REVIEW
Derleme

The Developing Technology of Artificial Intelligence in Endodontics: A Literature Review

Endodontide Gelişen Yapay Zeka Teknolojisi: Literatür Taraması

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ABSTRACT

Artificial intelligence (AI) is a term that interprets technologies that can perform cognitive functions emulating human intelligence. It works by help of the software to learn automatically from patterns or features in the data. It is a popular field of study that contains many theories, methods and technologies, as much as the following major subfields in healthcare and medicine. Use of AI is also popular in many fields of dentistry. The main use in dentistry is in dental education to simulate clinical work on patients and to minimize all the hazards associated with training on a live patient. In dentistry, the use of the deep learning algorithm has been investigated in cases such as the detection of dental caries, periapical lesions, temporomandibular joint problems, and skeletal classifications, and it has been stated that Convolutional Neural Networks (CNN) is a useful aid for diagnosis and treatment planning. This review article was focused on the use of AI in Endodontics such as detection of periapical lesions, prediction of treatment and retreatment methods, detection of root fractures, determination of working length, and evaluation of root canal system morphology and anatomy.

Key Words:

Artificial intelligence, Deep learning, Machine learning.

ÖZ

Yapay zeka (YZ), insan zekasını taklit eden bilişsel işlevleri yerine getirebilen teknolojileri yorumlayan bir terimdir. Verilerdeki kalıpları veya özellikleri otomatik olarak öğrenmek için yazılım yardımıyla çalışır. Sağlık ve tıpta aşağıdaki ana alt dallar kadar birçok teori, yöntem ve teknolojiyi içinde barındıran popüler bir çalışma alanıdır. YZ kullanımı, diş hekimliğinin birçok alanında da popülerdir. Diş hekimliğindeki ana kullanım, eğitim sürecinde klinik çalışmayı simüle ederek hastada meydana gelebilecek tüm tehlikeleri ve komplikasuonları en aza indirmektir. Diş hekimliğinde diş çürüklerinin, periapikal lezyonların, temporomandibular eklem problemlerinin tespiti, iskelet sınıflandırmaları gibi durumlarda derin öğrenme algoritmasının kullanımı araştırılmış ve Konvolüsyonel Sinir Ağlarının tanı ve tedavi planlaması için yararlı bir araç olduğu belirtilmiştir. Bu derleme YZ'nın periapikal lezyonların tespiti, tedavi yöntemlerinin belirlenmesi, kök kırıklarının tespiti, çalışma uzunluğunun belirlenmesi ve kök kanal sistemi morfolojisi ve anatomisinin değerlendirilmesi gibi endodonti alanındaki kullanımına odaklanmıştır.

Anahtar Sözcükler:

Yapay zekâ, Derin öğrenme, Makine öğrenmesi.

INTRODUCTION

Artificial intelligence (AI) is a term that interprets technologies that can perform cognitive functions emulating human intelligence. It works by owning the software to learn automatically from patterns or features in the data. It is a popular field of study that contains many theories, methods and technologies, as much as the following major subfields in healthcare. There are different categories of AI algorithms such as deep learning (DL), machine learning (ML), artificial neural network (ANN), and computer vision (1). ML and DL are algorithms which use for learning intrinsic statistical patterns and structures in data, which allows for the prediction of unseen data. Neural networks are popular ML types for complicated data structures like imagery, which have been formerly and extensively applied in medicine but much less in dentistry (2). ML and DL operate in 2 phases, the first phase is *"training"* and the second phase is *"testing"*. The parameters of the model set are determined by the training data. Retrospectively, the model uses data from previous samples, such as patient data or datasets containing several samples. These parameters are then applied to the test stage (8). The insufficient number of dentists compared to the population, fears, and discomforts related to dental treatment also pioneered the use of AI in dentistry (3). AI applications in dentistry are mostly virtual and use AI algorithms to distinguish between lesions and normal structures and to evaluate the risk factors and possible consequences (4).

The purpose of this review was to present the use of AI in dentistry and endodontics.

Understanding AI

The feature of AI is its ability to organize and take actions that have the best chance of achieving a specific goal. Machine learning is a subset of AI, which learns statistical patterns in data to finally cast predictions on unlabeled data. DL is a ML technique using multi-layer mathematical operations for learning and inferring complicated data like text, images, or video (8). Figure 1 shows the relationship among AI, ML, and DL with a Venn diagram.

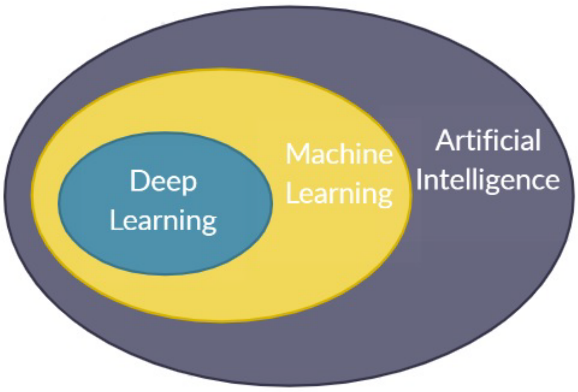

Figure 1. The relationship among AI, ML, and DL with a Venn diagram.

DL processes data in real time, without the need for human involvement, by collecting information from several data sources. Since they can execute numerous computations at once, graphics processing units (GPUs) are ideal for DL model training. Through layers of neural networks with a set of inputs that accept raw data, deep learning classifies information. Dental lesion photos can be used to train a neural network, which can then be applied to diagnose dental lesion images (Figure 2).

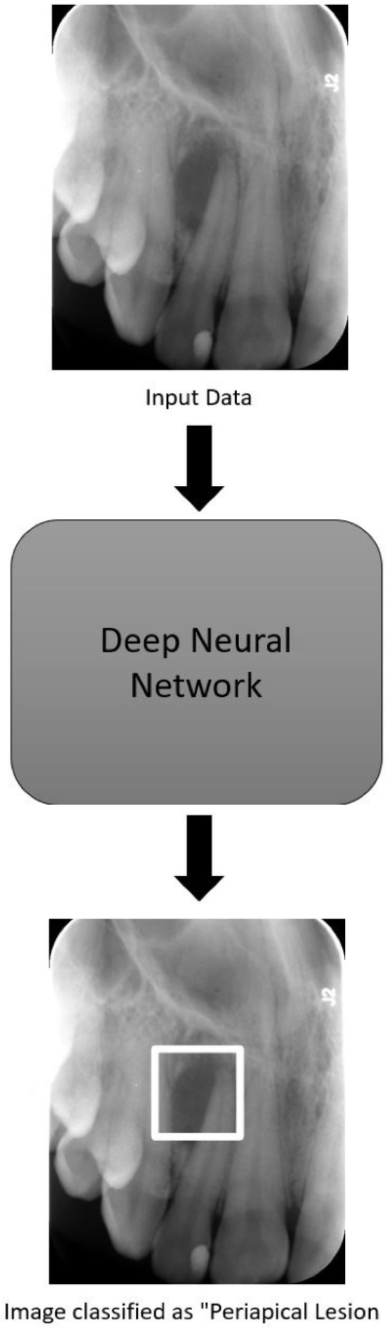

Figure 2. AI can be used to diagnose dental lesion images, as a neural network is trained with dental lesion images.

Imagine that we want to build a system that can classify images as containing, say, a house, a car, a person, or a pet. Initially, a large data set of images of houses, cars, people, and pets, each labeled with its category was collected and processed (5). Algorithms are needed to perform these operations. There are three types of ML algorithms: unsupervised, supervised, and reinforcement learning. In Supervised Learning, input is provided as a labeled dataset, and a model can learn from it to provide the result of the problem easily. Unsupervised learning means self-organized learning. Its primary goal is to investigate the underlying patterns and predict the outcome. It searches for hidden patterns in data. It can also find structure in its own input. Reinforcement learning is the use of sequences of rewards and punishments to form a strategy for operation in a specific problem space (6,7).

The Use of AI in Dentistry

There are many uses for AI in the field of dentistry. It is often used in dental education to simulate clinical work on patients and to minimize all the hazards associated with training on a live patient. Today, with the development of AI, more realistic robots have begun to be produced, and these robots can shake their heads, cough, move their tongue and even give a fatigue response when trying to keep their mouth open for too long (3).

Virtual dental assistants powered by AI can perform many tasks in the dental office faster and with fewer errors. It can help with many tasks, from clinical diagnosis to planning (8). With the ability to perform automated lesion segmentation, DL with CNN has become the predominant AI component used for diagnosis (4).

In dentistry, the use of the DL algorithm has been investigated in cases such as the detection of dental caries, periapical lesions, temporomandibular joint problems, and skeletal classifications, and it has been stated that CNN is a useful aid for diagnosis and treatment planning (9).

The Use of AI in Endodontics Detecting Periapical Lesions

Periapical lesions are a biofilm-associated oral disease characterized by bone destruction in the apical region of the tooth, affecting the periodontal tissues and host defense by infecting the root canal system of bacteria and other microorganisms (10). Early detection of periapical lesions might increase the success of treatment, prevent the spreading of the inflammation to surrounding tissues, and minimize further complications (11).

Periapical lesions are usually seen as radiolucencies in the periapical region of the involved teeth in radiographs (11). In the routine of endodontic clinics, two-dimensional (2D) diagnostic tools such as panoramic and periapical radiographs are most often used to detect the presence of apical lesions. However, the information obtained from these radiographs is unreliable because the actual three-dimensional (3D) anatomy is transferred to a 2D image (8).

Cone-beam computed tomography (CBCT) is an imaging method specifically designed to produce 3D images of the maxillofacial system. It is indicated for the diagnosis of pathology of endodontic and non-endodontic origins, imaging of root canal morphology, evaluation of trauma-related problems, and planning of treatments (12). Compared with 2D radiographic images, CBCT imaging has higher accuracy in detecting periapical lesions.

Setzer et al. (13) examined the use of AI in the detection of periapical lesions. In the study, according to the criteria previously stated by the clinicians, apical lesions were detected in 29 (47.5%) of 61 roots in 20 CBCT images and no lesions were detected in 32 (%52.5) of 61 roots. They assessed the use of AI, especially DL, for the automatic detection of periapical lesions in a localized CBCT environment. The DLS identified 27 true positive and 28 true negative cases. It was also shown that the accuracy of lesion detection with this DL algorithm generated in a constrained CBCT environment achieves similar results to clinicians' detection. This condition can be explained by even small changes at a single pixel level, which the human eye cannot detect, and can be found using AI-based networks, which has caused AI to be used more frequently in diagnosis and endodontic treatment planning (8).

In a study by Orhan et al. (14) images of 153 periapical lesions were obtained from 109 patients. Lesion volumes were calculated using manual segmentation methods using Fujifilm-Synapse 3D software (Fujifilm Medical Systems, Tokyo, Japan), then lesion detection, lesion localization, and lesion volume were re-examined using the Neural network. The results of their study have shown that AI systems based on DL methods can be useful for detecting periapical pathology in CBCT images for clinical practice.
In another study by Pauwels et al. (15) the diagnostic performance of CNNs with the performance of human observers for the detection of simulated periapical lesions on periapical radiographs were compared, and CNNs showed promise in periapical lesion detection.

Evaluation of Root Canal System Morphology and Anatomy

Knowing the root canal system morphology is an important factor affecting the success of endodontic treatment. In clinical routine, radiological imaging techniques are used for this purpose. For evaluating root canal configurations, CBCT images show higher accuracy compared to 2D radiographs. However, it cannot be recommended in routine clinical practice due to radiation problems (11).

In a study by Hiraiwa et al. (16) they analyzed the CBCT images and panoramic radiographs of 760 mandibular first molars of 400 patients who did not undergo root canal treatment. They examined the distal roots on the CBCT images and detected the presence of a single or extra root. Then, the image patches of the roots were segmented from panoramic radiographs and applied to the DL system, and the diagnostic performance in classifying root morphology was examined. As a result of the study, they found that the DL system showed high accuracy in the differential diagnosis of the presence of a single or extra canal in the distal roots of mandibular first molars.

Lahoud et al. (17) evaluated 433 CBCT radiographic segmentation of teeth by using the CNN algorithm. They indicated that AI performed as well as clinicians but faster. In a study by Jeon et al. (18) the use of a CNN system to predict C-shaped canals in mandibular second molars on panoramic radiographs was evaluated, and it was found that the DL system has significant accuracy in predicting C-shaped canals of mandibular second molars on panoramic radiographs.

Working Length Determination

Determining the correct working length is one of the most important steps in the success of root canal treatment. There are various methods used for working length determination. Examples of these are radiographic methods, digital tactile sense, the patient's response to, paper-point, and electronic apex locators (11).

In a study by Saghiri et al. (19) they evaluated the accuracy of ANN in a human cadaver model in an experiment to simulate the clinical situation of determining working length. They reported that the ANN (96%) gave more accurate results in minor anatomic constriction determination compared with an endodontist (76%) using radiographical methods. This result could be commented that the use of computer-based techniques becomes necessary to achieve successful working lengths soon (8).

Detection of Root Fractures

A vertical root fracture is defined as a broken parallel to the long axis of the root. Clinical detection of this condition is very difficult for dentists and endodontists (20). A vertical root fracture is more commonly associated with teeth which had undergone endodontic treatment (21). Early stages of vertical root fractures are difficult to detect as the patient is usually asymptomatic (22).

Fukuda et al. (23) evaluated the use of a CNN system for detecting vertical root fractures on panoramic radiography. They reported that CNN learning model has given good results as a tool to detect VRFs on panoramic images and can be used as a computer-aided diagnostic tool.

With imaging modalities like CBCT and intraoral radiography, it is hard to detect cracked teeth. They often have low sensitivity and do not show cracks clearly. Shah et al. (24) investigated a novel method that can detect cracks automatically in high-resolution CBCT scans of teeth using steerable wavelets and learning methods.

Prediction of Treatment and Retreatment Methods

Campo et al. (25) reported a case-based reasoning paradigm to predict the outcome of root canal treatment with risks and benefits. The system includes data from areas such as performance, recall, and statistical probabilities, telling whether or not treatment should be given. Case-based reasoning is the process of creating solutions to problems that investigate similar cases, important information, and knowledge and integrates them (11).

Although AI has many advantages, it has disadvantages such as limited data availability, accessibility, structure and sophistication, lack of rigor and standards in its development, and problems with ethics and responsibility (26).

CONCLUSION

In line with all the previous studies conducted in dentistry, it is clear that AI can be used more widely and successfully in dental clinics for both diagnosis and treatment procedures in the near future. Artificial intelligence can be relied upon to automate mundane radiology tasks. AI models could be developed enough to enable computer detection of some dental diagnostics that a human might miss.

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