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ARTIFICIAL INTELLIGENCE IN ENDODONTICS

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ABSTRACT

Artificial Intelligence (AI) is rapidly transforming healthcare and dentistry by improving diagnostic accuracy, treatment planning, and clinical decision-making. In endodontics, AI technologies such as machine learning (ML), deep learning (DL), artificial neural networks (ANNs), and convolutional neural networks (CNNs) have shown promising applications in disease detection, radiographic interpretation, root canal morphology assessment, working length determination, retreatment prediction, and regenerative procedures. AI systems can analyze large datasets with high precision and identify minute radiographic changes that may be overlooked by clinicians. Studies have demonstrated high accuracy rates in detecting periapical lesions, vertical root fractures, carious lesions, and pulpal diseases using CBCT and radiographic images. AI also enhances restorative dentistry by improving caries detection and restoration planning. Although AI cannot replace the expertise of dental professionals, it serves as a valuable adjunct that enhances efficiency, consistency, and treatment outcomes. This review highlights the working principles of AI, its major subdomains, and its current and future applications in endodontics and restorative dentistry, emphasizing its growing role in modern dental practice.

KEYWORDS: Artificial Intelligence, Endodontics, Machine Learning, Deep Learning, Dental Diagnosis.

INTRODUCTION

John McCarthy originally defined artificial intelligence (AI), a subfield of applied computer science, in 19561. Known as the "fourth industrial revolution," artificial intelligence (AI) simulates human-like intelligent behavior, critical thinking, and decision- making through computer technology.[2,3] There is evidence that AI can improve efficiency, accuracy, and precision to a level where it can compete with human doctors—at a lower cost and in less time. The medical field makes use of both virtual and physical types of artificial intelligence (robotics).[4] The virtual type addresses electronic health records,[4] drug dosage algorithms,[8] drug interactions,[9] imaging and osteoporosis,[6] appointment scheduling,[7] and mathematical algorithms used for diagnosis and prognosis.[5] The physical component comprises socially supportive robots for senior care, telepresence[11], rehabilitation,[12] and robotic aid in surgery.[10]

Despite the fact that AI won't ever be able to do the work of a dental surgeon, it's important to be aware of the potential future applications of this technology.[15]

With the exponential growth of health data and the developing of healthcare AI, applications of AI are becoming commonplace in many spheres of modern human life.

Supervised learning is the method most commonly used in dental applications. This type of learning makes use of large samples of data, each of which has either unique features or characteristics (such as patient photos, age, sex, number of cavities, etc.) or ground truth determination (such as whether the patient has previously had an endodontic visit) to improve accuracy. Following in the footsteps of the biological neurone system, which employs a dense network of connections between neurones for "learning," artificial neural networks (ANNs) use this data to deduce the link between attributes and the truth. Artificial intelligence has the potential to revolutionise the dental and medical industries by solving several clinical problems and relieving doctors of some of their responsibilities.[15]

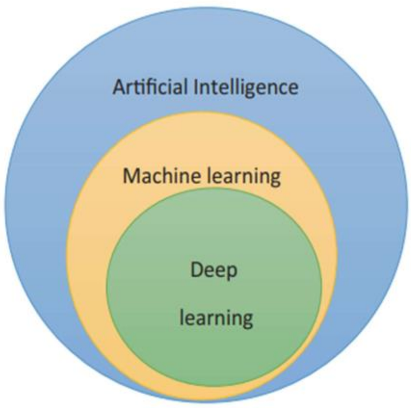
HOW AI WORKS?

Artificial intelligence (AI) functions in a two-stage process, predicated on "training" and "testing" respectively. The training data is what decides the model set's parameters. With a look back, the model uses information from previous instances, such patient records or data sets that include several examples. At that point, the test sets are subjected to these criteria.[16]

Historically, AI models were thought of as "black boxes" as they produced results without divulging the reasoning behind their calculations. Modern AI, on the other hand, creates a "heatmap" and supplies the factors that determine the forecast.[17]

In the healthcare industry, artificial intelligence comes in two varieties- Machine learning (ML) and deep learning (DL), as well as related topics like advanced analytics, computational linguistics, automation, intelligent agents, and probabilistic reasoning, are subcategories of AI. Without the need for explicit programming, machine learning improves controlled learning. Its primary objective is to enable automated knowledge acquisition without the need for human involvement.

The common subdomains of AI are:



Machine Learning (ML)

It is a well-known subfield of artificial intelligence (AI); it teaches machines to make decisions based on past performance and recognize patterns to draw conclusions by analyzing data.

These algorithms are employed to find the innate statistical patterns and structures in data. Without requiring human assistance, machine learning seeks to enable robots to learn from and resolve problems from massive data sets.

ML uses data (experience) and computational tools for training.[18]

It accomplishes this in order to evaluate the input data and process the knowledge obtained from prior experiences. The core of machine learning is "experience gathering" or "active learning."

It implies that computers learn from the data they get and enhance their characteristics by learning from their errors, all without the need for intricate programming or constructing a numerical model.[18]

Deep Learning

It is an ML approach and a subset of AI. It educates a machine to predict an outcome by processing data through layers. Deep learning is used to create a computational mode that automatically recognizes patterns in order to improve feature recognition.[20]

They investigate intricate systems, diseases, or entire organs using basic qualities like line, edge, and texture.[19,20] The distinction between feed forward and feed backward neural networks is comparable to that between deep learning and NNs. In addition to having more neurons than other networks to exhibit complex programs, greater processing power to train, and a preprogrammed character recognition feature, deep learning employs a more intricate layer-connection method.

In comparison to other networks, deep learning uses a more intricate method of layer connections, more neurons to exhibit complex programs, greater processing power for training, and a preprogrammed character recognition feature.[20]

APPLICATION OF ARTIFICIAL INTELLIGENCE IN ENDODONTICS

Innovation and technology breakthroughs have had a profound impact on the ever-changing healthcare sector. Among them, AI—in its many forms, including deep learning networks and machine learning algorithms—has become a game-changer. Artificial intelligence has the potential to greatly alter the healthcare system, and dentistry is just one of many fields that may feel the effects of this new technology. In the field of endodontics, artificial intelligence is gaining prominence.[23] Its importance in diagnosing diseases and designing endodontic treatments is now increasing.[24]

Using AI-based networks, even minute changes down to the pixel level may be detected, something a human eye would miss.

Some industries have seen the effects of AI's influence more than others. These include dental endodontics and restorative procedures. Artificial intelligence (AI) has improved endodontic diagnosis procedures that hitherto relied on radiographic interpretation, a subjective and variable endeavour. The reliability and precision of these procedures have been enhanced by AI algorithms. Furthermore, AI has enhanced root canal anomaly detection and treatment planning with its predictive powers.

Artificial intelligence (AI) has changed the game in restorative dentistry by making caries identification more objective and dependable, which was previously a subjective procedure. Restorative solutions are now more individualised, precise, and efficient because to AI's impact on restoration design and manufacture. Artificial intelligence also helps with the choice of restoration materials and procedures, which improves the final results of therapy.

IDENTIFICATION AND DIAGNOSIS

AI has also been demonstrated in trials to be a useful tool for identifying and comprehending abnormalities as well as for developing the necessary treatment plans.[25]

PERIAPICAL PATHOLOGIES

Periapical radiolucencies are a radiographic indicator of periapical pathosis. Apical periodontitis is commonly found as an inadvertent discovery on conebeam computed tomography scans (CBCT), panoramic radiographs, and periapical radiographs.

3D pictures produced by CBCT are devoid of bone and dental structural superimposition and deformation that could happen with conventional radiography.

A dentist is aware that having a trustworthy tool that can support well- informed decision-making and treatment planning is always essential.

An investigation into the potential application of an AI-based CNN model for periapical lesion detection on radiographs revealed that the model functioned effectively, exhibiting high sensibility and intermediate precision. This method could be very helpful for dentists in recognizing and detecting periapical lesions.[26]

With a remarkable 92.8% accuracy rate, another model was able to identify periapical illnesses on CBCT pictures.[27] Another study employed an AI-based model to identify the presence of a periapical lesion.

With a mean accuracy of about 77.2%, there were some surprising results. The authors claimed that the reference method outperformed this strategy, but that future research employing optimization techniques might improve the outcomes.[27]

Setzer et al. concluded that a DL algorithm with good lesion identification accuracy was trained in a restricted CBCT environment. Improved AI iterations could increase total voxel matching accuracy, as demonstrated by this study's 93% accuracy.[28]

Poswar et al. used a "multilayer perceptron neural network" for gene classification in order to examine the differences in gene expression between a periapical cyst and a periapical granuloma.

ROOT FRACTURE

"Vertical root fractures (VRFs)" are extremely rare in teeth that have received endodontic treatment. Studies have shown that 3.7% to 30.8% of teeth that have undergone endodontic therapy had VRFs. It is challenging to identify VRFs on radiographs and may call for the use of more sophisticated technology.[28]

Using CBCT images and periapical radiographs, Johari et al.[29] investigated the development of an AI-based model that uses a PNN architecture to identify VRFs on teeth that are intact and those that have had endodontic treatment. With an accuracy of 96.6%, the model showed good efficacy in diagnosing VRFs on CBCT images when compared to periapical radiographs.

ROOT CANAL MORPHOLOGY

Dentists must first comprehend and recognize root canal anatomy and root morphologies in order to perform a successful non-surgical root canal therapy.

AI can help detect faults in the location of new canals as well as any morphological abnormalities.
Hiraiwa et al.[30] examined the diagnostic effectiveness of a DL system for classifying the root morphology of mandibular first molars on panoramic radiographs."

Distal roots were examined for the presence of one or more roots on CB CT pictures.

The DL method showed an 86.9% diagnostic reliability for identifying whether distal roots were solitary or had supplemental roots.

WORKING LENGTH DETERMINATION

To guarantee satisfactory root canal treatment results, the right working length (WL) must be chosen.
Poor microbiological control, instrumentation outside the apical foramen, flare-ups, and periapical foreign body responses are common outcomes of inadequate WL determination.[31]

There are several methods for determining the apical foramen and WL, such as radiography, digital tactile sense, and the patient's reaction to a file or paper point.[32] Digital technology has shown advantages in locating the apical foramen, but it has also shown disadvantages in terms of errors.

Consequently, research has been conducted on the application of ANN to determine the accurate WL of teeth.
Saghiri et al. using an ANN method to determine the working length in a human cadaver model and demonstrated remarkable accuracy of 96%, outperforming the precision of experienced endodontists.[31]

RETREATMENT PREDICTIONS

"Case-based reasoning," or CBS for short, is the process of formulating answers to questions and uncertainties by drawing on prior experiences with related problems. Campo and associates.[32]

The outcomes of nonsurgical root canal retreatment, together with the risks and advantages involved, were predicted by Campo et al.[34] using CBS.

In addition to statistics on the effectiveness of the earlier procedure, the dangers associated, and the recall periods, the system offered data on whether retreatment should be carried out.

One advantage of the method is that it might be able to accurately predict the result of retreatment.

However, the method's weakness was that it relied too heavily on the information in the data and failed to consider all of the options.

REGENERATIVE ENDODONTIC PROCEEDURES

Bindal et al. looked at the use of neuro-fuzzy inference on dental pulp stem cells in different rejuvenation treatments. In order to predict the result of a hypothetical clinical situation, our approach assessed the stem cell viability after bacterial lipopolysaccharide treatment. Several regeneration regimens employed the neurofuzzy interpretation approach to predict cell survival following microbial infection. The researchers used the adaptable neuro-fuzzy inferencing method to assess how well the outcome predicted stem cell survival after pathogenic invasion.

CARIOLOGY

A CNN-based AI system trained on a semantic segmentation method produced an area under the receiver operating characteristic (ROC) curve of 83.6% for occlusal lesions and 85.6% for proximal lesions, respectively. This indicates a high degree of discrimination between the presence and absence of carious lesions.[36]

FOR PULPAL DIAGNOSIS

The application of AI has greatly benefited pulpal diagnosis, according to many studies. For example, on the basis of PRs, Tumbelaka et al. used an ANN to differentiate pulpitis, necrotic pulp, and normal pulp. Thirteen teeth (10 canines and 10 molars) were used in the study to show how digitising direct reading radiography improved the validity of pulpal diagnoses. Zheng et al. examined the diagnosis of pulpitis and deep caries on PRs using convolutional neural networks (CNNs) such as ResNet18, Inception V3, and VGG19 in a more recent study. Their inquiry, which utilised a massive dataset of 844 PRs (717 for training and 127 for testing), was enormously improved by a multi-modal CNN, in particular ResNet18 connected with clinical features.

CONCLUSION

In endodontics, AI might aid in clinical applications, particularly in the detection of periapical pathosis, root fractures, working length measurement, and disease prognosis. There is a requirement for good quality evidence to evaluate the performance of AI concerns its reliability, applicability, legal and ethical considerations, and cost-effectiveness, before widespread acceptance into routine clinical practice.

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