Review Article

# Artificial Intelligence – A Newer Vista in Dentistry

**Ranjith Raveendran[1]*, P Suresh[2], Sameera G. Nath[3]**

[1]Department of Orthodontics and Dentofacial Orthopedics, Government Dental College, Kannur, Kerala, India.
[2]Centre for Industrial Consultancy, Interdisciplinary Research, Innovation and Entrepreneurship(CIDRIE), Muthoot Institute of Technology and Science, Ernakulam, Kerala, India
[3]Department of Periodontics, Government Dental College, Kozhikode, Kerala, India.

## Abstract

Artificial intelligence (AI) is one of the newest fields in science and engineering. It refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions. In modern times, the applications of AI include health care as well. The present review outlines the progress and potential dental applications of AI in diagnosis, treatment, and disease prediction and discusses its impact on dentists, with the objective of creating a support for future research in this rapidly expanding arena.

**Keywords:** Artificial intelligence, Dentistry, Diagnosis, Disease prediction, Review, Treatment.

## Introduction

The world has changed dramatically. There have been significant scientific and technological transformations in every field. Modern medicine and dentistry are influenced by these advancements. One of the recent breakthrough is artificial intelligence (AI).[1] Human brain is a fascinating structure, center of intelligence, and simulating that it is a mystery to science. Turing machine developed by Alan Turing in 1936 can imitate human responses under certain specific conditions. This concept provided fundamental basis for the development of AI.[2,3] The aim of this article is to review the current application of AI in the field of dentistry based on electronic search on various data bases such as Google scholar, PubMed, and Scopus to outline the progress and potential applications of AI in diagnosis, treatment, disease prediction, and discusses its impact on dentists, with the objective of creating a backdrop for future research in this rapidly expanding arena.

## The Emergence of AI

AI is one of the newest fields in science and engineering. Work in this field gained momentum soon after World War II. The name, "AI," was coined by John McCarthy in 1956.[3] AI refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions.[4] Richard Bellman, a mathematician in 1976, defined AI as the automation of activities associated with human thinking abilities, which includes learning, decision-making, and problem solving.[5] AI as a science is very broad and encompasses various fields, including reasoning, natural language processing, planning, and machine learning (ML).[6]

An American Psychologist Frank Rosenblatt, on the basis of biological principles of neurons, developed the concept of *Perceptron* in 1957-1958. It is a mathematical model of a biological neuron, in which the electrical signals received from other neurons by dendrites are represented as numerical weighted sums of inputs, and provides outputs which are transmitted as outputs just as axons transmit the output of the biological neuron to the next neuron, as shown in Figure 1. This development of perceptron can be considered as a beginning of AI in the field of medical science.[7]

In 1974, Paul Werbos, an American social scientist, in his Harvard doctoral thesis explained the concept of Back Propagation that paved the foundation for the development of various computer programs and algorithms.[8-10]

In modern times, the real-world current applications of AI has helped improve the human life.[3] Examples include Amazon Alexa, Cortana, Google Assistant, Siri, and Bixby which are virtual assistants helping people complete their daily tasks and promise even greater cognitive computing in future.[11-13]

**Address for correspondence:** Dr. Ranjith Raveendran, Department of Orthodontics and Dentofacial Orthopedics, Government Dental College, Kannur - 670 503, Kerala, India.
Email: ranjidr@gmail.com

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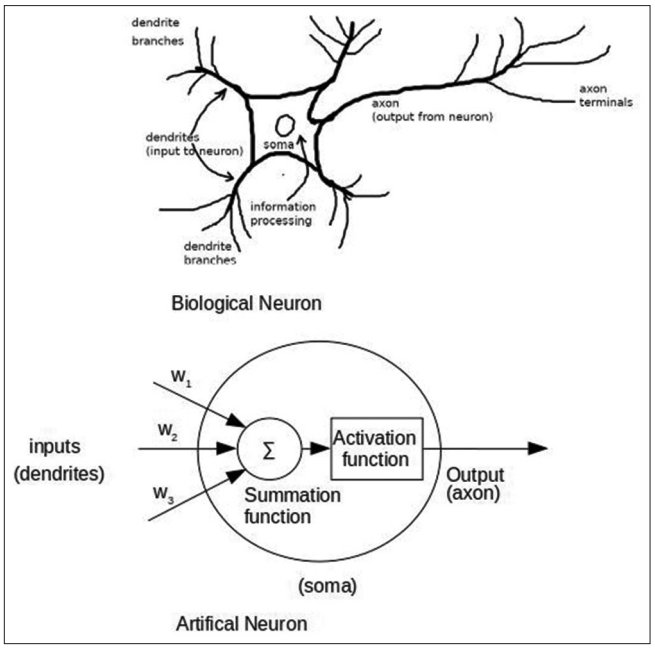


**Figure 1:** Structure of biological neuron and artificial neuron

AI with the help of various computer programs can improve patient care with better diagnosis and treatment planning and can reduces various errors occurring in health-care practice.

In this recent COVID-19 times, many states in India have utilized AI for monitoring or tracking mass violators of COVID protocol. Center of AI and Robotics, DRDO had developed an AI-based intelligent COVID detection application software ATMAN AI[14] that can classify images under different categories such as "normal," "COVID-19," and "pneumonia," using chest X-rays. Similarly launched COVIRAP (IIT Kharagpur) and qXR(Qure.ai, Mumbai) are diagnostic techs to detect infectious diseases such as COVID-19.[14] Tata Consultancy Services have also been using AI for the screening of X-ray plates and diagnosis of coronavirus. Accenture and Microsoft partnered with the Indian Government's Digital India Corporation to equip citizens with My Gov Saathi, an AI-chat bot to provide accurate, useful, and latest information related to COVID-19.[14]

AI has many subfields, namely, ML, artificial neural networks (ANNs), convolutional neural networks (CNNs), and deep learning (DL).[15] ML is an emerging topic in dentistry which facilitates computers to act without being explicitly programmed and can solve various issues without human input based on neural networks and DL. There are three primary stages in ML, namely, data preparation (data collection, data wrangling, and data enrichment), feature engineering (manually looking at data to find correlations if any), and algorithm selection (choosing suitable algorithms for the problem at hand, splitting of data into training testing and validation sets, training, and testing of the model). To apply ML for any problem, the steps involved would be to get the data, clean and prepare it, select a model and train it, test the model, and finally improve the model based on test results. The core of the ML process lies in training.

ANN involves a network of highly interconnected nodes that have the ability to learn from past examples. It has the ability of imitating human brain.[16] ANN consists of input layer, output layer and hidden layers in between, as shown in Figure 2. Artificial neurons in different layers were connected. Each connection was assigned with a weight representing its relative importance.[2]

On the other hand, DL is specific form of learning based on algorithms of neural networks.[16] DL neural networks have at least three hidden layers.[2] These are particularly useful for identifying features such as edges, corners, shapes, and macroscopic patterns in complex data structures, such as imagery.[17] CNN is a kind of DL neural network which showed outstanding performance in image recognition and classification.[17]

## AI in Patient Management

With the advancement of AI, virtual dental assistants has been created that will manage clinics with greater accuracy, less errors and less man power as to scheduling appointments, help in history taking, oral hygiene methods assessment, demonstrations, etc [Figures 3 and 4]. AI incorporated teleassistance is very helpful in case of any emergency and when the clinician is not available.[18,19] That future is not very far when a dental chair has voice command, can calculate patients weight, vital signs, and anxiety as the patient sits on the dental chair for treatment.[20]

## Applications of AI in Various Dental Specialties

### Prosthetic dentistry

Programs like *RaPid* are using AI with ML to fabricate ideal esthetic prosthesis.[21] These programs can integrate computer-aided design (CAD)/computer-aided manufacturing (CAM) to process dental restorations and finish restorations through fine grinding process of ready ceramic blocks.[22] AI in the field of implantology can accurately identify the position of the mandibular canal,[23] the type of bone, cortical thickness for making precise surgical guides, etc.[24]

## Conservative Dentistry and Endodontics

Aliaga *et al*. conducted a study using AI to determine the type of reconstruction best suited to the patient, predicting the longevity of each procedure.[25,26] Color matching is an important aspect of filling materials used to replace the defect. The use of AI by incorporating generic algorithms improves the precision and predictability of color matching in restorative dentistry.[27] Studies conducted by Saghiri *et al*. found that ANN system can be used for determining the working length in root canal treatment and showed exceptional accuracy of 96%.[28-30] AI-based models are incredibly effective when it comes to the detection of vertical root fractures on CBCT images and panoramic radiographs.[30-32]

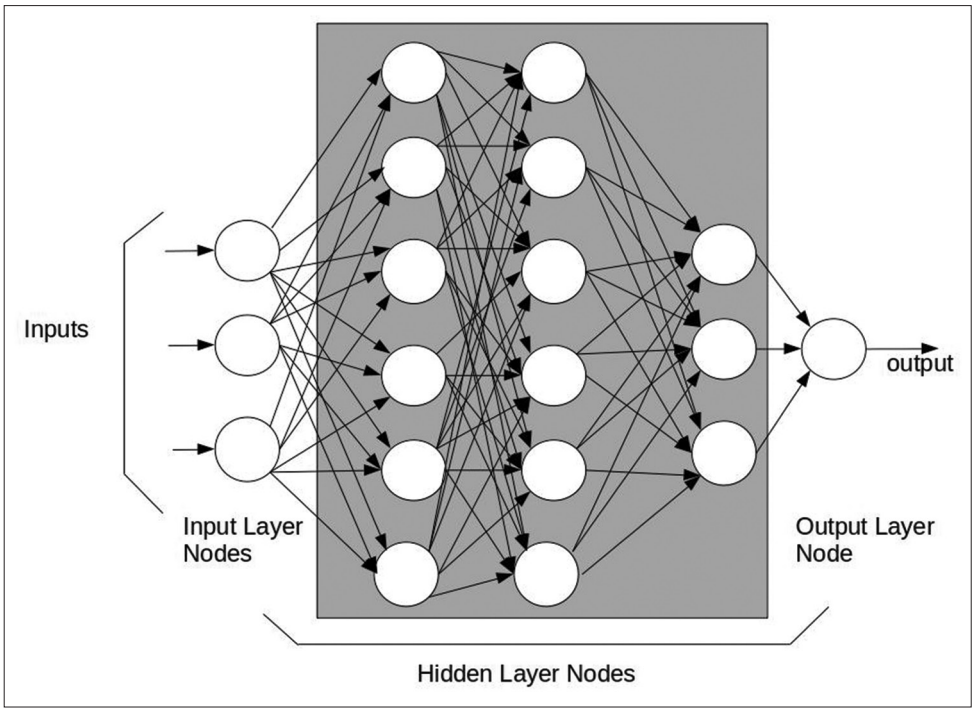


**Figure 2:** Artificial neural network

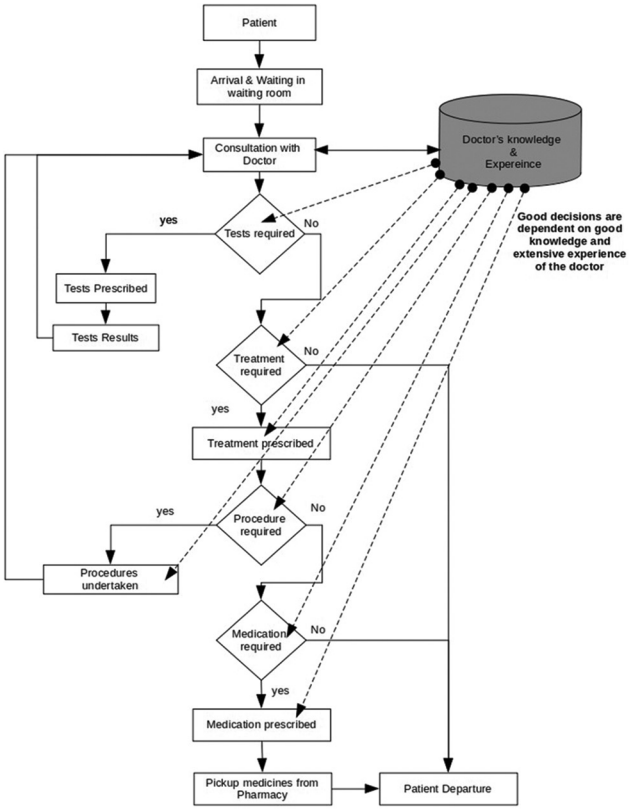


**Figure 3:** Traditional doctor patient interaction

## Orthodontics

Orthodontics has applied AI aimed for helping non-specialist dentists develop diagnoses and treatment plans.[33,34] Efficiently trained AI neural networks helps clinicians in reducing the subjective error of extraction decision. They were shown to be successful at predicting the extraction decision 80% of the time in one study and 93% of the time in two other studies.[35-37] Another application of AI is in the study model analysis especially to find out the size of unerupted teeth.[38] A recent review reported 5–15% better accuracy of landmark detection with automation than traditional methods in cephalometric analysis.[39,40]

Another application of AI is the assessment of maturity of a patient using cervical vertebrae for determining the growth status of a patient.[41] Studies reported that automated model demonstrated a mean accuracy of 77.02% in determining the stages of the growth and development of cervical vertebrae.[42,43]

AI also helps in prediction of growth and treatment outcome, for example, predicting change in lip curvature after orthodontic treatment with or without extraction,[44] prediction of post peer assessment rating based on pre peer assessment rating in Class II malocclusion, and prediction of prognosis of class III.[33,45,46]

Nowadays, aligners with gentle and constant force for tooth movement using special trays are manufactured based on CAD CAM technology. With the advancements of ML, various aligner companies claims to use AI algorithms for treatment planning and manufacturing of aligners.[47]

## Oral Radiology

Various automated neural network system that can correctly diagnose cysts, tumors from panoramic radiographs 83.0% of the time are applied for OPG evaluation.[33,48-50] Automated

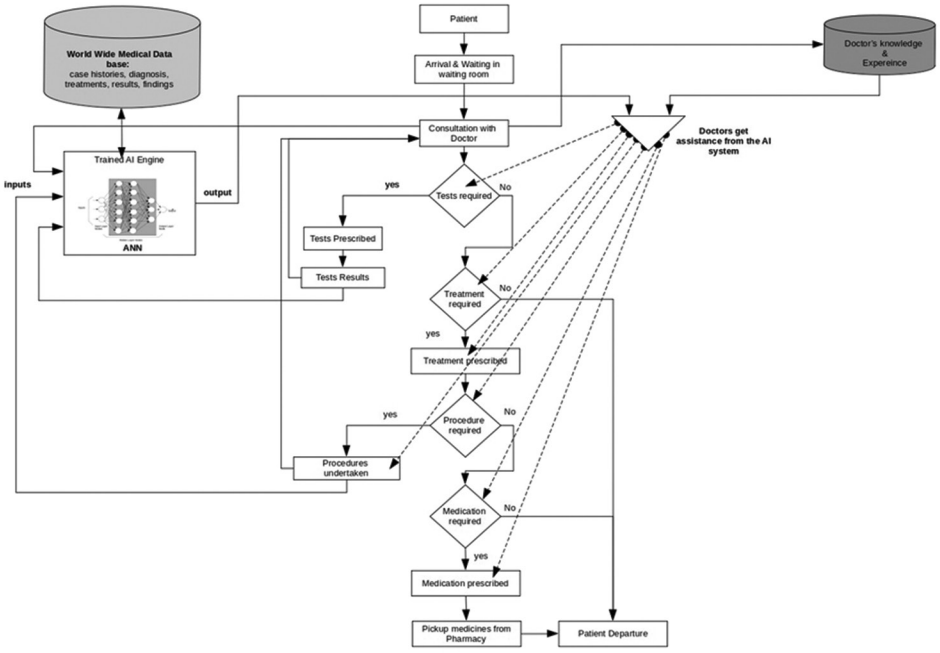


**Figure 4:** Artificial intelligence-assisted doctor patient interaction

algorithms are developed to predict maxillary canine impactions using Panoramic X-rays based on angular and linear measures,[51] for example, various radiographic analyzing software programs such as videa detect, Videahealth, and Denti. AI.[11] AI is also integrating into it the annotation of anatomical landmarks and segmentation of bone and teeth structures.[11] Orca Dental AI combines clinical expertise with AI to create diagnostic reports, treatment plan suggestions, and smart clinical predictions that assist users across the entire dental value chain.[51]

## Forensic Odontology

Forensic odontology helps in identifying people involved in crimes such as child abuse, crime, sexual assault, mass calamities, and other legal issues. Automated technique based on CNNs for staging lower third molar development for estimating the age of a person after applying on panoramic radiographs has been developed and showed remarkable results.[43,52-54]

## Oral Pathology

A major limitation related to morphologic diagnosis is the interpersonal variability among the pathologists. For predictable and progressively precise conclusion, it is imperative to present AI in the pathology space. Automated systems are of greater value for screening the patients for osteoporosis, oral cancer, and metastasis of the lymph nodes.[43]

## Smile Design

Various softwares are available for smile designing, for patient education, motivation, and communication. Advancements in the field of ML help us to incorporate more interactive methods based on cloud platforms so that real time smile can be designed based on patients macro, mini and micro esthetics and by creating a mock up model and preparation guide, for example, Smile Cloud.[11]

## Periodontics

ANN can effectively be used in classifying patients into aggressive periodontitis and chronic periodontitis group based on their immune response profile. The ANN also helps in accurate diagnosis of aggressive periodontitis and chronic periodontitis using relatively simple and conveniently obtained parameters, like leukocyte counts in peripheral blood.[55]

## Oral and Maxillofacial Surgery

AI can be used for robotic surgery, removal of tumor and foreign bodies, biopsy, and temporomandibular joint (TMJ) surgery.[21,56,57] Patcas *et al*. showed better treatment outcome in terms of esthetic improvement by applying AI to assess the impact of orthognathic treatment on facial attractiveness and estimated age.[58] Shoukri *et al*. applied neural network to stage condylar morphology in TMJ osteoarthritis (TMJOA). Predictive analytics of the AI's staging of TMJOA compared to the repeated clinicians' consensus showed 73.5 and 91.2% accuracy. The results suggest that TMJOA condylar morphology can be comprehensively classified by AI.[59]

## Augmented and Virtual Reality in Dental Teaching

Augmented reality is an interactive experience of a real world environment by computer-generated perceptual

information.[60] This new advancement has been used in training dental students.[21] At present, dental schools use simulators that have realistic manikins along with dental models incorporated in a dental simulated operatory. New technologies are being developed to include "haptic" (sense of touch) and "virtual lab environments" into the simulation exercises as these technologies are reported to increase motor skills and student efficiency as well as reducing the faculty time requirement. By incorporating AI to unified medical language system, there is a huge improvement in the quality of feedback that the preclinical virtual patient provides the students.[16,61,62]

## Limitations and scope of AI

The disadvantage of AI presently is the availability of insufficient and inaccurate data, the complexity of the mechanism and the cost involved in the setup.[16] However, there is tremendous potential for AI in future that will make dental care better, at lower costs, to the benefit of patients, providers, and the wider society.[17]

## Conclusion

The use of AI in dentistry has undergone considerable development. These systems can simplify the tasks, give a standardization to the procedures, and provide results in quick time which can save the dentist time and help the dentist to perform his duties more efficiently. A clear understanding of the techniques and concepts of AI surely have an advantage in the coming future. We soon hope to see AI to be completely implied in all specialties of dentistry.

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