Rama Univ. J. Dent. Sci. 2018 June 5(2):1-4 ISSN No. 2394-417X (print), 2394-4188(online)

Review Article

Artificial Intelligence in Dentistry: A Review

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Abstract

Humans have recreated intelligence for effective human decision making and to unburden themselves of the stupendous workload. Artificial intelligence can act as a supplemental tool to improve diagnosis and treatment care but intelligent machines can never be 'human'. The field of artificial intelligence is relatively young but has still come a long way in the fields of medicine and dentistry. Hence, there is a need for the dentists to be aware about its potential implications for a lucrative clinical practice in the future.

Keywords: Artificial Intelligence, Neural Networks, Fuzzy Logic, Hybrid Intelligent Systems, Dentistry

Introduction

With an enormous increase in the documented patient data, intelligent software for its computation has become a necessity [1]. Computer-based diagnosis is gaining momentum due to its ability to detect and diagnose lesions which may go unnoticed to the human eye [2]. The conventional approaches have provided much information, but are subject to limitations [3]. The deed of the constant search has given rise to artificial intelligence (AI), which is a highly evolved system capable of mimicking functioning of the human brain [2]. This review will give an insight into the current concepts and uses of artificial intelligence in various fields of dentistry.

The term "artificial intelligence" (AI) was coined in the 1950s and refers to the idea of building machines that are capable of performing tasks that are normally performed by humans. Machine learning (ML) is a subfield of AI, in which algorithms are applied to learn the intrinsic statistical patterns and structures in data, which allows for predictions of unseen data [4] . Alan Turing, a young British polymath devised the Turing test to suggest that machines can use available information and reason to solve problems like humans. The term artificial intelligence was coined by John McCarthy in 1956 [5] and it is defined as 'a field of science and engineering concerned with the computational understanding of what is commonly called intelligent behaviour, and with the creation of artefacts that exhibit such behaviour' [6].

Common terminologies used in artificial intelligence [7, 8]

1. **Machine learning (ML):** Machine learning is a branch of computer science that builds algorithms guided by data.
2. **Deep learning**: Specific form of learning based on algorithms of neural networks.
3. **Representation learning**: Representation learning is a subtype of ML in which the computer algorithm learns the features required to classify the provided data.
4. **Artificial neural networks (ANNs)**
   This involves a network 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.
5. **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 inter phase with voice controls is designed to assist the health care professional to work more efficiently with time saving and cost effective clinical dental practice.
6. **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."

7. Artificial neural network

Artificial Neural Networks were invented keeping the structure of the brain as its basis and it has the ability to imitate human brains [9]. 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 [10]. In 1955, Allen Newelland Herbert Simon developed programs of AI for the first time in records [11]. 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 medicinal science like diagnosis of diseases, biomedical identification image analysis and data analysis [12]. In dental practice also the clinical support systems are actively progressing.

Application in dentistry

Correct diagnosis is the key to a successful clinical practice. In this regard, adequately trained neural networks can be a boon to diagnosticians, especially in conditions having multi factorial etiology. Artificial intelligence in Dentistry started procuring its role with emergence of data computation and availability of large amounts of patient data. Like for example, in radiology a definite kind of algorithm is generated which further helps in diagnosis and treatment of oral pathology/disease.

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 [13]. These technologies enable simulation of the practical procedures in three dimensions and allow 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.

In dental education

With the recent incorporation of artificial intelligence in intelligent tutoring systems like in the Unified Medical Language System (UMLS); there is a huge improvement in the quality of feedback that the preclinical virtual patient provides the students [8].

Artificial intelligence and diagnostic dentistry

Proper diagnosis of any disease is the basis for successful treatment, artificial neural networks work well for this purpose especially in cases where the etiology of disease is multi factorial. Taking one example of Recurrent a phthous ulcer, a condition whose precise etiology is not known, and the diagnosis is made on its reoccurrence and by exclusion of other factors. Another one is internal derangement of temporomandibular joints where clinical and radiological diagnosis is considered as gold standard. When in several studies the diagnosis given by a dental surgeon is compared with the one obtained by ANN, results inferred high specificity and sensitivity of ANN. Thus, revealing the importance of AI in diagnosis of even complicated oral diseases and reducing the chances of human errors [14]. Even in radiology when vast amounts of patient data is recorded through digital IOPA (Intra Oral Peri Apical X ray), 3D scans etc., AI is then needed to gather and compute the data for prompt diagnosis and treatment of oral disease. ANN is also the gold standard to identify the patient at risk of development of oral precancers or oral cancers. Hence, AI could be able to satisfy the ever-existing requirement of a method to diagnose oral cancers at their early stage [15]. Genetic Algorithms and ANN are also useful in predicting the sizes of unerupted canines or premolars [16] and can also be standardized for predicting the tooth surface loss [17].

Artificial Intelligence in Patient Management

It can assist in coordinating regular appointments and alerts the patients and dentists about checkups whenever any genetic or lifestyle information indicates increased susceptibility to dental diseases (eg: periodontal screening for patients with diabetes and oral cancer screening for those who habitually use smoked or smokeless tobacco) [18]. It can also create a database about any relevant medical history or about any allergies that the patient may have. It can not only assist in clinical diagnosis and treatment but also provide emergency tele-assistance in cases of dental emergencies when the dental health care professional cannot be contacted [18].

Artificial Intelligence in Prosthetic Dentistry

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 [19]. The time consuming and laborious process of conventional casting is replaced by the use of CADCAM technology [20] which creates 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 aesthetics and also act as a motivational tool for the patient.

In periodontics

Lee et al. developed an architecture based on DCNN that consists of 16 convolution layers and two fully connected layers. The accuracy of their architecture in detecting periodontitis of premolars and molars was 81.0% and 76.7%, respectively. - Further, Rana et al. presented an auto encoder framework with convolution layers to segment gingival diseases from oral images. This model successfully distinguishes between inflamed and healthy gingival [21]. - ANN can also effectively be used in classifying patients into aggressive periodontitis and chronic periodontitis group based on their immune response profile. Therefore ANNs can be employed for accurate diagnosis of AgP or CP by using relatively simple and conveniently obtained parameters, like leukocyte counts in peripheral blood [22].

Artificial intelligence and orthodontics

The most talked about and recent revolution in orthodontic dentistry is AI driven customized Orthodontic treatment. Artificial Intelligence is now used in various phases of orthodontics starting from diagnosis to treatment planning and follow-up monitoring. 3D scans and virtual models are useful in assessing craniofacial and dental abnormalities [23]. 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.

Head and Neck Cancer

A study on Head and Neck Cancer attempts to use Convolution Neural Networks for performing segmentation of organs at risk from head and cancer in CT images [24]. Another study was performed which demonstrated that genetic programming (GP) performed the best in oral cancer prognosis when the features selected are tobacco smoking, alcohol drinking, tobacco chewing, histological differentiation of squamous cell carcinoma (SCC), and oncogene p53 [25,26]. The Artificial Neural Network may be of great importance for the identification and grading of patients with a high risk of oral cancer or pre cancer and further to plan a treatment regime.

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, and 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 [27].

Thus, AI application based dentistry is not a myth but turning into a reality. Although numerous scientific movies depict the invasion of AI on humankind, all optimistic human mind end up with victory of humankind on AI.

Advantages of Artificial Intelligence

1. Accuracy in diagnosis
2. Standardization of procedures
3. Saves time.

Disadvantages of Artificial Intelligence

1. The complexity of the mechanism
2. The cost involved in the setup

Conclusion

Artificial Intelligence is not a myth but our future in dentistry. Their application in every area is growing day by day. While in no way it can replace the role of dentist as dental practice is not about diagnosis of disease, but it also includes correlation with various clinical findings and provides treatment to the patient. Nevertheless, 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 orthodontics, endodontics and restorative dentistry (reconstructive surgeries). The only limitations to use of AI presently is the availability of insufficient and inaccurate data.

Hence, it's the responsibility of dentists and clinicians to focus on collecting and entering the authentic data in their database that will be fully utilized for AI in dentistry in near future.

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How to cite this article: Artificial Intelligence in Dentistry: A Review Rahul Srivastava, Sekhar Mukherjee, Shalini, Pragati Yadav, Rama Univ. J. Dent. Sci. 2018 June; 5(2): 1-4.