Artificial intelligence: The future of prosthodontics.

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Abstract

Technology has had an increasing impact on every facet of life and society. It has made almost every aspect of our lives easier, more productive, and delightful. Various aspects of technology are transforming dentistry for the better, Artificial Intelligence (AI) is one of them. It describes how technology develops software or a machine that can easily mimic human intelligence and perform specific activities. Nowadays, AI is gaining popularity because health science has adopted this dynamic technology. It executes various services precisely and saves time and money. AI is slowly digging its head in the sector of Prosthodontics and will continue to do so. It has shown the potential for providing a reliable diagnostic tool for tooth shade selection, automated restoration design, mapping the tooth preparation finishing line, but they are still in development. It is also helpful in patient documentation, diagnosis, patient management, health monitoring, robotic tooth preparation, and implant planning. So, the advancement of computer technology has introduced AI in health science that mimics human intelligence to accomplish miscellaneous work. So, applications of AI are widespread. In the recent pandemic, the COVID-19 era contribution of AI is ongoing. However, additional studies are needed to develop further and assess their clinical performance.

Keywords: Artificial Intelligence, tooth shade selection, automated restoration design, robotic tooth preparation, implant planning.

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Introduction

The human brain is a complex structure consisting of networks of interlinked neurons which transmit signals throughout the body. Since time immemorial, its complexity has made it one among the foremost intriguing human body structures for researchers.[1] The human brain has been one among the foremost fascinating structures to researchers and technologists for as long as history dates back. Moreover, over centuries, newer technologies have developed supported principles that attempt to mimic the functioning of the human brain. However, a machine which will think sort of a human remains a dream.[2] The sector of science and engineering has witnessed great inventions supported the principles that attempt to simulate the functioning of the human brain. This constant search has led to an advanced breakthrough to what is known as Artificial Intelligence (AI).[1] To scale back the stressful work and staffing, the event of artificial intelligence are often a boon to dental health care professionals.[4] John McCarthy, a mathematician, coined artificial intelligence in 1955 and is widely known as the father of artificial intelligence. He picks

up this term to elucidate the potential of machines to perform tasks which will fall within the range of "intelligent" activities.[4] AI is termed as a capability of machines that exhibits a sort of its intelligence. The aim here was to develop machines which will learn through data to unravel problems.[4] AI features a high capability to predict and control infection and save the additional step of the dentist. By using this system, doctors and staff achieve more efficiency and effectiveness. It measures pain within the patient teeth and helps to provide proper medication. It allows for the acceptable implementation of braces to straighten patient teeth and find a hidden cavity in teeth with the assistance of a scanned image. The dentist can store data of their patient, including diagnosis and therapy. Further, AI can predict the internal infection of teeth and pain time. It also provides the best simplest treatment and the accurate date of appointment.[5]

Key Aspects of AI:

Machine learning:
With machine learning, computers can infer their own rules using advanced algorithms. It's utilized in e-commerce, automobile, internet search, sensor, robotics, speech recognition, image recognition, etc.[6]
It is categorized into four types –

- **Supervised learning:** The pc features a reproducing data set correctly labeled by a talented human.
- **Unsupervised learning:** The pc doesn't use a reproducing data set, but it tries to take up the info without human guidance, separating the info into clusters or groups.
- **Semi-supervised learning:** It is difficult to supervise every dataset, so when a outsized amount of combined unlabelled data with a little amount of labeled data, the precision of machine learning are often improved.
- **Reinforced learning:** Hal Varian stated that it's a sort of sequential computer experimentation to reach a goal while interacting with a dynamic external environment.[7]

Neural network:
As the name suggests, it uses artificial neurons to set the algorithm and works almost similarly to the human brain. Neural networks are developed based on brain structure, and as the brain, they can recognize the pattern manage data and learning. It is a computing system based on the biological neural network that creates up the human brain. Neural networks are not dependent on any specific computer program written for them, but they can progressively learn and improve their performance.

A neural network comprises a set of units or nodes called neurons. These neurons are connected one to the other utilizing the synapse connection. A neuron can transmit a signal or information to a different neuron nearby by the synapse. The receiving neuron can receive the signal, transfer it, and signal subsequent one. Until producing an output, the method continues.

The most important advantage of artificial neural networks is that this type of system solves problems too complex for conventional techniques and those that do not have an algorithmic solution or are too challenging to be used.[8] They are helpful in various areas of medicinal science like diagnosis of diseases, biomedical identification, image analysis, and data analysis. In dental practice also, the clinical support systems are actively progressing.[9,10]
A study done by Kim et al. used an man made neural network to create a model which will anticipate toothache based on the association between toothache and daily toothbrushing frequency, toothbrushing time, use of dental

floss, toothbrush replacement pattern, undergoing scaling, and other factors like diet and exercise.[11]

Deep learning:

Deep learning is a machine learning component that utilizes different computational layers in a deep neural network to scrutinize the input data. Deep learning aims to construct a neural network that automatically identifies patterns to enhance feature detection.[4,12] It is a kind of machine learning that utilizes a network with different computational layers to analyze the input data. Deep learning is additionally referred to as a standard neural network. They collect features from the abstracted layer of filters and are primarily wont to process large and sophisticated images. [12]

Deep learning is a subdivision of machine learning based on learning pattern representations from data. Modern deep learning techniques turning into more complex involving tens or even hundreds of layers of representations (Chollet, 2017). Recently, deep learning has made significant progress and advancement, specifically in image recognition and object detection. Convolutional Neural Networks (CNNs) are a category of Neural Networks that have proven very efficacious in image recognition and classification. CNN's have successfully identified objects, scenes, and faces and provided vision in robots and autonomous self-driving cars. Recently, CNN's training to predict lung cancer and detect brain tumors on CT scans with high accuracy results. Traditional machine learning requires a subject matter expert to extract features from training data manually. In a deep learning framework, the algorithm automatically learns useful features directly from the training data, such as image, text, patterns, digital signals, etc.[13]

Deep learning is nothing but a software that mimics the network of human brain neurons. It is a subset of machine learning called deep learning because it uses deep neural networks. The machine utilize different layers to learn more about the data. The number of layers in the model represented the depth of the model. Deep learning is the new state of the art in terms of AI. In deep learning, a neural network operates the learning phase. The stacked layer on top of each other architect a neural network.[14] (Fig:1)

Applications in dentistry:

Proper medication:

- Provides information about the proper medication to a patient with the simplest way of treatment
- Inform the proper time of medication and also provide information about the side-effects if one do not follow time

Book appointment:

- Through this intelligence, the dentist can book an appointment without any human involvement
- Trace the level of disease and fulfill the regular task of proper appointment of time
- This technology applies the fastest pace to satisfy the regular task in dentistry

Communication:

- AI is applied directly to communicate with the patient
- Control all information systems in the hospital using different algorithms
- Maintain machine communication

Planning of best treatment:

- AI system has great potential for the design of best treatment of the complicated cases in dentistry

- Provides the best treatment at the proper time with high accuracy, which fulfills different challenges faced by dentistry
- Helping dentists to design smiles in minutes.

Detection of teeth loss:
- This technology automatically calculates the loss of patient teeth by using computer software
- It provides the cause of any disease in teeth and its best way of treatment

Monitor high-risk cases:
- Easily monitors the high-risk patient and generates decisions within a couple of seconds
- Helpful to monitor and decision making during robots performing surgery

Accurate decision:
- AI system collects background information about the patient's disease
- With the assistance of past medical history, it makes an accurate decision of the treatment

Teaching and learning:
- AI system is the best technology to automate necessary activities in education
- Dentistry students can learn the best methods of treatment of complex cases
- Provides the best way to point out the mistakes and improves the dentistry students
- In the longer term, AI can improve the teaching and learning process and may change the role of an educator.

Artificial Intelligence (AI) applications in Prosthodontics:

CAD-CAM and AI:

In the field of Prosthodontics, both the patient and clinician expect a gold-standard quality in prostheses. A huge set of workforce and machinery works behind the right output. Sometimes the workforce alone can fail to satisfy the expectations. The computer has this designing and manufacturing unit that permits us to design mill or print according to the patient's desire to save lots of time and energy. AI's considerable bonus is the ability to assess and learn from the many doctor-approved crowns in the database, with cases added to the cloud regularly. [3]

AI in Implant Planning:

Dental implant treatment planning are often most successful if we combine the CBCT image and intraoral scan. The introduction of AI in implantology can merge both and design future prostheses.[15] Using AI systems in radiographic interpretation provides many advantages to the physician and can contribute to solving this problem. Also, it's going to prevent wrong diagnosis and treatment planning (which could also be due to work intensity, carelessness, or inexperience) unnecessary loss of time/workload in dentistry.[16] The Finnish Center for Artificial Intelligence (FCAI) researchers, the University Hospital of Tampere, Planmeca, and the Alan Turing Institute proposed a new model to accurately and automatically identify the exact position of the mandibular canal for dental implant operations. Implant systems are often detected using deep learning-based object detection from panoramic radiographic images.

Clinical Environment and AI:

Augmented reality can improve patient comfort and reduce dental anxiety.AI will enhance its skill in scheduling the appointment timing, temperature setting for the patient, the music and therefore the entertainment of their taste, and even the lighting that relaxes the patient.[17]

AI Used in Zirconia Crown:

One study by Lerner et al. included 90 patients restored with 106 implant-supported monolithic zirconia crowns (MZCs) placed in the posterior area.[18] They investigated the standard of interproximal contact points, occlusal contacts, and chromatic integration and judged the chromatic integration, survival, and success rates of MZCs. Their study captured the primary optical impression using the CS 3600 R intraoral scanner and modeled the individual zirconia abutment in CAD software (Valletta R, Exocad, Darmstadt, Germany). Noticeably, during the production of the zirconia crown, the researchers utilized a totally digital protocol that employed AI to automate margin line design and successfully fabricated MZCs cemented on customized hybrid abutments. As reported, the 3- year survival rate and success rate of the MZCs made via a complete digital workflow were 99.0 and 91.3%, respectively.[19]

AI in Tooth Preparation:

Tooth preparation for crowns and bridges is daily work for a dentist. It is still challenging work, even in the case of an experienced dentist. The main challenge is to make sure that there is enough space for the restoration with the minimum amount of tooth preparation. The thought of employing a robotic arm to help dentists in preparing teeth is attractive and wise.[20] The mechatronics system can assist dentists in tooth preparation. The robotic arm can help the dentist utilize the tool smoothly and precisely during teeth preparation. The mechatronic system can minimize handshakes caused by fatigue and reduce the danger of iatrogenic dental injuries. The dentist's position accuracy was improved by 53% using mechatronic system because the mechatronic system can provide support and stability when handling dental drills. Therefore, the robot's high precision, skill, and speed can finally overcome the shortcomings of manual operation and improve clinical efficiency.[21] Yuan et al. developed a robotic oral tooth preparation system to enhance its quality, precision, and clinical efficacy to overcome the challenges of traditional manual methods.[22,28]

AI in Digital Impression:

Artificial intelligence is especially utilized in dental restorations to get digital impressions of the patient's teeth and soft and hard tissues. It obtains colorimetry almost like natural teeth and uses artificial intelligence to design restorations to get readable three-dimensional data.[23]

AI Used in Shade Matching:

In aesthetic dentistry, shade reproducing and color matching play an important role. It's difficult for patients and dentists to settle on the precise shade, appropriate material, and suitable configuration to form the restoration according to natural tooth color. Predicting computer color matching of dentistry is predicted on a backpropagation neural network (BPNN). However, BPNN has disadvantages like unstable and low accuracy. Li et al. introduced a genetic algorithm (GA) to optimize initial weight and thresholds in BPNN to reinforce the matching accuracy.[24,25]

Maxillofacial Prostheses and AI:

The bionic eye, developed in the US, has already been tested in a dozen patients with vision damages. Without the necessity for surgery, these devices can benefit people in achieving vision with the assistance of artificial intelligence. During this way, a sensible camera mounted on special glasses allows the user to read text or recognize faces. With the utilization of a small headset, the expertise processes the knowledge seized by the camera and converts it into audio, which conducts to the ears of the visually impaired

person. Patients can lose the sensory capacity due to amputation of limbs. Development of artificial skin by researchers from the California Institute of Technology and the federal polytechnic school of Zurich, changing this scenario. The tissue composed of a thin, transparent film of pectin and water senses temperature variations between 5 and 50 degrees Celsius. Artificial olfaction plays an important role in robotics by mimicking the human olfactory structure which will identify smells that compare to various fields, like environmental monitoring, disease diagnosis, public security affairs, agricultural production, and the food industry.[26]

Tongue Controlled Devices:

Our goal has been to develop non-invasive, self-controlling, and precise tongue-computer interfaces which will catch up on arm and hand functions, which is the uppermost priority for severely disabled individuals. The tongue drive system can analyze the motions of the tongue in the oral cavity and act based on the commands specified within the guidelines. These commands can then be used to access a computer, drive a wheelchair, or control the user's environment.[27]

Advantages of Artificial Intelligence:

- Reduction in human error.
- Performing tasks in almost no time.
- Logical and feasible decisions which result in an accurate diagnosis.
- Procedures are often standardized.

Limitations of Artificial Intelligence:

- Mechanism/system complexity.
- Costly setup.
- Adequate training is required.
- Data is usually used for training and testing, leading to "data snooping bias."
- The outcomes of AI in dentistry are not readily applicable.
- Lack of providence like experts.
- Absence of human compassion.

Conclusion:

The advancement of technology introduced artificial intelligence in health science that mimics human intelligence is to accomplish miscellaneous work. AI isn't a myth but our future in dentistry. Its applications in every area are growing day by day. While it cannot replace the dentist's role as a dental practice, it is not about disease diagnosis. Still, it also includes correlation with various clinical findings and the treatment delivered to the patient.

Nevertheless, a transparent understanding of the techniques and concepts of AI will indeed have an advantage in the coming future. Artificial Intelligence shall be an important part of prosthodontics in the future. AI only support the prosthodontist in performing the tasks professionally but in no way exchange the intellect of the human knowledge, skill, and treatment planning. Applications of AI are widespread. In the recent pandemic, the COVID-19 era contribution of AI is ongoing. However, additional studies are needed to develop further and assess their clinical performance.

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FIGURES:

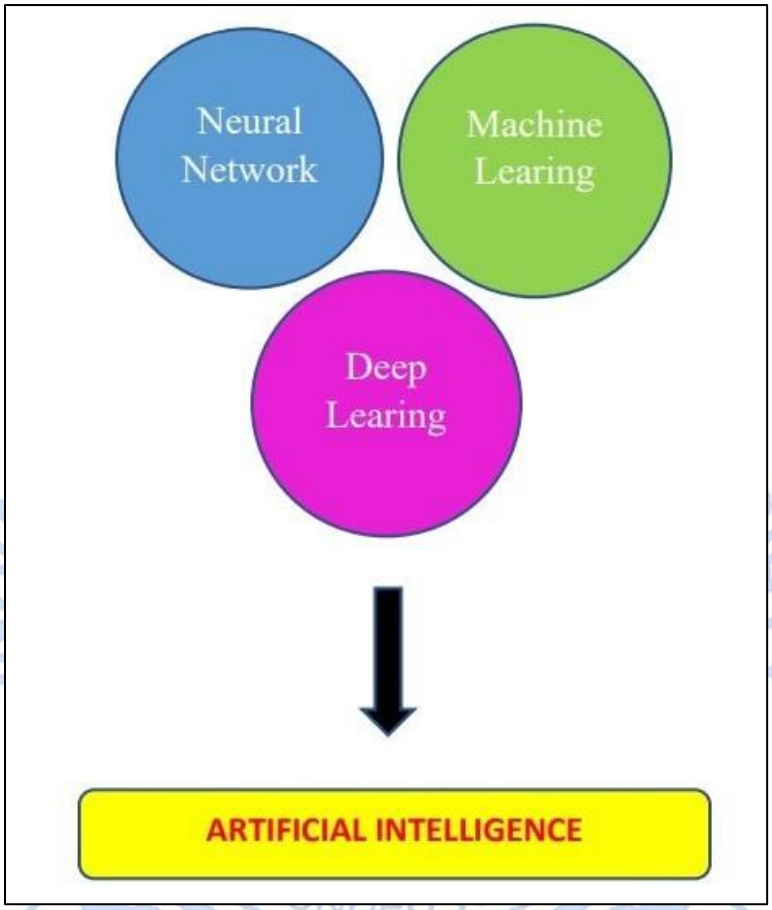

Figure 1: Key aspects of Artificial Intelligence