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Artificial Intelligence in Dentistry

[1]Deepak Narang, Reader, Department of Oral Medicine and Radiology, Deshbhagat Dental College, Punjab, India.

Corresponding Author: Deepak Narang, Reader, Department of Oral Medicine and Radiology, Deshbhagat Dental College, Punjab, India.

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Abstract

Artificial Intelligence (AI) is a technology that utilizes machines to mimic intelligent human behavior. To appreciate human-technology interaction in the clinical setting, augmented intelligence has been proposed as a cognitive extension of AI in health care, emphasizing its assistive and supplementary role to medical professionals.

While truly autonomous medical robotic systems are still beyond reach, the virtual component of AI, known as software-type algorithms, is the main component used in dentistry. Because of their powerful capabilities in data analysis, these virtual algorithms are expected to improve the accuracy and efficacy of dental diagnosis, provide visualized anatomic guidance for treatment, simulate and evaluate prospective results, and project the occurrence and prognosis of oral diseases.

Potential obstacles in contemporary algorithms that prevent routine implementation of AI include the lack of data curation, sharing, and readability; the inability to illustrate the inner decision-making process; the insufficient power of classical computing; and the neglect of ethical principles in the design of AI frameworks.

It is necessary to maintain a proactive attitude toward AI to ensure its affirmative development and promote human-technology rapport to revolutionize dental practice.

The present review outlines the progress and potential dental applications of AI in medical-aided diagnosis, treatment, and disease prediction and discusses their data limitations, interpretability, computing power, and ethical considerations, as well as their impact on dentists, with the objective of creating a backdrop for future research in this rapidly expanding arena.

Keywords*:* Big Data, Clinical Decision Making, Dental, Informatics, Machine Learning, Neural Networks

Introduction

What once seemed like science fiction is now becoming reality in health care. Artificial intelligence (AI) is a fast-moving technology that enables machines to perform tasks previously exclusive to humans. Advances in AI offer a glimpse of such health care benefits as decreasing postoperative complications, increasing quality of life, improving decision-making and decreasing the number of unnecessary procedures. When applied to the fields of medicine and dentistry[1],

AI can play a crucial role in improving diagnosis accuracy and revolutionizing care. AI is currently used for a variety of purposes in dentistry: identification of normal and abnormal structures, diagnosis of diseases and prediction of treatment outcomes. Furthermore, AI is used extensively in dental laboratories and is playing a growing role in dental education. The following review describes current and future applications of AI in the clinical practice of dentistry[2]

Artificial intelligence (AI), first coined by John McCarthy, refers to machines that can imitate human knowledge and behavior. This intelligent capability can be implemented by sequences of algorithms. With the improvement of computer hardware, it is possible for AI to process large datasets, computationally to reveal human behavior and and allow interaction with people. This technology qualitatively improves people's lives and continuously influences the world.

Machine learning is one of the AI fields that researchers and practitioners have applied broadly, using it for data analysis. Machine learning was first mentioned in 1959 by Arthur Samuel,2 who defined it as a process that enables computers to learn without being explicitly programmed. Nowadays, machine learning has made it possible for a computer to classify or predict an outcome from an extensive database.[3]

For example, Amazon Alexa (Amazon) was released as a virtual assistant, with the ability to recognize and understand different voices and accents. With the potential of adding "skills," it started helping people to complete their daily life tasks. AlphaGo (Google DeepMind) was programmed with deep learning, and it defeated several Go champions. In iPhone (Apple), the Apple A13 Bionic chip has been developed to handle the software demands of machine learning processes, such as the instant correction of low-light pictures. IBM Watson (IBM) was also introduced as an AI solution with the feature of cognitive computing[4,5].

This self-learning system was designed to solve problems without human assistance in several professional fields. The purpose of this article is to review the current applications of AI in health care and dentistry. Additionally, the future perspectives of AI in the dental profession will be addressed.

AI Methodologies

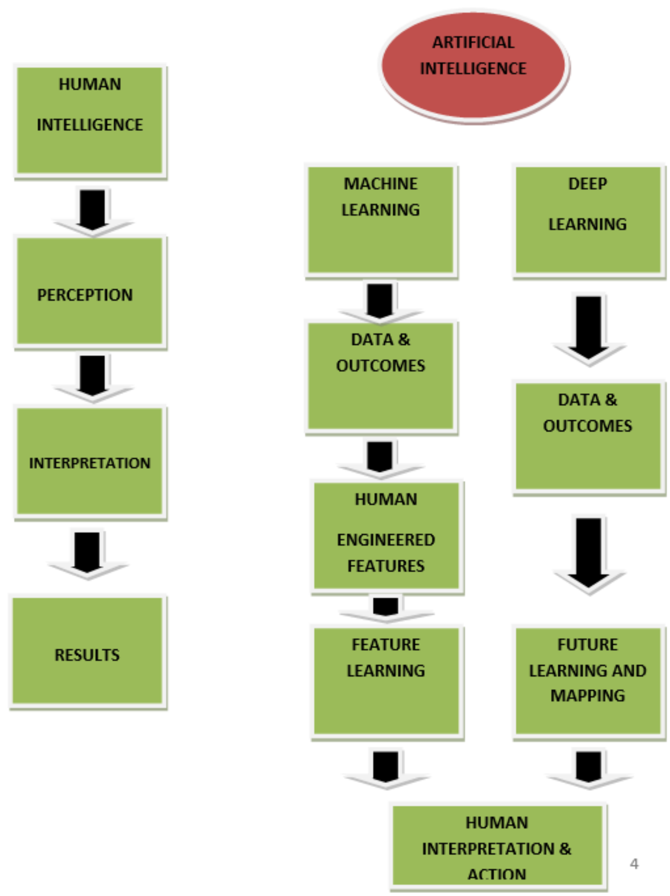

Fig 1: Human and Artificial Intelligence: Human intelligence is denoted by perception, interpretation and biological result. In comparison, Artificial intelligence which cannot replace Human Mind in any ways, but largely supports human interpretation and action. In Artificial Intelligence there are two categories- Machine

learning the features are firstly engineered by human experts and then learned. In deep learning, relevant features are learned and mapped in one step, this makes it more capable of handling complex data sets.

Ai applications in health care

With the potential to "train" a computer program to achieve highly intelligent capabilities, AI began emerging in the health care fields. Patient care could be improved with AI, which is a better diagnostic aid and reduces errors in daily practice. Medical image interpretation has developed from expert systems, through atlas-based models, to the future of deep learning[7].

The big data of digital radiographs can be used, as it has great potential to improve the diagnosis process in radiology with the aid of AI. 4 AI with deep learning could potentially assist medical radiology via automated data mining. New knowledge will be discovered with minimal human knowledge involvement. Wearable technology with the installation of intelligence applications can predict when a life-threatening crisis like a stroke may occur in a patient, giving clinicians the opportunity to provide effective, early interventions.

Electronic medical records and scientific databases can be analyzed in an efficient and applicable method using AI. The diagnosis of human congenital anomalies was improved with the emergence of big scientific data[8].

The support vector machine (SVM), a learning model of machine learning, has become a standard method of analysis in medical research. Complicated conditions such as traumatic brain injury can be classified with SVM. 6

In cardiovascular medicine, due to a need for precision in diagnosis and treatment, deep learning might play a critical role in its development. Identifying various cardiovascular diseases with high precision diagnosis would be possible with the implementation in deep learning[9]

In viral immune surveillance, utilizing AI to analyze viruses has improved translational research. Using AI technology can fill gaps in knowledge and improve costs and benefits. In disease management, AI has been widely utilized to analyze treatment outcomes or develop precision medicine[10].

These innovative machine learning algorithms can be considered as a powerful analytic tool that allows clinicians to conceptualize and study mood. In a meta-analysis, it was concluded that the application of machine learning algorithms could predict therapeutic outcomes in treating depression with an overall accuracy of 82%.[11]

In ophthalmology, AI could improve diagnoses and treatment options for many eye conditions including corneal ectasias, glaucoma, and age-related macular degeneration and diabetic retinopathy[12].

Clinical application of AI in dentistry

Radiology

CNNs (convolutional neural network) have shown promising ability to detect and identify anatomical structures. For example, some have been trained to identify and label teeth from periapical radiographs. CNNs have demonstrated a precision rate of 95.8–99.45% in detecting and identifying teeth, almost rivaling the work of clinical experts, whose precision rate was 99.98%.

CNNs have also been used for the detection and diagnosis of dental caries.10 In 3000 periapical radiographs of posterior teeth, a deep CNN algorithm was able to detect carious lesions with an accuracy of 75.5–93.3% and a sensitivity of 74.5–97.1%.

This is a considerable improvement over diagnosis by clinicians using radiographs alone, with sensitivity varying from 19% to 94%.11 Deep CNNs have great potential for improving the sensitivity of dental caries diagnosis and this, combined with their speed, makes them one of the most efficient tools used in this domain[13,14]

It can be integrated with imaging systems like MRI (magnetic resonance imaging) and CBCT (cone beam computed tomography) to identify minute deviations from normalcy that could have gone unnoticed to the human eye. This can also be used to accurately locate landmarks on radiographs, which can be used for cephalometric diagnosis.

1 - ML algorithm can detect a lymph node in head and neck image as normal or abnormal provided it is trained Radiologist by analyzing thousands of such images which are labelled as normal or abnormal.

Wang et al. first presented an article that used DCNNs (deep neural network, DNN) in the diagnosis and analysis of dental radiographs. In addition, Miki et al. conducted research that focused on classifying tooth types in dental cone-beam CT images via an automated method of DCNN[15].

Recently, Lee et al. studied DCNN using computed assisted diagnosis (CAD) system for the detection of osteoporosis on panoramic radiographs. The DCNN CAD system was compared to experienced oral and maxillofacial radiologist and the results showed high agreement between the two[16].

Orthodontics

ANNs (artificial neural network) have immense potential to aid in the clinical decision-making process. In orthodontic treatments, it is essential to plan treatments carefully to achieve predictable outcomes for patients.

However, it is not uncommon to see teeth extractions included in the orthodontic treatment plan. Therefore, it is essential to ensure that the best clinical decision is made before initiating irreversible procedures. An ANN was used to help determine the need for tooth extraction before orthodontic therapy in patients with malocclusion.

The four constructed ANNs, taking into consideration several clinical indices, showed an accuracy of 80–93% in determining whether extractions were needed to treat patients' malocclusions[17,18].

Periodontics

According to the 1999 American Academy of Periodontology classification of periodontal disease, 2 clinical types of periodontitis are recognized: aggressive (AgP) and chronic (CP) forms.

Because of the complex pathogenesis of the disease, no single clinical, microbiological, histopathological or genetic test or combination of them can discriminate AgP from CP patients.

Papantanopoulos and colleagues used an ANN to distinguish between AgP and CP in patients by using immunologic parameters, such as leukocytes, interleukins and IgG antibody titers. The one ANN was 90–98% accurate in classifying patients as AgP or CP. The best overall prediction was made by an ANN that included monocyte, eosinophil neutrophil counts and CD4+/CD8+ T-cell ratio as inputs. The study concluded that ANNs can be employed for accurate diagnosis of AgP or CP using relatively simple and conveniently obtained parameters, such as leukocyte counts in peripheral blood[19,20,21].

Endodontics

Although mandibular molars tend to have similar root canal configurations, several atypical variations may occur. To minimize treatment failures related to morphological differences and to optimize the clinical outcomes of endodontic therapy, cone-beam computed tomography (CBCT) has become the gold standard[22].

However, because of its higher dose of radiation compared with conventional radiographs, CBCT is not used systematically. To overcome such challenges, AI has been introduced to classify the given data using a CNN to determine whether the distal root of the first mandibular molar has 1 or more extra canals[23].

Radiographs of 760 mandibular first molars taken with dental CBCT were analyzed. Once the presence or absence of the atypia was determined, image patches of the roots obtained from corresponding panoramic radiographs were processed by a deep learning algorithm to classify morphology. Although the CNN had a relatively high accuracy of 86.9%, several limitations exist regarding its clinical integration[24].

The images must be segmented manually, which consumes a considerable amount of time. Furthermore, the obtained images must be of adequate size and should focus on a small region to allow the system to concentrate on the object being studied, while covering enough area to include pertinent information[24]

Oral pathology

Detection and diagnosis of oral lesions is of crucial importance in dental practices because early detection significantly improves prognosis. As some oral lesions can be precancerous or cancerous in nature, it is important to make an accurate diagnosis and prescribe appropriate treatment of the patient.

CNN has been shown to be a promising aid throughout the process of diagnosis of head and neck cancer lesions. With specificity and accuracy at 78–81.8% and 80–83.3%, respectively (compared with those of specialists, which were 83.2% and 82.9% respectively), CNN shows great potential for detecting tumoral tissues in tissue samples or on radiographs.

One study used a CNN algorithm to distinguish between 2 important maxillary tumours with similar radiologic appearance but different clinical properties: ameloblast MAs and keratolytic odontogenic tumours.

The specificity and the accuracy of diagnosis by the algorithm were 81.8% and 83.3%, respectively, comparable with those of clinical specialists at 81.1% and 83.2%. However, a more significant difference was observed in terms of diagnostic time: specialists took an average of 23.1 minutes to reach a diagnosis, while the CNN achieved similar results in 38 s[26,27].

Future of ai in dentistry

Due to the need for precision and instant information exchange in dentistry, AI will continue to connect with the dental profession in every aspect. The authors believe that, with the current trend and recent rapid development of AI, we can expect to see its impact on dentistry in the very near future.

Machine learning, especially deep learning, will help researchers better understand certain multifactorial diseases; with its aid, it will be possible to improve the collective knowledge of oral diseases/ conditions that are not currently fully understood.

Before each appointment, the AI patient history analyzer will evaluate the planned treatment with the patient's gender, age, vital signs, medical history, current medications, and health condition. The patient's dental history will be recognized from a series of radiographs and digital 3D images. With the AI patient manager, clinicians will be able to understand more about the preferences and characteristics of patients, which will improve patient management.

During the appointment, the proposed diagnosis will be generated by the AI problem detector using all of the information for the clinician as a reference. Recommendations for treatment will be provided to the clinician from the AI.

The critical medical concerns, such as allergies, disease interactions, and drug interactions will also be considered. Additionally, AI will provide clinicians with feedback during the treatment procedure to minimize human error.

The outcome and prognosis will be predicted precisely. Technologies designed for dental practitioners will assist clinicians in making precise diagnoses and recommendations for comprehensive treatment plans, along with calculating possibilities for each of these in a matter of seconds or less.

The future "AI Dental Assistant" will be able to analyze all available information about the patient and potentially read the relevant radiographs using pre-trained algorithms. Nevertheless, this tool will not replace the clinician's role; alternatively, it will assist the dental practitioner in making an improved and highly accurate diagnosis during dental treatment.

The role of AI will enable various interdisciplinary treatment proposals in treatment planning, with benefits and possible complications based on collected evidence.

Dental institutes and dental clinics will have the opportunity to build their patient library with AI in the future. With the big data including the electronic health records, digital radiographs, and the longitudinal follow-up data, it will be possible to establish a reliable source for training the AI system.

Nevertheless, it is noteworthy to mention that a basic understanding of how big data is collected and how AI algorithms are programmed is essential for dental practitioners. Knowing the advantages and current limitations of AI tools can help clinicians to select the AI service wisely as more products enter the business.

The use of AI by dental insurance will further develop and ultimately allow for immediate claim approvals. This will allow clinicians to upload their radiographs, intraoral scans, and photos to an insurance provider and instantly have an answer to their insurance claim, therefore providing transparency in the process and allowing patients to get faster dental care without the fear of no insurance coverage.

In addition to the clinical techniques, the dental patient experience will increase with the use of AI. The technology will learn patient preferences to allow for an overall better experience. AI will learn on what days and at what time the patient prefers to visit the dentist, what temperature they may like the room or chair, what music or entertainment they prefer, and even the lighting that most relaxes this patient. By improving the experience of dental patients, more patients will have proper oral health care and therefore better systemic health.

Advantages of AI

Tireless performance of the tasks which saves time

1. Logical and feasible decisions without any involvement of human emotions which results in an accurate diagnosis
2. Standardization of procedures

Disadvantages of AI

1. The complexity of the mechanism
2. The cost involved in the setup
3. Enormous data is required for training and precision and therefore is it is difficult to achieve accuracy in rare conditions or diseases.

Limitations and concerns

Using AI to solve problems requires the algorithm to be comprehensive with multiple applications to solve a single question. Like the nature of data mining, AI might only reflect the results subjectively with associations, not with causality. Direct interpretation will not be provided with AI; a misinterpretation might occur with the misconduct of the algorithms.

AI programs still need to be developed in collaborations that involve experienced clinicians and expert computer engineers to minimize potential risks of AI. Several problems were reported with IBM Watson and indicated that AI application in health care still might not be mature and requires substantial improvement. Liability will be another growing issue if the diagnostic work begins to depend too heavily on the AI system.

Clinicians should always be aware and cautious when interpreting information provided by AI. Safeguarding medical information under HIPAA (Health Insurance Portability and Accountability Act of 1996) compliance in the use of AI is another concern. Most of the machine learning requires data for training.

Exchange of training sets and applying models should be performed with caution to avoid violating HIPAA regulations.

Conclusion

AI technology has impacted the health care industry and led researchers and companies alike to invest in the medical field. In the authors' opinion, the progressive development of AI in dentistry will benefit clinicians and researchers to integrate different fields of knowledge and improve patient care.

However, it is essential to be aware of the potential errors in interpretation of data via AI programs. To minimize output errors, it seems logical currently to combine AI technology with conventional methodologies.

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