Review Article

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# Artificial Intelligence in dentistry: An upcoming asset

**Abstract:**
The field of artificial intelligence is relatively young but has still came a long way in the field of medicine and dentistry. Since AI can mimic the intelligence of humans to undertake complex predications and decision-making in healthcare sector, it is being used in dentistry for identification of normal and anomalous structures, disease diagnosis and treatment outcome. This review aimed to discuss the various application of AI in dentistry. We are ushering in a modern age, and AI is undeniably the future of dental practice, where it is expected to establish high-quality patient care and innovative research and development, facilitating advanced decision support tools. The key to AI advancement is creative inter-professional coordination among medical professionals, scientists and engineers. Ai has shown accuracy and precision in various aspects. However, before incorporating AI models into our routine dentistry, it is still required to certify their cost-effectiveness, dependability and applicability.

**Key-words:** Artificial intelligence, neural network, deep learning, dentistry

## Introduction:

Artificial Intelligence is a technology that enables computers and machines to simulate human brain. It imitates intellectual behavior, critical thoughts, and decisions making that are characteristic of human brain using technology.[1] The term 'artificial Intelligence' was coined by John McCarthy in 1956 at a conference at Dartmouth. In 1959, Samuel, one of the pioneers of Machine Learning defined Machine Learning as "a field of study that gives computers the ability to learn without being explicitly programmed". He taught a computer to play chess better than human.[2]

## Types of Artificial Intelligence:

Artificial Intelligence can be broadly divided into two categories:

A. AI based on capabilities

B. Ai based on functionalities

**A. AI based on capabilities:** There are three types of Artificial Intelligence based on capabilities

## Narrow Artificial Intelligence:

It is also known as weak AI because it is trained to perform a particular task. However, it cannot perform outside of its defined task

## General Artificial Intelligence:

It is also known as Strong AI. General AI is can perform any intellectual task with efficiency like human. It would have ability to learn, understand and function similarly to a human.

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### Artificial Super Intelligence:

It is a level of Artificial Intelligence in which computers are able to outperform humans in any task due to cognitive capabilities. Super Intelligent AI would be able to learn, think, reason and make decisions.

## B. AI based on functionalities:

### Reactive Machines:

These machines have no memory and are designed to perform a specific task. Since they cannot recollect previous memories, they can only work with presently available data.

Example of Reactive machine is IBM Deep blue that defeated chess grandmaster Garry Kasparov in 1997.

### Limited Memory:

Limited memory machines are able to store past information and outcome for a short period of time, to decide what might happen next. Self Driving car is an example of limited Memory machine which can store the speeds of vehicles in its vicinity, their respective distance, speed limits and other relevant information for it to navigate through the traffic.

### Theory of Mind:

A person experiences different emotions and feelings that have a complete impact on their behavior. AI with Theory of Mind functionality would understand the thoughts and emotions of human beings. These AI systems in nearby future will need to modify their behavior to be able to interact with us. These types of AI have ability to analyze voice, facial expressions and other data to monitor and respond appropriately to human on their emotional condition. Example of this technology is Sophia (2016) which is a robot that looks like human, is able to interpretation of human's emotion and conversation with them. This type of AI could be useful in applications such as customer service.

### Self awareness:

The Self awareness AI is one step ahead of its predecessor. It not only understands human emotions but have beliefs, requirements and emotions of its own. Self awareness AI has human- level consciousness and equivalent human intelligence. At this moment, this AI has not been developed.

## Components of Artificial Intelligence:

### 1. Machine Learning:

Machine Learning is a subfield of Artificial intelligence. It relies on various algorithms to train computer systems on historical data. When exposed to new data inputs, ML can make accurate predictions and decisions on their own. (Figure 1)

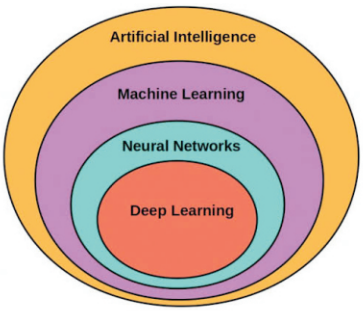


Figure 1: Components of Artificial Intelligence

### It is further subdivided into four types:

(a) Supervised ML

(b) Unsupervised ML

(c) Semi-supervised ML

(d) Reinforcement ML

### (a) Supervised Machine Learning:

This type of ML uses labeled datasets to train machine, which predict outputs, but require supervision to train models. Some of the applications of supervised learning are Medical Diagnosis, Image segmentation, speech recognition, spam detection and fraud detection.

### (b) Unsupervised Machine Learning:

Unlike supervised learning, it uses unlabeled datasets to train machines. In unsupervised learning no supervision is required to generate output. It does not require dataset to train machine. The aim of unsupervised learning is to categorize the unsorted dataset according to differences, patterns and their shared characteristics. Applications of unsupervised learning are anomaly detection, recommendation system and to detect plagiarism and copyright in text data for articles using document network analysis.

### (c) Semi-supervised learning:

Semi-supervised learning comprises of both supervised and unsupervised machine learning. Although it uses both labeled and unlabeled datasets to train models to predict the output, mostly contains the unlabeled datasets. Applications of Semi-supervised learning are speech analysis and protein sequence classification.

### (d) Reinforcement Learning:

In reinforcement learning, machine learns from experience or past data and does not use labeled data. It can be used in resource management, robotics and video games.

## 2. Neural Network:

Neural Networks are subset of Machine learning and are the backbone of deep learning algorithms. They are called "neural" because they mimic how neurons in brain signal one another.

An artificial neural network (ANN) is a machine learning algorithm, which is inspired by biological neural network. Artificial Neural networks are made up of node layers – An input layer, one or more hidden layers and an output layer. Each node is an artificial neuron that connects to the next, and each has a weight and threshold value. One node gets activated when its output is above threshold value. It thereby sends data to next network's layer. No data passes along if output is below threshold value. (Figure 2)

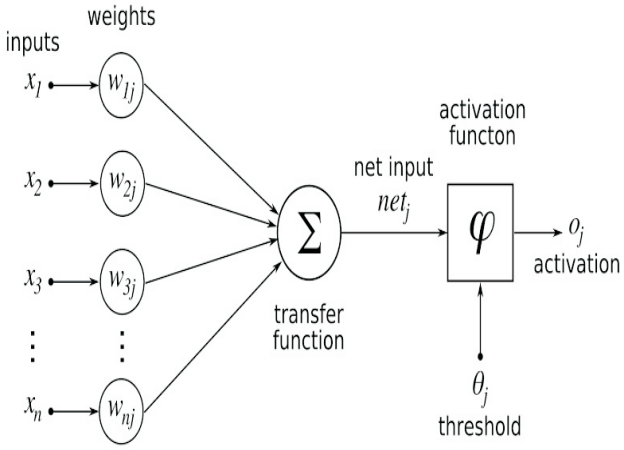


Figure 2: Structure of Artificial neural network

## Recent advances in artificial neural network

### (a) Convolutional neural network:

Convolutional neural network is a special type of neural network that is designed for processing of images or other spatial data. Convolution neural network contains a three dimensional arrangement of neurons instead of standard two dimensional array. The first layer is called convolutional layer. Each neuron in the convolutional layer only processes the information from a small part of visual field.

The convolution operation uses a filter, over the input image and produce map. After the convolution layer, there is pooling layer which is responsible for the aggregation of the maps produced by convolutional layer. As the last layer, the CNN have a fully connected dense layer, to generate valuable output. This type of neural network is commonly used for advanced cases such as facial recognition, Optical character recognition and natural language processing. (Figure 3)

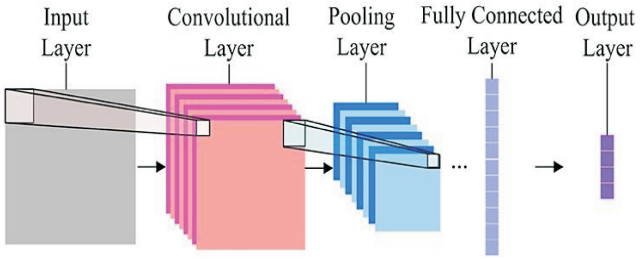


Figure 3: Structure of Convolutional neural network

### (b) Recurrent Neural Network:

Recurrent neural network is another special type of neural network that is designed for processing sequential data. It has one or more recurrent layers, which have loops or cycles that allow the nodes to store and reuse information from previous inputs. In the recurrent neural network model, each node behaves like a memory cell, which work to ensure intelligent computation and implementation by processing the data they receive.

RNN has a strong feedback loop. Hence neural network solutions can 'self-learn' from their mistakes. If an incorrect prediction is made, the system learns from feedback and tries to make the correct prediction while passing the data through the algorithm the second time. (Figure 4)

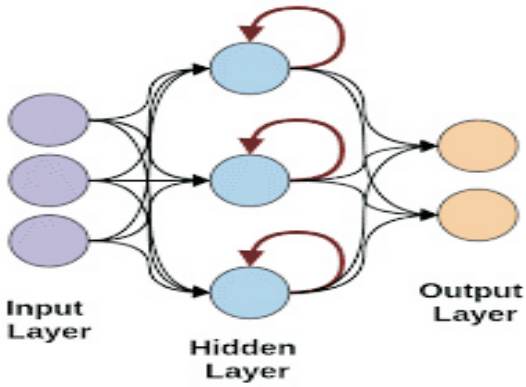


Figure 4: Structure of Recurrent neural network

### (c) Long Short memory network (LSTM):

These types of network can learn and memorize long term dependencies in data and retain past information over time.

They are used in time series forecasting

### (d) Generative Adversarial Network (GAN):

These are the type of network capable of generating new data instances that look similar to the training data. GAN has two components: A Generator, which learns to generate fake data and a Discriminator, which learns to distinguish between

generator's fake data and the real sample data. GAN are widely used by video game developers to increase the resolution of images and textures.

### 3. Deep Learning:

Deep learning is a subset of machine learning that uses multi-layered neural network, called deep neural network, to simulate the complex decision making power of human brain.[3]. These networks are trained using large amount of data to identify patterns and make predictions. Most common type of deep neural network are Convolution neural network (CNN) and Recurrent neural network (RNN).

Structure of neural network consists of input layer, hidden layer and output layer. That is the main difference between basic neural network and deep learning. A basic neural network (ANN) might have one or two hidden layers, while a deep learning network might have dozens or even hundreds of layers. Increasing the number of layers and nodes may increase the accuracy of network.

Deep learning can be useful to solve many complex problems such image recognition, voice recognition and natural language processing. (Figure 5)

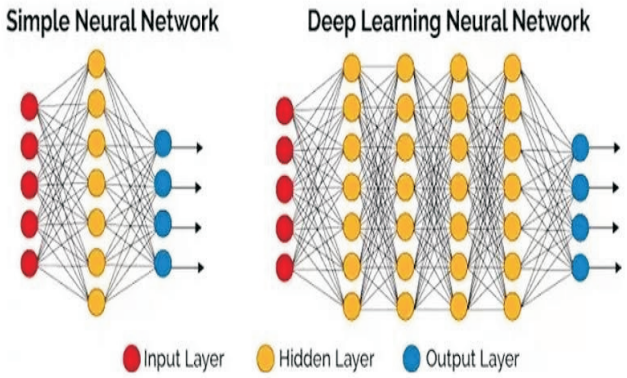


Figure 5: Difference between Artificial neural network and Deep learning neural network

### 4. Generative AI:

Generative is a form of artificial Intelligence in which algorithms automatically produce content in the form of text, images, audio and video. These systems have been trained by massive amount of data, and work by predicting the next word or pixel to produce a creation. Generative AI uses Generative adversarial network (GAN) to create new content.

### Examples:

**Chat GPT:** This language model has a foundation of GPT architecture that generate text

**DAL-E2:** This model generates images from text prompt.

**Midjourney:** It is a text to image generator Tool.

**Gemini (Previously called Bard):** It is a generative AI Chatbot created by Google, based on its model of same name. It is able to answer questions asked by users or create new content from text or image prompts.

**Synthesia:** This AI tool generates videos using text inputs.

### Applications of AI in Dentistry:

### Artificial Intelligence in Patient Management:

AI based virtual dental assistants can carry out tasks in dental office with more accuracy and fewer mistakes, and it requires less manpower for their functioning than an actual human. It can help with clinical diagnosis, treatment planning, booking and coordinating regular appointments, and notification to patients and dentists about check-ups.[4,5]. It can also create a database that is highly helpful in informing the dentist about the patient's medical history, any allergies and habits that may have, such as smoking and drinking.[ 6,5]

### Artificial Intelligence in Dental Education:

The area of intelligent tutoring system has advanced significantly since 1980. It is helpful in training of students, as it replicates for the clinical work on patients, thereby eliminating any ill effects involved by doing the same on a live patients. Some of the robots have developed, that mimic typical patient gestures and responses with a realistic silicone skin, ability to blink, roll eyes, sneeze, gag reflex and even display fatigue from having to keep mouth open for long.[5,7]

Preclinical virtual patient feedback to students has significantly improved with introduction of artificial intelligence in intelligent tutoring systems such as Unified Medical Language System (UMLS).[6,5]

### AI in Pediatric Dentistry:

Behavior Management is a challenging task in pediatric dentistry. Behavior management can be better achieved through devices such as 4D goggles, animations, movies and virtual reality based games.[8]. AI enabled pain control technology is a smarter way towards an injection free pediatric dental practice. In children, anesthetic nanorobots if introduced in a suspension into the quadrant of interest, will reach the pulp via gingival sulcus, lamina propria and the dentinal tubules and block the action potentials in the sensory nerves upon activation by the dentist till the desired duration and they can command the robots to deactivate.

**Prediction model:** Genetic Algorithms (GA) and Artificial Neural Network (ANN) have found useful in prediction and interpretation of biological activities such as dental caries.

If a proper training database representing values for a particular population is established, GA and ANN can be used to predict the size of unerupted teeth.

An artificial neural network derived model was used in a study, to predict toothache on the basis of its association with tooth-brushing time, daily tooth-brushing frequency, toothbrush replacement pattern, use of dental floss, undergoing scaling and other epigenetic factor such as diet and exercise. The result of Toothache Predictive Model was of great accuracy which recognized oral hygiene, adequate eating habits and prevention of stress as the essential factors in preventing toothache.[7,9]

Analysis of space loss is essential in prediction of future arch form and devising the treatment plan. Regression equations from measurement derived from diagnostic cast and radiographs were developed to meet this need with varying success.[7]

In this era of technology, institutions like 'Kolibree Artificial Intelligence' are incorporating AI in toothbrushes to making a smarter one. A smart toothbrush is incorporated with three-dimensional (3D) motion sensors, a gyroscope, an accelerometer and a magnetometer that detects the location and angle of the brush. The smart toothbrush then analyzes data to provide instant feedback to the user. The patient or the parents of the children gets to know the oral hygiene status via this technology.[10]

## AI in Conservative Dentistry and Endodontics:

Root Morphology: A dentist must have a comprehensive understanding of root canal morphology to provide successful root canal therapy. The ability of Deep Learning (DL) algorithm helps in evaluating root canal morphologies and their three dimensional alteration after instrumentation.

Vertical Root Fracture: Diagnosis of vertical root fracture is a challenging task.ML, CNN and probabilistic neural network is helpful to diagnose vertical root fracture.

Periapical Lesions: Accurate diagnosis of periapical lesions can be achieved by AI.

Working length determination: ANN diagnosis method helps to improved radiographic working length determination.

Retreatment prediction: The case based reasoning (CBR) system is able to forecast the outcome of retreatment with reasonable accuracy. [11]

Prediction of color changes: It is possible to predict the color changes obtained by bleaching before the procedure, with the help of AI.[12]

Restorative material: Nanorobots can be used for caries excavation and subsequent restoration with tissue engineered biological materials resulting in a near original form of teeth with respect to shape and thickness.[7]

## AI in Oral Radiology:

AI can be integrated with imaging technologies such as MRI, CBCT, IOPAR, RVG to recognize any abnormalities, even slightest deviation from normalcy that might go unnoticed from human eyes.[13,14,6]

## AI in Oral and Maxillofacial Surgery:

Artificial Intelligence has also found extensive use in the field of maxillofacial surgery.[12]. AI algorithms can analyze patient's data and images to plan the optimal placement of dental implants, which can improve the accuracy of implant placement henceforth, reduce the risk of any complications. AI can assist in design of surgical guides used in dental implant surgery. These guides are custom made to fit a patient's mouth and guide the implant placement. AI can help dentists create more accurate and precise guides.[15]

Extent of facial swelling has been predicted by Zhang et al using ANN models to anticipate postoperative facial swelling due to extraction of impacted mandibular 3$^{rd}$ molars with 98% accuracy. This would greatly benefit clinicians for determining the prognosis of treatment. A study by Yilmaz et al. used handcrafted engineered features in CBCT to differentiate periapical cysts from keratocysticodontogenic tumors with 94% accuracy.[8]. In another study by Patcas et al., it was found that effect of orthognatic surgery on facial attractiveness and age estimation can be assessed fairly well with deep learning.[12]

## AI in Prosthodontics:

A design assistant known as RaPid, has integrated with various factors like anthropological calculations, facial measurement, ethnicity and patient preference, is helpful to provide esthetic prosthetics.[5,6]

It is possible to predict the facial soft tissue changes in patient that will occur after complete denture fabrication with the help of AI.[12]

Virtual reality simulation (VRS) technology has been employed to simulate facial profiles post treatment. This helps dentists to efficiently design the treatment plan, provide

better aesthetics and also act as a motivational tool for patients. [8]

## AI in Periodontics:

Early diagnosis of periodontal disease by conventional radiograph has limited accuracy, which can be analyzed by neural networks. It may be useful tools for assessing radiographic bone loss and obtaining image-based periodontal diagnosis. ANN can also be used to accurately diagnose Aggressive Periodontitis or Chronic Periodontitis using relatively simple and easily obtained parameters such as leukocyte counts in peripheral blood.[16]

## AI in Orthodontics:

AI is helpful in orthodontic diagnosis and treatment planning. Conventional impressions are replaced by digital impression with the introduction of intraoral scanners. With the help of these 3D scans and virtual models, aligners can be printed with customized treatment plan. After collection of data, AI creates an algorithm to detect which tooth needs to be moved, at which point how much pressure will be required. 3D aligners can execute precise treatment with the added advantage of reduced treatment time, lesser number of appointments and progress monitoring.[14,13,17]

## Limitations:

Despite the outstanding results of AI techniques they are still require an enormous personal data from patient, for training of AI algorithms. AI must be integrated into dental practice; however the legal framework must be formed to protect personal and confidential information. On 13th March 2024 European Union passed world's first AI ACT for safeguarding fundamental rights.

Dentistry is a set of benefit from some of the most fascinating uses of AI. Dental chairs are now available with voice command. Dental chair light with AI software called Bio/Screen oral examination light is available which can differentiate healthy and unhealthy tissues easily. The recent inventory is 'Hapitc Glove' with sense of touch to fulfill the human touch relation.[18]

## Conclusion:

Incorporation of AI in dentistry increases the efficiency and better patient outcome. Future clinical applications of AI techniques might be feasible but still requires more fundamental research.

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