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Artificial intelligence with the application in medicine and dentistry

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ABSTRACT

Aim To review and summarize the current literature on the concept, history as well as the current and tentative applications of artificial intelligence in medicine and dentistry.

Methods Data sources: Collection of data were taken from electronic databases such as PubMed, Scopus, arXiv and Google Scholar. Study selection: Full-text articles and conference-proceedings regarding artificial intelligence, artificial neural network, machine learning, deep learning, and big data, and related articles in the medical and dental field were included in this review.

Conclusions Artificial intelligence is a breakthrough technology that is rapidly progressing and has been continuously implemented to achieve maximum human utility. With the enormous increase in documented information and the large amounts of recorded patient data along with the emergence of this technology, the use of machine learning and deep learning have recently become a necessity in modern healthcare. These technologies can also serve as a useful modality for several applications within these fields. Notwithstanding these many advancements, artificial intelligence still has some limitations, but its opportunity is limitless, as there is still tremendous potential for consecutive research in the medical and dental fields.

INTRODUCTION

The term artificial intelligence (AI) was first introduced by McCarthy in 1956 (1). It refers to the development of smart machines, particularly smart computer program. AI is also related to the similar task of using machines to understand huaman intelligence, but AI needs are not limited to biologically measurable methods. It is a system that is run by non-natural, computer hardware and software design in the same way as human intelligence is (2). Furthermore, the Dartmouth Summer Research Project on AI (Dartmouth Workshop) proposed the following seven characteristics (1).

1. Simulating higher functions of the human brain.
2. Programming a computer to use general language.
3. Arranging hypothetical neurons in a manner, so that they could form concepts.
4. A way to determine and measure problem complexity.
5. Self-improvement.
6. Abstraction: Defined as the quality of dealing with ideas rather than events.
7. Randomness and creativity.

Currently, AI can be described as the branch of computer science (1) that focuses on automation of smart actions, which depends on strong theory and connects to the principles of a specific area. Such concepts are the data structures used in the representation of knowledge, the algorithms required to the application of that knowledge, computer language and program technique used in their operation (3).

Most people are unaware that they use AI in their daily life. People use, manage and respond to this neural network every day, directly or indirectly; for example, Amazon recommends a book or Netflix suggests a film or TV show. Such recommendations are based on algorithms, which are basically an instance of logic written in computer software to produce the output from a given input that examines what customers have previously bought or watched. The algorithms learn from those purchases by using them to suggest other items customers might enjoy (4). In academia, where analyzing plagiarism is a task almost as labor-intensive as creating an original work, the Turnitin computer application provides a platform called the Authorship Investigate tool, which examines an article for plagiarism by matching the sentences as well as document information; such as, the date created and last modified, in order to support authors to avoid plagiarism and develop their writing skills (5). Hence,

artificial intelligence lies behind those algorithms.
The aim of this work is to review and summarize the current literature on the concept, history as well as the current and tentative applications of artificial intelligence in medicine and dentistry.

METHODS

Data were collected from electronic databases such as PubMed, Scopus, arXiv and google scholar.
Study selection: Full-text articles and conference proceedings regarding artificial intelligence, artificial neural network, machine learning, deep learning, and big data, and their related articles in the medical and dental fields were included to this review.

DISCUSSION

Strong and weak AI

There are two sub-concepts of AI, strong and weak (2), that can be distinguished by the currently encompassed meanings of brilliance. In this context, intelligence is characterized as the capacity of a system capable of acting appropriately in an uncertain environment. Strong AI therefore designates intelligence with a universal ability to deal with unpredictable situations, to be able to function in the same manner as a human being's intellect, and also to include its power of comprehension and even its consciousness. At first, an attempt to implement AI originated from a strong AI notion in 1936. This was based on a project proposed by Turing (6). Conversely, weak AI is very achievable. Instead of trying to emulate a human mindfully, weak AI focuses on creating knowledge that is concerned with a specific task. It is fundamentally different from a human's intelligence since it is essentially learned from those who lead the AI development.

Human brain to artificial neural network

Learning is most important for the human brain. The brain not only experiences a biochemical change, but also an anatomical alteration at the same time. This anatomical alteration will simultaneously change all the connections between each neuron (7).
The human brain consists of multiple neurons, which connect to each other with their dendrites and axon to form the neural networks. The neurons communicate and process the information obtained from the senses. Most neurons within the brain are grouped to create a nervous system. Such nerves pass electrical impulses, the excitation from neuron to neuron. The dendrites receive the impulse from an adjacent neuron's terminal button or synapse, then transfer the impulse to the nucleus. The electrical impulse is processed here and then transferred to the axon. Among the dendrites, the axon is a long branch, bringing the impulse to the synapse. Subsequently, it transfers the impulse to the next neuron's dendrites. Thus, the human brain requires a complex network of neurons to process complex information (8).
In 1943, McCulloch and Pitts (9) suggested neural networks as a way to replicate the human brain. Artificial neural networks (ANN) as an alternative to traditional analytics constitute an essential element of AI in the processes of artificial reasoning. As such, ANN is based on the biological nervous systems of the neurons present in the human brain (10). The concept itself is similar to neural signals and the human brain's operation, in which, the neurons are created artificially on a computer.
ANN starts with the input information in the network that transfers through each neuron by connections which are supposed to be the dendrites in the artificial neuron. There is a specific weight for each connection, which corresponds to the strength of each signal. When these input signals pass through the connections, they are regulated according to the connection's weight by multiplying the input with its weight and then summarizing them by a simple arithmetic method to activate a node. In the node, there is a threshold logic unit, this function can be considered as the nucleus. If the measured value is greater than the threshold value, the value could be considered as the neuron output passing through the axon to another neuron. Connecting many artificial neurons in layers creates an ANN (11). This concept was successfully developed in 1958 by Rosenblatt (12), who was determined to create an artificial neuron to classify the image and denominate his invention as the perceptron.
However, there is still a large difference between humans and ANN. ANN still relies on algorithms based on step-by-step thinking (13), commonly called brute force, described as a programming style which does not include any shortcuts to improve performance, but relies instead on pure computer power to consider all the possibilities until a solution to the problem is found (14). Therefore, difficult tasks require extremely large computer resources. Moreover, researchers have created the methods and algorithms to handle uncertain and incomplete information with the idea of the probability theory to cope with those situations. Unlike machinery, humans are intuitive to solve several problems and do not always employ their thinking skills into consideration of all the probabilities, but are mostly based on reasoning (15). This sub-symbolic thinking is what AI seeks to get as close as possible.
In addition to the aforesaid, Turing, who developed a current concept of AI, forwarded this conviction by successfully developing a properly designed machine, the so-called universal Turing machine. It is a virtual machine capable of solving all mathematical problems. If all problem-solving processes can be reduced to a mathematical equation, a computer machine would be

capable of performing relatively simple computational forms that could solve all problems with suitable behavioral commands. In 1950, The universal Turing machine project is known as the launch of the modern concept of AI. Turing (16) developed the imitation game test, or Turing Test. If a person did not know that his or her contact was AI and did not know if he or she was talking to another person or AI during a conversation, then AI had exceeded a person's intelligence level. This is what the game of imitation means.

There are still many misunderstandings about the terms machine learning (ML), deep learning (DL) or AI. Most people think all these words are the same, but AI simply means replicating a human brain, and the way a human brain thinks, functions, and works. Meanwhile, ML is an essential part of AI (17) consisting of the most advanced techniques and models that enable computers to predict data. On the other hand, DL is a better designed ML field that uses multilayered neural networks to provide a high accuracy for each particular task (16, 18).

Machine learning

In 1959, Samuel (19), one of the pioneers of ML, preliminary defined ML as "a field of study that gives computers the ability to learn without being explicitly programmed", whereby he taught a computer to play checkers. The goal was to teach it to play checkers better than himself, which obviously was not something he could program. Then, in 1962, the system defeated the Connecticut, US state checkers champion.

ML is a branch of computer science interested in finding patterns in the data and making predictions using those patterns. Through the most essential part of ML, the iterative learning process, ML algorithms seek to optimize over a certain dimension, i.e. they generally try to minimize error or increase the probability of their predictions becoming correct until they are unable to achieve any less error (20). ML's objective is to find the proper strategy to answer accurate predictions and ML can be divided into three categories, based on the input sample differences (21), which are the following.

1. Supervised learning: The sample has both input data and corresponding output labeled. It is the most widely used kind of learning to make a tagged suggestion when uploading a photo. For example, Facebook can tell a person's face apart from their friend's face.
2. Unsupervised learning: The samples only have an input feature vector; no corresponding output mark exists. The objective is to identify all specimens by using methods, such as, clustering or grouping. For example, YouTube can find the pattern in the frame of videos and compress those frames, so that the videos can quickly stream to the viewer.
3. Reinforced learning (RL): In a dynamic and interactive environment, the learner performs a specific action in which the objective is to achieve the maximum cumulative reward value through experimentation of trial and error. For example, children learn to walk because no one tells them how; they just practice, stumble and get better balance until they can put one foot in front of the other.

RL has become the most commonly used ML algorithm, after it was first introduced in 1956. RL is a form of active learning (exploration and exploitation) compared with supervised learning and unsupervised learning (22); particularly, it is a strategic learning process that develops on the basis of the situation. RL emphasizes state-based behavior to achieve a maximum predicted reward where RL communicates with its environment through a process of trial and error and learns the optimal strategy by optimizing cumulative rewards (22, 23).

Deep learning

DL is basically a neural network with multiple hidden layers (16), which can be called a subtype of ML (16, 18). The basic concept behind DL is to combine low layer features to form abstract and easily distinguishable high layer representations through multilayered network structures. Through DL, deeply embedded representations of features can be obtained by eliminating the limitation caused by manual feature selection complexity and high dimensional data (24).

As a technology used to learn more about ML, at the beginning of the 21st century, DL models with multilayer neural networks made superior performance breakthroughs complex scenarios such as speech and image processing. One example is Sophia, Hanson Robotics' most advanced social humanoid robot, which was activated in 2016 (25). Sophia uses visual data processing and face recognition to imitate human movements and facial expressions. Sophia can also answer certain questions and conduct simple conversations using voice recognition along with speech synthesis technology to allow her to respond to the conversation. Multiple techniques allow Sophia to be able to communicate with humans (26). The AI program inside Sophia can analyze conversations and extract data that would be able to improve future answers. Sophia is a breakthrough technology. Likewise, ELIZA, an early natural language processing program created between 1964 and 1966, was the first attempt at simulating chatterbots (27). With the enormous expansion of computational learning theory and statistical learning, RL and computer processing power, DL algorithms have been introduced in an endless stream.

Big data

Big data is relatively new and gathers and stores large amounts of information (28). The big data theory includes all kinds of information that are not processed. The term 'big' is simulated from the numerous amounts of data, which indicates the character for big data in volume. For example, Walmart Inc., the American hypermarket corporation, conducted 110 terabytes of records in 2000, 500 petabytes in 2004, 161 exabytes in 2006 and 400 exabytes in 2010 (29); likewise, YouTube carried 28 hours of uploaded video every minute in 2011 and received up to 300 hours per minute in 2018 (30). Moreover, the IDC report, commissioned by Dell EMC predicts more than 40 zettabytes of digital data in 2020 (31) that support the data scientists to pay attention to the impacts of big data. Size is the cornerstone of the big data concept (30), but the most significant is not the data volume, usually handling and processing such large data sets is logistically challenging (32). The benefit of big data is gained by knowledge extraction that leads to better decisions and strategic movements.

Additionally, data mining is the process of discovering patterns in large data sets involving methods at the intersection of machine learning, statistics, and database systems (33). As a data analytics branch, it is an interdisciplinary computer science and statistics subfield with an overall objective of extracting information from a data set and turning the information into a comprehensible structure for further use (33). Since data mining can reveal patterns in the data, the target data set must be large enough to include these patterns, while remaining sufficiently succinct to be exploited within an acceptable time limit.

Big data has five common characteristics called the 5Vs: volume, variety, velocity, veracity, and value (34). Big data is another outstanding innovation in the IT sector after the Internet of Things (IoT) and cloud computing. For these reasons, in 2008, Donovan (35) successively published an article for the need for big data to continually evolve.

Moreover, big data typically has characteristics, such as multisource, polymorphic, heterogeneous, complex, high-dimensional, and exponential development, which leads directly to the complexity of gathering, storing, processing, mining, and value application of such stream data (34). This also poses a huge challenge to the application of ML algorithms.

Big data is a source of many challenges for conventional ML. From the above-mentioned 5V features, these challenges can be analyzed to include the following five aspects (36).

1. Volume challenge: The size of training data set far exceeds the memory capacity of a computer.
2. Variety challenge: data is often presented in various modalities, such as video, audio and text.
3. Velocity challenge: Big data also has to be processed in a certain period of time in a timely manner; otherwise, the functional value will be lost.
4. Veracity challenge: Big data quality, reliability, uncertainty, and incompleteness will cause uncertainty.
5. Value challenge: Big data's value density is usually low, making it difficult to perform data mining.

The collected information and phenomenon are data-oriented and regularized based on statistics, AI, data mining and other methods to develop new knowledge management approaches from a single dimension to multidimensional integration (36). In examining ML in the 21st century as an example, it is possible to integrate a supervised learning class in statistical ML, DL, and Transfer Learning using a simple data mining method to create a new data mining technology that breaks the traditionally associated description of the relationship to develop and promote causality. This would have broad prospects for applications in many areas.

In the digital context where businesses are increasingly seeking to benefit from personal data, various aspects of personal information, processed and monetized in competitive markets, need to be considered. Nevertheless, there is still a statement about a fundamental right secured by the data protection laws of the European Union (EU) and the EU Charter of Fundamental Rights.

The General Data Protection Regulation (GDPR) became enforceable in May 2018 (37), and is a regulation in EU law on data protection for all EU Member States including EU-related organizations even if they are based outside of Europe, which means the GDPR would have an impact internationally (38). As GDPR focuses mainly on data protection, this applies to data protection activities from impairment or misuse. It signifies the regulation of the use of personal data in the legal context. The data protection definition can also form part of the right to privacy, which in effect relates to a state of restricted accessibility. The GDPR covers any aspect that essentially could identify people, such as, name, contact details, location, health records, and some digital behavioral information (39, 40).

Since the widespread commercial use of data processing clearly shows that personal data is a valuable asset worth investing in, the GDPR also puts great attention on the privacy protection and institute rules in all EU Member States by greatly expanding the scope of the commitments.

The organization's data controllers must prove they have a lawful reason for holding that kind of data and even show that they are storing it safely. Thus, there is an outline called "six GDPR privacy principles" (41). The data controllers are responsible for adhering to these standards and must be able to demonstrate the compliance activities of the organization. The six principles (41) are the following.

1. Lawfulness, fairness and transparency: With respect to the data subject, personal data must be handled legally, reasonably and transparently.
2. Purpose limitations: Personal data can only be collected for specified, explicit, and legitimate purposes.
3. Data minimization: Personal data can only be obtained what is required for business function purposes.
4. Accuracy: The personal data must be kept correct and up to date.
5. Storage limitation: Personal data cannot be stored if it no longer needs to be used for the specified purposes.

6. Integrity and confidentiality: Personal data must be handled in an appropriate manner.

Today, in the big digital world, the protocol enforced by the GDPR would certainly properly unlock the big data around patients' data information in the health field.

Application of AI in the medical and dental fields

Applications of AI, such as theorem proving, image recognition, expert systems, natural language processing, and robotics, have evolved in countless abundance. Those innovations have also revolutionized the field of medicine and dentistry over the past decade (42).

There are countless opportunities for AI in the medical field; so far, the most successful fields of medical AI are diagnosis and prognosis prediction (43). Medical AI is a significant contribution to support decision making in medical practice. The following are some of the diagnostic-related articles.

One of the most famous medical AI is the "IBM Watson AI platform", which is deployed by cancer centers to help medical professionals provide an appropriate diagnosis and determine the best treatments for patients (44). They have developed advanced algorithmic solutions using the DL and ML platforms to analyze medical oncology and radiology images for faster and better accuracy than a human operation. However, there was a report about unsafe treatment recommendations because of the hypothetical scenario instead of the real patients' data treatment records.

Sakai et al. (45) studied the potential of a Bayesian model prediction of acute appendicitis. The AI system assessed the probability of disease in new cases based on the preceding conditions of the patients' records: 50.9% (86 out of 169) of the patients were diagnosed with acute appendicitis during their disease. With respect to other test methods, in the Bayesian network model the error rate was the lowest. The area under the receiver operating characteristic curve also indicated that the Bayesian network model offered the most reliable results.

Kitporntheranunt and Wiriyasuttiwong (46) created medical expert software for diagnosing ectopic pregnancy. The program used an interactive backward chaining inference algorithm to evaluate the medical records and available information of the patients, and successfully detected ectopic pregnancy in 31 out of 32 cases.

Azarkhish et al. (43) investigating alternative approaches of determining serum iron, showed that the iron level could be predicted with an acceptable result by analyzing other standard laboratory data using ANN (96.29% accuracy) and the adaptive neuro-fuzzy inference system (90.74% accuracy). These results showed that the AI system drew conclusions and guided physicians on the possibility of anemia, as a result of iron deficiency, which was only based on the results from peripheral laboratories.

AI can be integrated with many image systems to identify minor deviations from the normal that could have gone unnoticed by human eyes; Tsuchihashi (47) proposed a 95% accuracy of the program for an automated diagnosis and marked prostate cancer by an AI system integrated with telepathology. Additionally, in 2014, Wu et al. (48) assessing the computerized diagnosis of early knee osteoarthritis from MRI images, concluded the accuracy of the diagnosis using a radial basis function as a network classifier, which was in 75% of the cases.

Not only can the AI system predict the diagnosis, but it can also forecast the results of the treatment as well. In 2010, Qidwai et al. (49) introduced a new technique for presuming recovery of the patient after spinal column surgery based on the preoperative data analysis in the Traditional Fuzzy Inference Framework. The results showed a high predictive performance for 501 patients (about 88%). Thus, the model was able to help make efficient decisions. Even if there is complexity during treatment, AI can provide an alternative option for a better solution. Wright et al. (50) also predicted which would be the next prescription drug for treating diabetic patients based on current drug patterns. Using the Constrained Sequential Pattern Discovery using Equivalent Class (cSPADE) algorithm, the result concluded from data sets of pharmacological treatment trends that conformed to the guidelines. The model was able to predict the prescribed medication for 90% of patients when predicting by drug class, and for 64% of patients when predicting at the generic drug level.

Data extraction from large quantities of collected organizational information can analyze new knowledge, or so-called data mining. In 2008, Roberts et al. (51) showed that the use of ML algorithms could be based on significant extracts from medical texts and relevant links in the patients' records. To identify the patterns of interest, large data sets could, therefore, be analyzed. This study was conducted on the system for storing, integrating, and presenting clinical information for research purposes in the Clinical E-Science Framework (CLEF). The study used clinical data from the Royal Marsden Hospital's (UK) 20,000 patients.

As mentioned above, the AI contribution to the medical profession until now has mainly arisen due to the emergence of big data. In contrast to the medical field, it is evident that AI in the dental field remains at a basic step (2) although technology for other AI applications has made remarkable progress. However, dental AI is mainly related to the prediction of diagnoses and prognoses (10). The following are some of the diagnostic articles.

In 1998, the Food and Drug Administration (FDA) began approving the marketing of AI algorithms designed to interpret medical images, such as the software for proximal caries diagnosis, Logicon Caries Detector (LCD; Logicon, Los Angeles, CA, USA) (52). It is an automated caries detection system that analyzes via digital X-ray images, studies on using this software for proximal caries detection were still less successful than those of human observers (53-55).

Kim et al. (56) were able to forecast toothache for 80% of the cases examined by using an AI system based on the multiple neural network model. Researchers arranged 131 neurons in the input layer, six neurons in the hidden layer and one neuron in the output layer for a consequence of the dental pain prediction,

Bas et al. (57) employed ANN for prediction of the use of the clinical signs and symptoms of two subsets of internal disorders of the temporomandibular joint and normal joint. Clinical symptoms and diagnoses were established as a gold standard and used to learn the neural network in 161 patients with temporomandibular joint conditions. The AI analysis was submitted for the results of 58 new patients after the learning process. The study was completed with about 0.03-24.22% of relative error with the finding that an ANN application could serve as a valuable diagnostic tool in the diagnosis of subtypes of the disease since it could produce very high specificity (89-100%). In addition, they suggested that the greater the data fed to the training set, the greater the normalized system error could be reduced.

The overall goal of data mining is to extract information from a data set and turn the information for further use into an understandable framework. These are some of the information for which it is applied:

Korhonen et al. (58) found that dentists detected caries in their new patients more successfully than their old ones by using a data mining technique. The study was performed by means of an AI system with the data obtained during the general physical exams.

Tamaki et al. (59) used an AI system to create a data mining method for identifying correlations, anomalies and statistically significant trends. A high level of Streptococcus mutans and Lactobacillus have been successfully identified as high-risk factors for caries development in schoolchildren.

Käkilehto et al. (60) have examined many electronic dental records of patients to achieve scientific conclusions about the longevity of dental restorations by using AI data mining techniques. Some of the outcomes revealed that the survival rate of a dental amalgam was found to be superior to other restorative material especially on occlusal surface; the composites were shorter than the amalgam but longer than the glass ionomer, and the 60% of silicate restorations were suggested to replace five years later initial placement due to the shard drop of survival curve.

Nieri et al. (61) successfully identified several possible factors using the Bayesian network analysis, that may affect the results of the treatment of impacted maxillary canines. The result revealed that the alpha angle of pretreatment was a determinant of the period of the orthodontic traction. researchers also addressed the relation between the greater angulation of the impacted canines with more severe crowding and a greater distance from the occlusal plane of the impacted canine.

Relative to other areas of healthcare, standardization in dentistry is low, as most of the treatment options distinctly depend on clinician preferences (62-64). Alternatively, the AI system could also perform some complex treatment plans. In 2010, Xie et al. (65) used a decision-making expert system to identify the factors influencing the decision-making and to assess the need for dental extraction in malocclusion patients before orthodontic treatment. They had a success rate of 80% to decide whether treatment with dental extraction should be performed in a specific situation. Using AI and large data sets that include diagnostic results, treatments, and outcomes are now possible to obtain the effectiveness of different treatment modalities in the specific symptoms and anatomical conditions. For this kind of development, this technology would advance the quality of treatment. The AI system can not only carry out treatment planning but can also predict the treatment results. In analyzing hyper-nasalization in the speech of patients treated for oropharyngeal cancer, De Bruijn et al. (66) investigated the applicability of ANN in order to evaluate the patient's hyper-nasalization. The sound of speech in 51 patients with 18 control sounds was recorded. Those properties were analyzed in the full range of speeches, and the study was considered feasible based on their results, whereas the parameter of prediction varied between moderate and poor.

In 2017, Khanna and Dhaimade (67) proposed the concept of virtual dental assistance to perform a number of simple tasks in dental clinics with greater precision, less human resources, and fewer errors than human counterparts. Some of these tasks included the following.

1. Booking and coordinating regular appointments.
2. Alerting the patients and dentists about check-ups whenever any genetic or lifestyle information indicated increased susceptibility to dental diseases.
3. Managing the paperwork and insurance.
4. Assisting the clinical diagnosis and treatment planning.
5. Alerting the dentist before every appointment about any allergies of the patients.
6. Alerting the dental healthcare provider about any relevant medical history.
7. Setting up regular reminders for patients who were on tobacco or smoking cessation programs, etc.
8. Providing tele assistance in case of dental emergencies where no contact with the dental professional was possible.

In oral and maxillofacial surgery as well as implantology field, AI software has contributed to the development of surgery, as one of the greatest uses for surgical operations with robotic surgery, which perform semi-automated tasks that are the major challenges for robotics. In 2017, the first autonomous dental implant robot in the world was used in China, which was only six months after the US Food and Drug Administration (FDA) certification was granted to the first robotically assisted surgical system/ software, YOMI (68). This robotic system consists of robotic guidance or computerized navigational software for dental implants carried out by human teams. YOMI gains the benefit from both the surgeon's skill and the robotic surgery to eliminate human error during surgery with the ability to make adjustments in line with the patient's movements during the operation. Soon, robots could be operating on the patient's mouth under the dentist's supervision for all kinds of work.

CONCLUSION

This review investigated the AI, ML, and DL and their applications in clinical medicine and dentistry, which has shown the most innovative area of computer use in healthcare. AI can clearly be a tool for significant developments in improving the patient's health. Apart from human skills, there is no doubt that AI can never replace dentists or physicians. Clinical practice is not only concerned about the diagnosis, but also correlates with the clinical findings and provides personalized patient care. Although AI can assist the medical and dental fields in many ways, still, the final decision must be made by the professional as the overall treatment is a multidisciplinary approach. However, the scope of further AI research in the health field will definitely be increased. The research should be integrated with clinical practice. Thus, in the near future, physicians could develop a quick therapeutic approach by enhancing the patient's diagnosis with a medical AI platform and instantly receive treatment recommendations based on the available patient's data and information received from the available journals.

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Pathompong Roongruangsilp participated in the data acquisition and manuscript drafting under supervision by Pathawee Khongkhunthian as the mentorship.

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