ARTIFICIAL INTELLIGENCE IN DENTISTRY AND DENTAL EDUCATION

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ABSTRACT

Artificial intelligence(AI) is becoming an important tool for many aspects of society.Speech recognition, internet searches and social media use artificial intelligence to personalize what you see and say.Health care is an expanding area which uses artificial intelligence.With more sophisticated hardware artificial intelligence is branching out into diagnosis and image interpretation Investigators are developing uses for artificial intelligence in all aspects of dental care.By using AI, dental offices can expedite processesthat are performed by the dentist and assistant, and therefore, make the office more efficient.The objective is to give an overview of what artificial intelligence is and describe some of the ways it may be useful in dentistry and dental education.

KEYWORDS

Artificial Intelligence, Dentistry, Dental Education, Machine Learning

1. INTRODUCTION

Artificial Intelligence has many applications in society[1].The uses for AI in health care are still being developed especially in image analysis and analyzing medical records.In this article we will give an overview of artificial intelligence technologies and describe some of the applications in health care and dentistry.

Table 1. Definitions.

Artificial Intelligence	Create systems to perform functions requiring human intelligence
Machine Learning	Subfield of artificial intelligence; computers perform functions by learning patterns rather than being programmed
Deep Learning and Artificial Neural Network	Type of machine learning; Uses many layers of data, some are hidden
Convolutional Neural Network	Subfield of deep learning; Uses an operation with application in image analysis

2. DISCUSSION

Artificial intelligencecan be considered development of machines doing tasks associated with humanintelligence.It is a branch of computer science in which programs are developed that can

apply knowledge to tasks performed by humans.The term artificial intelligence was first used in the 1950's by John McCarthy [2].It is generally defined as intelligent computer programs capable of learning and applying knowledge to complex tasks normally performed by humans.AI is now used in many ways in daily living as in assistants like Siri and Alexa and home devices such as smart thermostats.When a google search is done there are ads generated based on search history. With the internet AI programs are used to provide more personalized searching and shopping[3].

A set of rules called algorithms are created for a machine to perform tasks.The basis of AI are algorithms.The term AI and its rise in the scientific community started back in the 1950s when storage of information became more affordable and accessible.Over the years there has been many uses in the medical and dental field for utilizing data to develop methods aiding in the diagnosis and treatment of patients.

Machine learning is a subset of artificial intelligence [4]. It involves using computer algorithms so that computers can learn on their own.The term machine learning was introduced by Arthur Samuel in 1959 [5].The computers do not need to be programmed to do a certain function. The machine learns and can make predictions from the data provided.The computer system performs tasks by learning data patterns rather than being programmed [6].Recently, machine learning has made it possible for computers to classify and predict certain outcomes through a very extensive database [7].

Artificial neural networks (ANN) are a subset of machine learning.This is based on the nervous system which has layers of neurons.The artificial neural receives input (data) and produces an output after processing the data.There are also hidden layers which can determine patterns in the data.

The training of neural networks became possible when there was a large amount of labeled data, more powerful computing hardware and improved training techniques [6].Each network is composed of nodes or "neurons" that perform an operation.

Deep learning is a form of machine learning that uses computers to learn patterns in large amounts of data.Machines are given data and then learn from the data by themselves. It is a subset of artificial neural network [8].Deep learning improves with additional data.The data is represented as a hierarchy of concepts with each complex concept related to simpler concepts.

Convolutional neural network (CNN) is a subcategory of deep learning that is useful in image analysis.This has many layers that are used to learn features of an image [9].Convolutional neural networks mimic the behavior of the brain cortex, which contains a complex structure of cells [6].The architecture of deep CNNs allows for the formation of complex features to arise from simpler features (e.g. image intensities), therefore eliminating the need to detect specific features [6].CNNalgorithms are the foundation of new technology systems used in medical and dental image detection and diagnosis.

AI applications in dentistry have already started.Voice activated commands are commonly used with Amazon Echo and Alexa devices. Google home serves a similar function[10].With improved technology speech recognition has expanded to language translation.An emerging area is image analysis.AI is being used in radiology for diagnosis and treatment planning. It may help with caries detection. Customized dental restoration and orthodontic treatment may be performed with AI [10].

Over the past 10 years, we have already seen the transition from traditional films to digital radiographs, making dental imaging and diagnosing more efficient and easier to store.From

reading and analyzing radiographs, to predicting caries risk and doing treatment plans, many technological tools using deep learning are emerging in parallel with advancing AI. Researchers are looking to further improve these techniques, prompting questions about how this might affect how dentistry will be taught in the future.

AI has been used in performing everyday tasks in clinics.There are already several companies with products out for preliminary use [11].AI can be used to retrieve and analyze patient records. It also helps communicate and schedule patient appointments without the need for human-human contact [11].

In an ideal dental office with the use of technology, the hope is to expedite processes that are normally carried out by human assistants and dentists and not to replace the responsibilities.In the near future, AI will be able to analyze all components of the patient's history, such as age, gender, medical history, medications, and vital signs, along with their radiographs and dental 3D images to create the most precise and beneficial treatment plans for patients [7].By doing so, the time it takes to do these tasks will also be reduced significantly, allowing the dentist to spending more time with patients.

Deep learning CNN algorithms may be useful in the detection and diagnosis of dental caries in periapical radiographs [12].Lee et al used a CNN network with 3000 periapical radiographs. With this set of data, the CNN developed an algorithm to detect and diagnose dental caries.The diagnostic accuracies ranged from 82-89% between premolars and molars.

The use of cone beam computed tomography (CBCT) has also led to great success in developing algorithms specific to orthodontic analysis in patients with craniofacial deformities.Algorithms that weigh tooth-extraction/non-extraction decisions in orthodontic treatment also have excellent performance with the rate of coincidence between the recommendations given by the optimized model and the actual treatments performed was found to be 90.4% [13].

AI has also been found to be useful in restorative dentistry as well.After compiling various information from radiographs and other notes, AI technology was able to determine the most suitable material for long-term restoration of caries [14].

In the field of endodontics the accuracy of ANN was also evaluated by identifying the correct working length of root canals.The evaluation of endodontists was accurate in 76% of the teeth [15].The ANN found correct anatomic position in 96% of the teeth and was more accurate than endodontic markings compared to actual working length measurements using a stereomicroscope as a golden standard after tooth extraction [15].This is very important to those in clinical practice because it allows for the potential of long-term maintenance in teeth that were treated via root canal.

AI technology is also being utilized in dental schools.The goal is to achieve hands-on learning in the clinic through scanning by 3D intraoral scanners.Instead of having faculty members check the quality of the procedure and treatment performed by the student dentist, AI may be able to give unbiased and objective feedback to the student in the future.Columbia University College of Dental Medicine has already incorporated radio frequency identification (RFID) into instruments to understand usage times, installed cameras into the chairs to record student's providing treatment, and sensors to record the time of patients seating and departure [16].By incorporating the use of AI technology, dental students will be able to learn more effectively and objectively to provide the best care for their patients [7].With RFID faculty can analyze how long each instrument is used and in what sequence as to give feedback on the student's technique [16].The

tags also help instructors know the amount of supplies used, which is important information that dentists will need in future practice.

Another feature of AI in dental education is the use of digital technology in dental chairs.Rather than hydraulics to control chair movements, some of the functions of new dental chairs connect to the internet where the maintenance technicians can diagnose and troubleshoot any issues [16]. They are also able to collect a variety of biometric measures such as body temperature, heart rate, and sweat of the patient via sensors.This can potentially be useful in detecting the patient's stress levels during their dental visits.The information from these new chairs will help to teach students about patient-centered care and prepare them for a future that will increasingly emphasize the use of AI as tools.

At the Penn Dental Medicine students use gloves with sensors to practice things like extracting teeth [17].The data collected can be used to help students in their dental learning.

AI has allowed students to use CAD/CAM software to practice their manual dexterity skills.At NYU College of Dentistry students in the Removeable Prosthesis course have been using Dentca Academy software to practice teeth setup placement in dentures, a task normally done in lab with the proper equipment.

Dental and nursing students collaborate and train at the New York Simulation Center for the Health Sciences (NYSIM) through clinical simulations, telehealth, and virtual patient cases at NYU College of Dentistry [18].In conjunction with supervising faculty, the patient simulators are able to guide and give the students feedback on their responses to case studies.

Since the outbreak of the COVID-19 pandemic, much of conventional practices and protocols in dental schools have changed in order to protect patients, staff, and students.Schools understand that there is a need to change the curriculum in order to accommodate the changing times [19]. This is most evident in the shift from in-person lectures to online videoconferencing.

Clinical training has also been disrupted with COVID-19.Robot patients may be used for clinical simulations. Extensive programming is needed so that the robot patient simulates a real patient.

Tanzawa et al. [20] used 88 dental students at Showa University to implement an objective structured clinical examination, part of which was a task of 'cavity preparation using the robot patient'.Students were also given a questionnaire to assess responses to the robot patient.From the questionnaire, 95% of students agreed that the robot patient had educational value for risk management training and 89% agreed that it had educational value for cavity preparation. However, only 58% agreed that it had educational value for communication skills. The majority of students (95%) preferred the robot patient compared to traditional mannequins and 88% of the students considered robot patients necessary in dental education.

There are advantages and disadvantages to the use of AI in dental education.Although AI does increase efficiency and allow for students to continue learning during this time of social distancing, it can never truly emulate working on a physical manikin and holding high and slow speed handpieces.AI has shown some promise in this area but as mentioned before, there needs to be more data collected. Nassar et al. did a critical review on the use of computer simulation (CS) and virtual reality (VR) in dental education in operative and restorative dentistry.They found that CS was effective in teaching operative skills like cavity preparation and light curing. However, VR fell short in enhancing efficiency as it needed to work on giving more timely feedback [21].This suggests that although AI is a promising tool in dental education, there needs to be more data and research performed before it becomes integrated into standard practice.

AI is a transformational tool for health care that can help automate many health care functions resulting in improved clinical care for all patients.

3. CONCLUSION

Artificial Intelligence pertains to the idea of machines using statistical patterns in data to perform human functions. These functions can contribute to dental education and clinical dentistry.With the use of AI, a dental office can expedite processes that are done by the dentist and the assistant. AI can be used in dental treatment planning, image analysis, and record keeping.In addition, it can also be useful in analyzing patient's history and medications.These routine tasks do not need to be performed by the dental workforce. Any AI application will help to improve the efficiency and care of dentistry and automate health care functions.

AI does not replace the dentist, but can be a helpful addition to diagnosis. It can be used to make the dentist's job more efficient. Ultimately the dentist is in charge of patient care.

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