Review Article

Artificial Intelligence – Decoded for the Dentist

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Abstract

Now-a-days, everybody is familiar with the use of advanced web search engines like Google, recommendation systems as used by YouTube, Amazon, and Netflix, understanding human speech (such as Siri and Alexa), self-driving cars (e.g., Tesla), automated decision-making and competing in strategic game systems (such as chess and Go), self-driving and self-parking vehicles, Google maps for navigation, rider apps such as uber and ola. All these are applications of artificial intelligence (AI) in different aspects of life. Dentistry is also benefitting from the applications of AI. This article is a literary review on the applications of AI in the field of dentistry.

Keywords: Aligners, Artificial intelligence, Computer-aided design computer-aided manufacturing, Deep learning, Dentistry, Machine learning, Smile design

Introduction

It started in 1950 when Alan Turing founded the modern computer and laid the foundation for artificial intelligence (AI). The "Turing test" was based on the fact that the intelligent behavior of a computer is the ability to achieve human-level performance in cognition-related tasks.[1] Conventionally, we employ statistical methods to establish the patterns and associations in evidence-based medicine. Computers learn the art of diagnosing a patient through two broad techniques - flowcharts and database approach which requires feeding a large amount of data into machinebased cloud networks as the range of symptoms and disease processes encountered in routine medical and dental practice is vast.

AI in medicine can be divided into two subtypes: Virtual and physical.[2] The virtual aspect ranges from applications such as electronic health record systems to guidance in treatment decisions. The physical part deals with robots assisting in performing surgeries, intelligent prostheses for handicapped people, and elderly care.

John McCarthy who coined the term AI in 1955 is recognized as the father of AI. In 1978, Richard Bellman defined AI as the automation of activities associated with human thinking abilities, which includes learning, decision-making, and problem-solving.[3]

Artificial neural networks (ANNs) were invented keeping the structure of the brain as its basis and it has the ability to imitate human brains.[4] In 1951, Minsky and Dean Edmunds developed the stochastic neural analog reinforcement calculator, which is recognized as the very first neural network in its developmental history.[5] In 1955, Allen Newell and Herbert Simon developed programs of AI for the first time in records.[6] The greatest advantage of these systems is that they have capability to solve the problems that are too complex to be solved by conventional methods. They are useful in various areas of medical and dental science like diagnosis of diseases, biomedical identification, image analysis, and data analysis.[7]

In AI, there are two categories – in machine learning (ML), 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.[8]

ML, first described by Samuel, is part of AI and its purpose is to facilitate machines to learn from data so they can resolve issues without human input. ML models such as Genetic algorithm,

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ANN, Fuzzy logic can use data and execute various functions and are used in dental applications.[9] The purpose of neural networks is to create networks that function like the human brain. Deep learning is the component that utilizes the network with different computational layers in a deep neural network to analyze the input data and identify patterns. Deep learning is also known as convolutional neural networks (CNNs). They collect features from the layer of filters and are primarily used to process large and complex images.[10-14] Clinical decision support system is defined as, any computer program that has been designed to help health professionals in making clinical decisions, and also deals with the medical data or with the knowledge of medicine necessary for interpreting such data.[15]

Genetic algorithms have also gained success during the last decade as optimization methods for complex problems. They are stochastic search methods which are based on the principle of survival of the fittest in natural selection. It includes approaches such as mutation, inheritance, selection, and crossover to search for a better option of the problem. The greatest advantage of genetic algorithms over conventional methods is that it works on the basis of problem solution instead of analytical relations concept of conventional methods. Despite being a powerful optimization tool, it works on simple rules, which makes it easy to implement. Łodygowski T and co-workers used genetic algorithms for the optimization of dental implant system to reduce the problem of mechanical fracture and to provide long-term strength to the implant.[16] Another study done by Li *et al.* used a genetic algorithm along with back propagation neural network to improve the tooth color matching which is one of the greatest challenges in prosthodontic dentistry.[17] A recent study reported the genetic algorithm-based approach to detect dental caries in early stages to avoid the severity of decay.[18,19]

The idea behind fuzzy logic is to imitate human reasoning ability that works with not so clear terms. Mago *et al.* designed a fuzzy logic-based expert system that accepts imprecise values of dental signs and symptoms associated with mobile teeth to assist dental professionals in decision-making.[19]

Ambara *et al.* designed a fuzzy logic based expert system that is time and cost friendly and consultation can be done without using any tools that reduce fear of the patient.[20] Hererra and co-workers used a fuzzy logic-based system that predicted the color change after tooth bleaching on the basis of tooth's initial chrome values.[21] The fuzzy logic system has a set of rules that correspond to pre-bleaching shades of the well-known Vita commercial shade guide.

Augmented reality (AR) used widely is an interactive experience with the real world in which a three-dimensional (3D) virtual object is consolidated in a 3D real environment. This leads to superimposition of computer-generated virtual content over real environment.[22] The term augmented reality was coined by Caudell and Mizell in 1990 and the first system was developed by Sutherland in 1968.[23] Virtual reality is the combination of many technologies that allow the operator to interact with virtual objects in real time. AR is commonly used technology applied in various medical and dental science areas. Some of the applications of AR in dentistry include: (1) The oral and maxillofacial branch of dentistry in which AR provides clear graphical information of operative sites, (2) the placement of dental implants dental implantology is made easy by graphically information provided by AR. (3) orthognathic surgery, (4) dental education, and (5) in live anatomy.[24-29]

A number of drivers for this uptake of this AI technology have been identified (Naylor, 2018).[30]

1. Diagnostic imaging
2. Digital health data are collected
3. AI allows to integrate different and heterogenous data
4. AI facilitates research and discovery
5. AI can streamline regular work and increase the interaction between the doctors and patients and reduce time for record keeping (Israni and Verghese, 2019).
6. AI can make health-care more participatory as patients will be empowered by self-monitoring and self-management.
7. Continuous non-invasive monitoring of health and behavior.
8. Diagnostic and treatment costs may be decreased and AI may also help to address shortages in workforce

We see three main reasons why dentistry has not yet fully adopted AI technologies.

First, medical and dental data are not as available and accessible as other data, or the available data may be biased (Gianfrancesco *et al.,* 2018).

Second, processing data and measuring and validating results is oftentimes insufficiently replicable and robust in dental AI research (Schwendicke *et al.,* 2019).

Third, the outcomes of AI in dentistry are often not readily applicable: The single information provided by most of today's dental AI applications will only partially inform the required and complex decision-making in clinical care (Maddox *et al*., 2019).

Dental Applications of AI

AI in patient management

Virtual dental assistants based on AI can perform various tasks in dental clinics with less error and more precision. It can be needed to book a patient's appointment in the clinic, taking proper medical and dental history of the patient, managing insurance as well as assisting the dental surgeon in adequate diagnosis and treatment planning. It also works by warning the dental professional about the habitual details of patients like use of tobacco or alcohol and medical history of the patient. In this way, a virtual database of every patient is created which then helps the dentist in diagnosis and treatment of disease. It will also be beneficial in patients follow-up and online emergency health consultancy.

AI and orthodontics

Intelligence is now used in various phases of orthodontics

starting from the need for orthodontic treatment, need for extractions, esthetic outcome and expected facial attractiveness, diagnosis to treatment planning, and follow-up monitoring. 3D scans and virtual models are useful in assessing craniofacial and dental abnormalities. With the help of these 3D scans, aligners can be printed, and treatment can be customized. After these printed aligners, a data algorithm is created that intelligently decides how the teeth or tooth of the patients should be moved, how much pressure should be applied and even also recognize the pressure points for that specific tooth/teeth. The AI-conjugated aligners not only provide precise treatment but also reduces the chances of error and time for treatment.[31]

AI and radiology

AI provides the additional capability to learn more to be a dental professional. When integrated with imaging methods like magnetic resonance imaging and cone beam computed tomography it can identify even the minute deviations from normal which remains unnoticed by human eye. For example, ANN is used by dental professional teams to localize minor apical foramen thereby magnifying the precision of working length determination by radiographs and in diagnosis of proximal caries. ML algorithms can detect an abnormal or normal lymph node in head-and-neck image provided a trained radiologist who can interpret by analyzing thousands of such images which are labeled as normal or abnormal.[32,33]

In another in vitro study, ANN also aided in the determination of shade, light-curing unit, and composite Vickers hardness ratio of bottom to top composites.[34] AI technology is found useful in assisting de-bonding probability of composite restorations in restorative dentistry.[35]

AI and prosthetic dentistry

Automated robotic systems (mechatronics) can fulfill the requirements of typical dental operations with accurate, safe, and 3D tooth preparation.[36,37] The AI CNN can be utilized for classifying dental arches and designing removable partial dentures.[15] Computer-aided design computer-aided manufacturing-based systems are used in dentistry to attain finished dental restorations with great precision. Furthermore, AI-based systems are used to design inlays, onlays, crowns, and bridges. This system has replaced the conventional method of casting the prosthesis and reduces time and errors.[38,39]

AI in periodontics

ANN can also effectively be used in categorizing patients into aggressive periodontitis and chronic periodontitis based on their immune response profile.

AI in forensic dentistry

AI helps in age determination and facial reconstruction purposes using several machine learning models.

AI and esthetic dentistry

Smile design is a useful tool for treatment planning and patient motivation. The software used in smile design rely on the input and preference of the clinicians who upload the patient photos, virtually modify the smile, and create a mock-up model and a surgical guide for achieving the chosen smile.[40]

AI and restorative dentistry and endodontics

Detection of caries, determination of working length, evaluation of periapical regions, designing the restorations, shade selection of composites etc., are invaluable contributions of AI in this field.

Conclusion

AI is proving to be indispensable in dentistry but it is still under development and the possibility of errors exists. AI needs to be used along with conventional methodology for efficient patient management.

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