International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page:www.iscientific.org/Journal.html

A review of the Literature on artificial Intelligence in Dentistry

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Abstract

Due to advances in science and technology, Artificial intelligence (AI) has become more relevant in dentistry in recent years. The phrase "artificial intelligence" (AI) refers to the use of technology and machines to perform tasks that would typically be finished by humans. Dental technology uses artificial intelligence (AI), a relatively new technology, extensively. When it comes to carrying out tasks like gathering, processing, and extracting patient data to help with disease diagnosis, treatment planning, clinical judgement, and prognosis prediction, AI can be a great supplement.

Keywords: Artificial intelligence, endodontics, dental, technology

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1. Introduction

Artificial intelligence (AI) models created for use in the health region have undergone enormous development as a result of technological advancements in the health sciences [1]. AI is a useful tool that can assist dentists and other medical professionals in lightening their workloads [2]. A comparatively recent technology that is widely used in dentistry is artificial intelligence (AI) [3].AI seeks to develop a multi-task algorithm that can make decisions across various domains [2].In 1955, John McCarthy coined a term which explained the possibility of machines to carry out activities that can be encompassed within “intelligent” tasks. In the year 1956, McCarthy, also broadly acknowledged as the “Father of Artificial intelligence,”. The composition of the technology used in AI consists of a neural network pattern almost identical to human brains. This neural design imitates human thinking and is composed of firmly interconnected neurons [4].

By identifying solutions to a range of clinical issues and simplifying the work of clinicians, AI systems have the potential to revolutionise medicine and dentistry [5]. Computer science and robust datasets are combined in the field of artificial intelligence (AI), which makes it easier to solve problems in a variety of contexts. In order to create intelligent systems that automatically learn and develop without explicit programming, machine learning (ML) uses statistical learning algorithms [3]. A subfield of computer science known as artificial intelligence (AI) concentrates on creating cutting-edge software applications that demonstrate the traits that people typically related with intellectual capability in human behaviour, such as knowledge acquisition, language comprehension, rationality, problem-solving, and many others [5].

Dental professionals have primarily used AI technologies to diagnose diseases, plan treatments, make clinical judgements, and forecast outcomes. The use of AI in endodontics has primarily focused on locating the apical foramen, confirming the working length, projecting periapical pathologies, root morphologies, retreatment predictions, and identifying vertical root fractures [5].

1.1. How do models of artificial intelligence function?

A phase of "training" and a phase of "testing" are both involved in how AI functions. The training data identifies the model set's parameters. The model utilizes data from earlier examples, such as patient data or data from data sets with different examples, retrospectively. The test sets are then subjected to these parameters [6].The AI methodologies comprise primarily knowledge-dependent AI and data-driven AI. The knowledge- dependent AI is based on a top-down approach to modeling human knowledge and the self-reported knowledge and idea which humans employ to deduce a solution to a problem. AI which is commonly known as machine learning (ML), employs a bottom-up approach, contrary to knowledge-based AI. Artificial neural networks (ANN) and decision trees are two examples of algorithms that AI uses to figure out the relationships between data instances and labels. The vertebrate nervous system, which is a highly interconnected network system and operates similarly to ANNs in that it receives signals, performs mathematical calculations, and then transmits the processed data to the next higher level [7].Machine learning (ML) and related fields like deep learning (DL), computational linguistics, automation, advanced analytics, and probabilistic reasoning and intelligent agents are subcategories of artificial intelligence. Without explicit programming, machine

learning improves computer-controlled learning [5].Artificial intelligence technology is based primarily on simulating how the human brain works. The first AI algorithms to be created were machine learning algorithms. These algorithms are used to uncover the inherent statistical structures and patterns within the data. Convolutional neural networks (CNNs) are designed to solve equations by passing through a series of convolutional filters and are trained on a large number of datasets. Deep learning (DL) or CNNs were created to mimic how the human brain works. Medical imaging for systemic illnesses like cardiovascular disease and respiratory disease has extensively used AI models. AI models are created to diagnose conditions affecting the mouth, including oral cancer, periodontal disease, and dental caries [1].

1.2. AI Classification

There are many ways to implement AI; various AI systems can carry out a variety of tasks, and researchers have developed a variety of AI classification techniques. There are 2 types of AI: weak AI and strong AI. Weak AI, also known as narrow AI, employs a programme developed to handle a single or narrow range of tasks. Examples include computer vision, such as Tesla Autopilot and face recognition, reinforcement learning, such as AlphaGo and automated manipulation robots, natural language processing, such as Google translation and the Amazon chatbot, and face recognition. Strong AI, which has its own awareness and behaviour that is just as flexible as human behaviour, is AI that has the same capacity and intelligence as humans [2].

- ANN is a fundamental model for deep learning and consists of a set of neurons and layers [2].

- CNN is a deep learning model that is primarily used for image generation and recognition. CNN has convolution layers, which is the main distinction between it and ANN [2].

1.3. Machine learning

Machine learning (ML), a separate field of study, is where AI research is at the moment. Machine learning is an AI subset, that uses algorithms to anticipate outcomes based on a dataset. These algorithms are used to discover data's inherent statistical patterns and structures. Machine learning aims to make it easier for machines to learn from and solve issues from large data sets without the need for human intervention [4].

1.4. Neural networks

A prominent sort of ML model is neural networks, which are made up of a series of algorithms that calculate signals using artificial neurons. Its objective is to create neural networks that closely resemble the human brain. Two ANN types that have recently gained popularity are "convolutional neural networks (CNNs)" for image classification and "dilated convolutional neural networks (DCNNs)" for sematic scene partitioning [4].

1.5. Deep learning

Deep learning is a part of ML that process information using a deep neural network with multiple computational layers. To enhance feature identification, deep learning is utilized to develop a computational model that detects patterns automatically. They employ simple features such as line, edge, and texture to study complex systems, pathologies, or entire organs [4].

1.6. Clinical decision support systems (CDSS)

"Any computer system that aids healthcare providers in making clinical choices by handling clinical data or medical knowledge" is referred to as a CDSS. The inference engine (IE), knowledge base (KB), explanation module, and working memory are the four essential components of most CDSS [4].

1.7. Applicationof Artificial Intelligencein Dentistry

Applications of AI in dentistry can be categorized into diagnosis, treatment planning, and treatment outcome forecast. The most well-liked application of AI in dentistry is diagnosis. By producing diagnoses that are more precise and effective, AI can lighten the workload of dentists. On the one hand, dentists are using computers to make decisions more and more [2].

2. ArtificialIntelligencein Endodontics

An incorrect diagnosis may cause unanticipated pain, which could have a negative effect on the treatment strategy and ultimately cause patients to have unpleasant experiences. The successful outcome of the endodontic treatment depends heavily on the preoperative evaluation of the tooth before beginning RCT. Medical imaging and diagnosis diagnostic models have greatly advanced as a result of ongoing, rapid advancements in technology [1].

3. Recognition of Periapical Lesions

It can be complicated for clinicians to detect periapical lesions on radiographs. According to research, a periapical radiolucency requires at least 12.5% cortical bone loss or an average mineral bone loss of 7.1% in order to be visible on a two-dimensional radiograph [8]. Additionally, there is a lot of subjectivity involved in how radiographs are interpreted [3].When compared to periapical radiographs, Cone Beam Computed Tomography (CBCT) has proven to be more reliable in the diagnosis of periapical lesions. According to research by Patel and colleagues, CBCT has a detection sensitivity of up to 100%, whereas periapical radiographs have a detection sensitivity of only 28% for periapical lesions [9]. CBCT volume interpretation, however, can be tiresome and time-consuming. Additionally, the clinician may fail to notice minute density changes in CBCT volumes, especially if they lack formal training as oral radiologists. AI is currently being developed to help the clinician localise periapical pathosis in order to solve these problems. In the future, AI might be able to "read" CBCT scans, alerting the clinician to potential apical pathosis lesions as well as other potential odontogenic or non-odontgenic lesions [3].In the field of endodontics, AI models such as convolution neural networks (CNN) and artificial neural

networks (ANN) are being used to study the root canal system anatomy, measure working lengths, find periapical lesions and root fractures, forecast the success of retreatment procedures, and forecast the survival of stem cells in dental pulp [5]. A study by Orhan *et al*. concluded that AI systems were comparable to the manual segmentation methods and were 92.8% reliable in correctly detecting a periapical lesion [10].

4. Detection of Fractures

It is very difficult to detect crown and/or root fractures using radiography. The diagnosis of vertical root fractures (VRF) using CBCT imaging is only 78% accurate, according to a recent systematic review and meta-analysis. By improving AI's ability to diagnose VRF, unnecessary treatment of irreparable teeth as well as the extraction of incorrectly diagnosed, perfectly healthy teeth can be avoided [3].

5. Identification of Root Canal Morphology

The clinician needs to be aware of the root canal morphology of the tooth being treated in order to complete a successful root canal procedure. Periapical radiographs, bitewing radiographs, and CBCT imaging have traditionally been employed for this reason. However, assessing these imaging methods can be difficult without the right training and experience. Additionally, following root canal instrumentation, AI has been used to precisely measure root canal curvatures and three-dimensional canal changes [3].Commercial AI software providers, like Diagnocat (LLC Diagnocat, Moscow, Russia), enable practitioners to examine patients' CBCT images and identify the type of root canal morphology that is present. AI may be able to help clinicians select the best endodontic files for cleaning the root canal system [3]. On cone-beam computed tomograms (CBCT), a deep learning (DL) AI system has been found to be able to identify extra roots in molars [7].

6. Determination of Working Length

A crucial stage of root canal therapy is identifying the apical limit of the root canal system. The root canal system can be thoroughly mechanically and chemically disinfected with the help of an accurate working length (WL) determination. Additionally, the proper WL shields the periodontal tissues from instrumentation that extends past the canal's terminus [3].The majority of the time, periapical radiographs and electronic apex locators are combined to determine canal length. To assist the clinician in locating the apical terminus on radiographs, AI algorithms are currently being developed [3]. When compared to the actual measurement made after a tooth was extracted, AI was 100 percent accurate in estimating the root length [11].

7. AI in Outcome Prediction

An AI-based module enables precise clinical decisions regarding the prognosis of a tooth or root canal. By taking into account factors linked to diagnosis and prognostic risk determination, AI can help clinicians predict the long-term prognosis of the various treatment options before and after intervention [1,3].

8. Photorealistic 3D Reconstructions

The use of AI-enhanced algorithms to produce photorealistic 3D reconstructions of the tooth anatomy, the root canal space, and common orofacial lesions is an exciting area that has been attracting more attention. Cinematic rendering (CR) is the name given to this innovative reconstruction technique. Based on CBCT data sets, CR can produce these photorealistic 3D images by using high dynamic range rendering lightmaps to simulate a natural lighting environment. By better exhibiting the anatomical details, this may increase the diagnostic accuracy [3].

9. Robotics &Microbots

The creation of AI-guided robots to assist in providing actual treatment to patients is another potential future use. Neurosurgery and orthopaedics have both used image-guided robotic surgery frequently. An interactive map of deep anatomy, vasculature, and pathology is made using tracked technology and preoperative or intraoperative images. The sense of pressure or tension that is typical of endodontic tactile sensations is not possible with robotic systems. The most recent robotic models under development are making an effort to solve this issue by giving surgeons continuous, real-time sensory feedback [3].The ultimate therapeutic approach for eliminating bacterial biofilm colonies that adhere to the dentin is being continually improved in endodontics [3].

10. Cariology- A CNN

based AI system, trained on a semantic segmentation method, was found to generate an area of 83.6% and 85.6% under the receiver-operating characteristic (ROC) curve for occlusal and proximal lesions respectively, signifying an excellent discriminating ability between the presence or absence of carious lesions [7].

11. Regenerative Endodontics

When the predictive ability of stem-cell viability under different bacterial lipopolysaccharide concentrations was studied using a neuro-fuzzy system (a form of ANN), a determination coefficient of 0.81 was obtained which shows that 81% of the predictive ability can be accounted for the DL system [7].

12. AI inPeriodontics

The disease known as periodontitis is one of the most common. It may result in tooth loss or even tooth mobility. Early detection and treatment of periodontitis are necessary to prevent severe cases. AI helps in diagnosis and treatment planning for periodontal conditions [2].

13. AI in Orthodontics

AI is an excellent tool for resolving orthodontic issues because it traditionally takes orthodontists a lot of time to diagnose malocclusion. AI can be used to simulate the differences between the appearance of pre- and post-treatment facial photographs to plan treatments and predict their outcomes. With the aid of AI algorithms, the effects of orthodontic treatment, the skeletal patterns, and the anatomic landmarks in lateral cephalograms can be clearly seen [2].

14. AI in Oraland Maxillofacial Pathology

Oral cancer is the most severe type of OMFP. The main applications of AI research have been in the detection of tumours and cancer using radiographic, microscopic, and ultrasonographic images [2]. The viability of stem cells can be predicted with the aid of AI [6].

15. AI in Forensic Odontology

Artificial intelligence is a scientific advancement that has been heavily utilised in forensic medicine. It has proven to be very useful in identifying the biological age and gender of healthy and sick people. It is also used to forecast mandibular morphology and analyse bite marks [6].

16. AI in Prosthodontics

The design of restorations is where artificial intelligence is primarily used in prosthodontics. The design of removable dentures is where the majority of the current ML algorithms are concentrated [2].

17. Challenges Associatedwith AI

Despite possessing a lucrative potential, the adoption of AI comes with the following challenges: [7]

i. A colossal amount of data is required for precisive training, which limits its potential to diagnose rare conditions such as periapical lesions other than the endodontic origin.

ii. The technology involves complex mechanisms and often it remains uncertain how the datasets are designated, curated, and handled and may persist unvalidated and insufficiently replicable to dental applications.

iii. Affordability is also a roadblock to adopting this technology in daily clinical practice as the installation of the machine incurs huge costs. Besides, the software programs also require frequent upgradation to adapt to the changing needs.

18. Future prospects

Even though the presented AI models have shown promising results, it is still necessary to confirm their generalizability and reliability using relevant external data collected from recently enrolled patients or amassed from other dental facilities. The goal of future AI research in dentistry is to not only improve AI model performance to expert levels but also to find early lesions that are invisible to the naked eye [6].

19. Conclusion

AI can be utilized as a supplemental tool for the benefit of clinical dentistry. The field of endodontics can benefit from the current AI models' promising applications in the detection of periapical pathosis, root fractures, working length estimation, and treatment outcome prediction. To ensure accuracy and consistency, it is essential to build these AI models using data gathered from knowledgeable clinicians.

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