Review Article

Dentistry and Artificial Intelligence

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Abstract

Artificial intelligence (AI) is a technology which is quickly advancing and has captivated the minds of researchers across the globe. The adoption of artificial intelligence (AI) in healthcare is developing while profoundly changing the face of healthcare delivery. AI is being employed in a horde of settings including hospitals, clinical laboratories and research facilities. From data processing and finding relevant information to using neural networks for diagnosis and to the introduction of augmented reality and virtual reality in dental education, its inception has witnessed some of the exceptional achievements in dentistry. The key applications involve diagnosis and treatment recommendations, patient engagement and adherence, and administrative activities. Thus, this circumstance demands every dentist to get acquainted with this technology as the future of dentistry is adjoining the execution of its applications. The need for proper documentation of the patient's information, quick and dependable treatment protocols through robotics in the field of surgery has encouraged the utilization of these software technologies in assisting the dentist to diagnose and treat the patients productively. However, this technological advancement is still in the phases of outset and this article is an endeavor to highlight the role of artificial intelligence in dentistry.

Keywords: Artificial Intelligence; Dentistry; Augmented Reality; Virtual Reality; Robotics; Surgery; Diagnosis and Treatment

Abbreviations

AI: Artificial Intelligence; ANNs: Artificial Neural Networks; CBCT: Cone Beam Computed Tomography; CDSS: Clinical Decision-Support Systems; CT: Computed Tomography; ML: Machine Learning; MRI: Magnetic Resonance Imaging; BRONJ: Bisphosphonate-Related Osteoradionecrosis of Jaw; TMJ: Temporomandibular Joint; U.K: United Kingdom; MeMoSA: Mobile Mouth Screening Anywhere; 2D: Two Dimensional; 3D: Two Dimensional; 4D: Four Dimensional; CADCAM: Computer Aided Design-Computer Aided Manufacturing; CNN: Convolutional Neural Networks; VRS: Virtual Reality Simulation; AF: Apical Foramen; COVID-19: Corona Virus Disease-2019; DMFT Index: The Decayed, Missing and Filled Teeth Index

Introduction

One of the most intriguing structures to researches and technologists for as long as the history dates back is human brain. Newer technologies have developed over centuries based on principles that try to mimic the functioning of it, however even today the machine that can think and act like a human is still a dream.

Today, we know a similar function as "artificial intelligence" (AI). Artificial intelligence (AI) is defined as 'a field of science and engineering concerned with the computational comprehension of what's commonly called intelligent behavior, and with the creation of artifacts that show such behavior' [1].

It's basically a zone of computer science that emphasizes the production of intelligent machines that work and respond like humans. The human brain is a matchless structure composed of networks of interlinked neurons which transmit signals all through the body. This unexampled nature of human brain has consistently made researchers and scientists curious from time immemorial.

Artificial neural networks are inspired by the biological neural system and its ability to learn through example. Mathematical models based on artificial intelligence now serve in support of certain diagnoses. Technology has likewise changed the field of medicine and dentistry in the last decade.

Heaps of information can be assembled and computed to create an AI for aiding quick diagnosis and treatment planning. The machines do have a marginally upper edge over humans in terms of number of working hours they can place in without fatigue. Whereas human intellect and mind needs break before they perform competitive tasks

In the field of dentistry, AI is slowly nudging its head in radiology, orthodontic treatments, restorative and prosthetic dentistry, endodontics, implantology and the recent addition being voice command dental chair without any physical input from doctor in the least [2].

History

One of the most important visionary and theoretician was Alan Turing (British mathematician), in 1936 proved that a universal calculator - known as the Turing machine - is possible [3]. Turing's central insight is that such a machine is capable of solving any problem as long as it can be represented and solved by an algorithm. Creation of "The Logic Theorist" designed by Newell and Simon in 1955 can be considered the first AI program which marks the development of modern AI. John McCarthy in 1965 coined the term Artificial Intelligence [4].

Concept of AI

There are two sub concepts that divide the whole scope of meanings currently included by the term "AI" they are strong and weak

AI. Strong AI was to operate in same way as human intelligence through non-natural and artificial hardware and software reconstruction. Weak AI attempts to implement a system that develops the problem-solving ability by itself through learning using some of the sense and thinking mechanisms of people [5].

To understand the concepts in AI one should be familiar about various terms [6,7].

Machine learning (ML)

Machine learning is a branch of computer science that builds algorithms guided by data.

Deep learning

Specific form of learning based on algorithms of neural networks.

Representation learning

Representation learning Is a subtype of ML in which the computer algorithm learns the features required to classify the provided data. This does not require a hand labelled data like ML.

Artificial neural networks (ANNs)

This involves a networks of highly interconnected computer processors that has the ability to learn from past examples, analyze non-linear data, handle imprecise information and generalize enabling application of the model to independent data thus making it a very attractive analytical tool in the field of medicine.

Clinical decision support system CDSS

A Clinical decision support system (CDSS) is a system between a broad dynamic (medical) knowledge database and an inferencing output mechanism that are a set of algorithms derived from evidence-based medical practice executed through medical logic modules. Currently, the intuitive interphase with voice controls are designed to assist the health care professional to work more efficiently with time saving and cost effective clinical dental practice.

Augmented reality

Defined as "a technology that superimposes a computer-generated image on a user's perspective of the real world, accordingly giving a composite view".

Virtual reality

A computer-generated reenactment of a three-dimensional image or environment that can be communicated with, in an apparently real or physical path by an individual utilizing unique elec-

tronic equipment.

Applications in dentistry

Different tasks in routine dental set up can be performed with less labour and greater precision with the help of virtual dental companions. These tasks include coordinating appointments, executing insurance and paperwork's [7] and alarming the dentists about subject's comorbidities as well as habits like smoking and alcoholism. Teleassistance would benefit the patient in dental emergencies when the practitioner is unavailable [8]. The chair positions, water dispensing and light control can be efficiently handled with voice command that do not need any manual input from clinician [2].

E-learning in dentistry

Clinical dentistry is a major part of dentistry for learning the skills and to enhance patient care. Traditionally, pre-clinical operative training for dental students is combination of theoretical teaching and practical learning. augmented and virtual reality has been incorporated into tutoring intelligent education system and training in dentistry [8]. These technologies enable simulation of the practical procedures in three dimensions and allows access to clinical and surgical techniques. The practice sessions can be done several times till the students get trained over the subject prior to actual handling of real clinical cases reducing the risk of iatrogenic error.

Oral medicine and maxillofacial radiology

The diagnoses and treatment of lesions of oral cavity can be screened and classified into suspicious altered mucosa undergoing premalignant and malignant changes with the help of AI [9,10]. Genetic predisposition of oral cancer for a large population might be accurately predicted using AI [10]. ANNs (Artificial Neural Networks) may act as an adjuvant diagnostic tool for dentist in the diagnoses subtypes of temporomandibular disorders [11], predict the factors appearing to be related to the occurrence of recurrent aphthous ulcers [13], used to predict the occurrence of BRONJ (Bisphosphonate- related osteoradionecrosis of jaw) associated with dental extraction in patients taking bisphosphonates for the management of osteoporosis [34], to recognize and correctly diagnose patients with different facial pain syndromes [35,36], to classify morphological variations of the mandibular condyle that define the exact location of the morphological changes on the condylar surface. It will improve the comprehension of clinicians re-

garding the shape changes that occur in patients with TMJ osteoarthritis [33].

Images of the oral cavity for remote interpretation by specialists can be captured using Mobile Mouth Screening Anywhere (Me-MoSA) app [12].

Image recognition using AI systems has shifted from science tale into reality within the radiology practice in the last 20 years. AI gives added advantage in head and neck imaging due to its distinctive ability to learn and may be assimilated with other imaging modalities like CBCT, MRI to work out minute deviations from normality that would have gone unrecognized with human eye. Illustrations including definite location of landmarks on radiographs aids in detection of vertical root fractures [15], Cephalometric analysis, diagnosis of maxillary sinusitis on panoramic radiographs and Waters' radiographs [33], to detect Sjogren syndrome on CT [33]. Economically these might be translated into a far better patient care.

Incorporation of Artificial Intelligence in 3D printing helps manufacturing in its prefabrication stage. Predicting the possible failure of the printing process and resolving the overhang problem can be achieved using an AI software [33]. With Intelligent algorithms solution to any problem can be found quickly enough, thereby enabling 3D printers to perform effectively and guides to resolve any quality issues.

Some future recommendations for radiologists will be they should be familiar with AI terminology and hierarchy, should begin to integrate health informatics, computer science and statistics courses in their curriculum, training the radiologist for logic, statistics, data science and be aware of other sources of information such as genomics and biometrics, to integrate data from disparate sources with a patient's clinical condition. Radiologists should understand the challenges related to preparation of training data sets for supervised learning [6].

Pediatric dentistry

AI has numerous potential applications which would change the face of behavioral pediatric practice in future. AI enabled restorative dentistry with computer-aided design and manufacturing would emerge a boon to pediatric restorations in terms of time and aesthetics.

In the mixed dentition period, the sizes of unerupted premolars and canines can be predicted using ANN.

AI enabled pain control gadgets is the new, smarter way towards injection-free pedodontics practice. The various 4D goggles, movies, animations and virtual reality-based games can be used as a behavior modification aid for pediatric patients [18].

Oral and maxillofacial surgery

AI software programs has helps in planning surgeries by preserving the vital structures around to the smallest detail before the actual surgery with higher intra operative accuracy [19]. One progressive clinical application is image guided surgery that admit further accurate surgical resection thereby decreasing need for revision procedures. The enormous use of artificial intelligence in oral and maxillofacial surgery is alongside the evolution of robotic surgery where human body motion and human intelligence is simulated [20].

A comparative study conducted by Raphael Patcas., *et al.* on facial attractiveness between artificial-intelligence based scoring and conventional rater group in cleft patients uncovered equivalent outcomes among them [21]. It introduces a novel method in dentistry to rate facial attractiveness, by a face detector and a dedicated CNN (Convolutional Neural Networks). This study made it evident that the presented AI-based scoring is in need of further perfection and refinement to differentiate cleft features of the face that negatively influence the human perception of attractiveness.

Pathology

Microscopic morphology is taken into account the gold standard in diagnostic pathology. Pathology specimens undergo multiple processes that include formalin fixation, grossing, paraffin embedding, tissue sectioning and at last staining. In general, it's human pathologist who gives pathology diagnosis by analyzing the specimen. However, the main limitation related to morphologic diagnosis is that the variability among the pathologists. In this way, for predictable and progressively precise conclusion, it is imperative to present AI in the pathology space. Further the need of computer-aided image classification system with quantitative analysis of histological features for rapid, consistent and quantitative diagnosis is necessary [12].

Orthodontics

Diagnosis forms the core of the treatment in orthodontics. AI helps in diagnosis, planning treatment and monitoring the progression of treatment by analyzing the radiographs and photographs [22]. With the advent of intraoral scanners and cameras making of dental impression is being replaced by digital impressions [23] and the above data is fed into the system; the set algorithms and AI software helps in predicting tooth movements and final outcome of the treatment [24], to predict orthodontic treatment plans, including the determination of extraction/no extraction and anchorage patterns [25], to identify the factors that influence decision-making before orthodontic treatment and evaluating the need for tooth extraction of patients with malocclusion [37]. Customized aligner-based orthodontics can improve case acceptance when combined with latest technologies.

Periodontics

Deep learning analysis using radiographs can help in diagnosing and treatment planning of periodontal diseases by the early detection of periodontal changes [26] bone loss, and changes in bone density and detection of peri implantitis [27]. This helps in early intervention in implantology.

ANN (Artificial Neural Network) can also effectively be used in classifying patients into aggressive periodontitis and chronic periodontitis group based on their immune response profile [28].

Prosthodontics

AI combined with designing software's can aid the dentist to design the best possible and aesthetic prostheses considering number of factors like facial measurements, anthropological calculations, ethnicity and patient desire.AI plays a major role in identifying the type of bone, cortical thickness for making precise surgical guides for placing implants [29]. The time consuming and laborious process of conventional casting is replaced by the use of CADCAM technology [30] which creates a 2D and 3D models thereby reducing human errors. Virtual reality simulation (VRS) technology can be used to simulate the facial profiles post treatment. This enables the dentist to efficiently design the esthetics and also acts as a motivational tool for the patient [31].

Conservative dentistry and endodontics

Periapical granulomas, abscesses, and cysts are the most common periapical lesions that are evident on radiographs, but some may go unnoticed as images may be noisy or have low contrast. AI can accurately locate tooth areas prone to caries and complex peri-

apical pathoses, define the boundaries of lesions in a more precise way, and enable their differentiation.

Detection and characterization of proximal caries is possible with the help of Logicon Caries Detector [16,17].

AI can help in analyzing the life span of different restorative materials and to choose them wisely for suitable cases [38] and aid in successfully locating the minor apical foramen (AF) thereby strengthening the accuracy of working length [14].

Community health sector

The primary goal of AI in dentistry should be the analysis of the relationship between prevention and treatment techniques in the field of public health as well as analytics of patient outcomes. AI have been developed for diagnostic recommendations, therapy protocols, biomedical pharmacy, personalized medicine, patient monitoring, and even foresight of epidemiological disease expansion from a global perspective.

Machine-learning models are more useful than statistical models for predicting DMFT index and caries risk in 12-year-old children and can be used to predict the DMFT score [39] and also able to determine independently the life-long mean index of carious teeth, extracted teeth and/or filled permanent teeth [38].

Artificial Intelligence (AI) based oral health tracking mobile app is "Denta Mitra". It enables a person to monitor his or her dental status through an AI based scanner in the app, measures and reminds users on oral hygiene periodically and helps the person to connect with nearby dentist, book appointments and virtually consult dentists by the app.

AI can also show its expertise during any crisis/pandemic situation. In today's worldwide health crisis, the medical industry is looking for new technologies to monitor and controls the spread of COVID19 (Coronavirus) pandemic. It can easily track the spread of this virus, identifies the high-risk patients, and is useful in controlling this infection in real-time [32].

Advantages of AI

The advantage of using AI is, it helps in reaching greater degree of precision and accuracy by reducing human error. It is always available.

Service robots often come with built-in capabilities to analyze the personality and are capable of performing daily tasks, thereby increasing human capacity and bolster emotional well-being.

Patients previous and current health problems can be analyzed since AI can accumulate and keep their data in a single place. It enables the physician to make a more accurate diagnosis. The prediction of potential health problems a person can have in the future can be done using database of health apps which consist of millions of symptoms, diagnosis of particular cases.

Verily developed by Google specializes in forecasting both non-contagious and hereditary genetic diseases enabling health experts to anticipate potential threats and avoid them in the future, taking appropriate measures today. Management of healthcare facilities can be improved using predictive analytics.

Disadvantages of AI

It's creation requires immense expenses as they are very complex machines.

AI neglects to develop a bond with humans which is a fundamental credit when comes to delivery of health care to patients. It can perform just those tasks which they are designed or programmed to do, anything out of that they tend to crash or give unimportant yields which could be a significant backdrop. Artificial intelligence cannot be improved with experience.

To get the appropriate comparison, the AI database ought to contain adequate information about the patients of the particular group. Accordingly, if there is an absence of information about a person from a certain background, AI can provide an inaccurate diagnosis. The software programs need frequent upgradation. Likewise, if there is a breakdown, the expense of obtainment is very high. With that, recovery requires enormous time too.

Also, currently the field of AI includes very few experienced programmers and few practical products have reached the market as yet.

Conclusion

The field of artificial intelligence has grown tremendously in the last decade transforming the way of practice in medicine and dentistry.

Intelligent systems play an important role in dentistry as a way to obtain a quick diagnosis and treatment plan for complex problems. The clinical applications of artificial intelligence are ceaseless, and the field is in its beginning stage, with ongoing active research. These systems have a promising and splendid future both in general dentistry and maxillofacial radiology.

However, AI may never fully replace the human dentist. As technology improves, AI will help dental professionals perform at a higher level by making their jobs much easier without human error. The future of dentistry is bright with artificial intelligence and new technological advancements becoming the standard in every

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