillofacial tissues, prosthetic dentistry is the art and science of dentistry that deals with the diagnosis, treatment planning, rehabilitation, and preservation of the oral structures function, comfort, and health. The primary areas of focus for prosthodontics are the treatment and creation of fixed and removable dental prostheses, the preparation of finishing margins next to the tooth for improved extension and fitting of the prosthesis, implant surgery, and the creation of maxillofacial prostheses. keeping the right maxillo-mandibular relationships and choosing a tooth colour for better aesthetics. AI has many benefits that can be used in different treatment protocols. [28]

Challenges To Face In Artificial Intelligence

Major obstacles to the implementation of AI systems in the healthcare industry include the management and sharing of clinical data. The initial training of AI algorithms as well as ongoing training, validation, and improvement require personal data from patients. Additionally, the advancement of AI will encourage data exchange between various institutions and, in some cases, across international borders. Systems that safeguard patient privacy and confidentiality must be modified in order to integrate AI into clinical operations. [29] Therefore, anonymizing personal data is required before considering a wider distribution. [30] The medical community is sceptical about secure data sharing even though these safeguards are possible. A significant problem is the transparency of AI algorithms and data. The accuracy of the annotations and labelling of the training dataset has a significant impact on how well AI systems perform predictions. Data with poor labels can produce subpar outcomes. [31] Clinic-labelled datasets could have varying levels of quality, which would limit the effectiveness of the resulting AI systems. Health care professionals should also be able to defend the judgements and projections made by an AI system in addition to having a thorough understanding of them. [32]

CONCLUSION

New technologies are developed and embraced quickly in the dental industry. With characteristics like high accuracy and efficiency when using objective training data and properly training an algorithm, AI is one of the most promising technologies today. Dental professionals can use AI as an auxiliary tool to lighten their workload and increase precision and accuracy in disease prognosis, diagnosis, and decision-making. A future for AI in the healthcare system cannot be discounted given that numerous AI systems for various dental disciplines are being developed and have so far yielded encouraging preliminary results. AI systems have the potential to be a great resource for oral health professionals.

Conflicts Of Interest

The author declares that he has no conflicts of interest and has no affiliation with any of the companies mentioned in the text.

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