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Scope and Implications of Artificial intelligence in dentistry. A Review. For (2022)

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ABSTRACT

Humans have recreated intelligence for effective human decision making and to unburden themselves of stupendous workload. The neural networks are a part of Artificial Intelligence and are similar to the human brain in their work. The field of Artificial Intelligence has shown a marked development and growth in the past few decades. Its application is expanding in the areas that were previously thought to be reserved for human experts. When applied to medicine and dentistry, Artificial Intelligence has shown tremendous potential to improve patient care and revolutionize the healthcare field. Artificial Intelligence has been investigated for variety of purposes, specifically identification of normal and abnormal structures, diagnosis of diseases and prediction of treatment outcomes. The advantages of this process is better efficiency, accuracy and time saving during diagnosis and treatment planning. Being an upcoming field, artificial intelligence has a long way in the field of medicine and dentistry. Hence, there is need for the dentists to be aware of its potential implications for a lucrative clinical practice in the future. Substantial data for this article was collected from different databases and original and systematic review articles previously published. This review will focus on application, advantages, disadvantages and limitations and future application of artificial intelligence in dentistry.

Keywords: Dentistry, Artificial Intelligence, Neural Networks, Electronic Health Records, Clinical Decision Support, Hybrid Intelligence System, Healthcare, Robotics.

Introduction

With an 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 need 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]. AI applications are expanding into areas that were previously thought to be reserved for human experts. When applied to medicine and dentistry, AI has tremendous potential to improve patient care and revolutionize the health care field. In dentistry, AI is being investigated for a variety of purposes, specifically identification of normal and abnormal structures, diagnosis of diseases and prediction of treatment outcomes[4]. The advantages of this process are better, efficiency, accuracy, and time saving during the diagnosis and treatment planning[5]. Artificial intelligence (AI) may be used in planning more effective therapies, prophylaxis, and the reduction in treatment costs[6]. We can benefit from AI in medicine, mostly in the fields such as radiology, pathomorphology, and oncology (using “Thermalitics” technique in breast cancer detection), in cardiology (to help in ECG analysis), in psychiatry (to diagnose, prevent and treat mental illnesses), nuclear medicine, and many others[7].

Artificial intelligence is also spreading in dentistry due to the technological advancements and digitization of dentistry. Dental second opinions can now be made by computers in many dental fields. NNs in dentistry can be used to make the process of diagnosis more accurate, rapid, and efficient[5]. Substantial data for this article was collected from different databases

and original and systematic review articles previously published.This review describes some current and future applications of AI in dentistry and outline the overall picture of the possibilities of using neural networks in modern dentistry.

Definition:

The term artificial intelligence was coined by John McCarthy in 1956 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 artifacts that exhibit such behaviour'[8].

Common Terminologies Related To Artificial Intelligence:

1. Machine Learning:

Machine learning is the subfield of artificial intelligence in which algorithms are trained to perform tasks by learning patterns from data rather than by explicit programming[9]. Machine learning techniques invariably involve parameter tuning with regards to the underlying technique, such as, the number of neurons, layers or epochs in a neural network technique; membership function selection in fuzzy logic; population size, selection strategy, mutation rate, crossover rate in genetic algorithms as well as in the hybrid techniques that use fuzzy logic or neural network or both[10]. In healthcare, the most common application of traditional machine learning is precision medicine – predicting what treatment protocols are likely to succeed on a patient based on various patient attributes and the treatment context. The great majority of machine learning and precision medicine applications require a training dataset for which the outcome variable (eg onset of disease) is known; this is called supervised learning[11].

2. Deep Learning:

The ML is a subset of AI, meanwhile, DL, in turn, is a subset of ML. The term deep learning refers to artificial neural networks (ANN) with complex multilayers. Deep learning has more complex ways of connecting layers, also has more neurons count than other networks to express complex models, with more computing power to train and further has automatic extraction of the feature[12]. The pattern of connections between neurons defines the particular neural network's architecture, and the fine-tunable strengths of those connections are called the weights of the neural network. In medicine and dentistry, one of the most commonly used subclasses of ANN is the convolutional neural network (CNN)[4]. A common application of deep learning in healthcare is recognition of potentially cancerous lesions in radiology images. Deep learning is also increasingly used for speech recognition and, as such, is a form of natural language processing (NLP)[11].

3. Clinical Decision Support System:

CDSS actually is any computer system designed to help healthcare professionals make clinical decisions through managing clinical data or medical knowledge[13]. Most CDSS have four basic components: Inference Engine (IE), Knowledge Base (KB), Explanation Module and Working Memory. The Inference Engine (IE) is the main part of any such system, containing the knowledge about the patient from which to draw conclusions regarding certain conditions. The collected patient data may be stored in a database or may exist in the form of a message and is known as the working memory[14].

4. Artificial Neural Networks (ANNS)

Artificial neural networks are highly interconnected network of computer processors that are inspired by the biological nervous systems[15]. McCulloch and Pitts (1943) invented the first artificial neurone using simple binary threshold functions. An important milestone came 1958

which worked on a multilayer feed forward mechanism. Another breakthrough in this technology came in 1974 as "backpropagation" learning[16]. ANN consists of a variable number of artificial neurons or nodes connected in hierarchical layers: an input layer, one or more hidden layers, and an output layer. Their ability to learn from historical examples, analyse non-linear data, handle imprecise information and generalise enabling application of the model to independent data has made them a very attractive analytical tool. They have been used in the clinical diagnosis, image analysis in radiology and histopathology, data interpretation in intensive care setting and waveform analysis[8].

Clinical Application And Studies Conducted In Relation To Different Dental specialties:

1. Restorative Dentistry:

Dental caries is the most common dental disease and that is why its disclosure in the early stage is crucial. For the screening and diagnosis of dental caries, dentists mostly use dental probes. The method is very subjective and is based on the dentist's experience[17]. Additional tests such as radiographs are essential in modern dentistry and can enhance the detection of caries. Dental caries detection on radiological images might be assisted by neural networks, which makes the examination faster and more precise. Algorithum can be used to locate the edges of anatomical and pathological structures, which might be very similar to each other due to the image noise and low contrast[5].

2. Endodontics:

Artificial intelligence has an increasing relevance in endodontics. It can be useful in detecting periapical lesions and root fractures, root canal system anatomy evaluation, predicting the viability of dental pulp stem cells, determining working length measurements,

and predicting the success of retreatment procedures. Artificial neural networks may be used as a decision-making system for locating the minor apical foramen on radiographs[5]. In Saghiri et al.'s research, endodontic files were used to determine the length of the canals on the radiology images with the use of artificial neural networks and without. The measurements were taken before the extraction of the teeth and after the extraction with the use of stereomicroscopy. The correct assessment made by the endodontics was strict in 76% and by the artificial neural network in 96%[18] . This shows that artificial neural networks may be used to assess the localization of apical foramen more precisely than humans.

Apical periodontitis is an inflammatory process mainly caused by the bacterial infection of the root canal system. It may be detected through radiographic diagnostics and manifest as periapical translucencies that are also named periapical lesions. Setzer et al. in their research used deep learning to detect periapical lesions on cone-beam computed tomographic (CBCT) images. The accuracy of finding the lesions was 93%. Artificial neural networks may not only be used in dental radiology, but also in genetics as it comes to endodontics[19]. In the study of Poswar et al., artificial intelligence was used to analyse the gene expression for radicular cysts (RCs) and periapical granulomas (PGs). The results showed that not only the inflammation, but also other biological processes may individuate the RCs and PGs because of their different gene expression[20].

3. Orthodontics:

The most common fields of orthodontics where neural networks may be used are in diagnosis and treatment planning, automated anatomic analyses, assessment of growth and development, and the evaluation of treatment outcomes[5]. Peilini et al. used an ANN in their study to predict whether patients need extractions or not in their treatment plan. Moreover, they took the anchorage patterns into consideration. The accuracy of the artificial neural

network in the success of the treatment plan was 94.0% for extractions and 92.8% in the prediction of the use of maximum anchorage. These results indicate that ANN can be used by orthodontists to make more precise treatment plans[21]. In the research by Kök et al., the cephalometric and hand-wrist radiographs were obtained from patients aged between eight and 17 years. The growth-development periods and gender were determined from the cervical vertebrae by using ANN and the accuracy value of the results was found to be 94.27%[22] . Auconi et al. developed a system based on artificial neural networks with the purpose to predict the treatment outcomes in class II and III patients. The analysis could anticipate the co-occurrence of auxological anomalies during individual craniofacial growth and possibly localize reactive sites for a therapeutic approach to malocclusion[23].

4. Oral &Maxillofacial Surgery:

Implantology is an area that is developing very rapidly and the use of neural networks might be very helpful in daily practice because of the need for high precision and meticulous planning. Neural networks in dental surgery might be widely used in many areas starting with the orthognathic surgeries, changes in the bones or post extraction complications. Dental implant treatment planning with the usage of three-dimensional cone-beam computed tomography (CBCT) images can be facilitate by AI systems. The quality of the osteointegration can be assessed by using convolutional neural networks[5].

Patcas et al. indicated that artificial intelligence may characterize the impact of orthognathic surgery on facial attractiveness and age appearance. According to the algorithms, most patients'appearance improved with treatment (66.4%), resulting in a younger appearance of nearly one year[24]. Extraction of the lower third molar is one of the most popular dental surgery procedure. The paresthesia of the nerve after mandible wisdom tooth extraction is quite a common complication. Byung Su Kim et al. used the panoramic images before the

extraction and the anatomical relationship between the nerve canal and dental roots was used by the CNN to predict the occurrence of nerve paresthesia. However, the authors concluded that two dimensioned images as panoramic radiographs may lead to more false positive and false negative results, therefore, future research is needed[25].

5. Periodontology:

Periodontitis is a wide spread disease that concerns billions of people worldwide and if untreated, leads to tooth mobility and in severe cases, to tooth loss. To prevent this from happening, early disease detection and effective therapy needs to be carried out. Periodontal probing has limited accuracy because of the individual examiner's assessment.Commonly used additional examinations are dental radiographs, whose evaluation also depends on the examiner's experience. To minimize errors in diagnosis, some authors have used neural networks[5]. Krois et al. evaluated panoramic radiographs with the help of convolutional neural networks to detect periodontal bone loss in percentage of the tooth root length. The results were compared with the measures made by six experienced dentists. The CNN had higher accuracy (83%) and reliability than the dentists (80%) in detecting periodontal bone loss[26]. Convolutional neural networks can assess the marginal bone level, top, and apex of implants on dental periapical radiographs. study by Jun-Young Cha et al., the bone loss percentage was calculated and classified by the automated system. This method can be used to assess the severity of peri-implantitis[27]. Other authors have also used neural networks to evaluate radiographic bone loss, and in this way, developed an automatic method for staging periodontitis according to the new criteria proposed at the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions[5]. Vadzyuk et al. took into consideration the psychological features to predict the development of periodontal disease. They concluded that patients' level of anxiety and stress hormone levels had an

impact on periodontitis. Assessment of the condition of teeth hard tissues, the level of oral hygiene, and the evaluation of psychophysiological features with the use of neural networks can effectively predict the risk of periodontal disease development in young people[28].

6. Prosthodontics:

To provide ideal esthetic prosthesis for the patient various factors like anthropological calculations, facial measurements, ethnicity and patient preferences has been integrated by a design assistant, RaPid for use in prosthodontics. RaPiD integrates computer aided design, knowledge based systems and databases, employing a logic based representation as a unifying medium. With the help of Artificial Intelligence, the computer can actually guide the dentist during the entire procedure of making a digital impression and aid in making an ideal impression[8].

Non- clinical and Administrative application of AI:

1. 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[29]. ANN has sufficient precision for the design and chairside manufacturing of dental prostheses, based on digital image acquisition following tooth cusps assessment. It can have a great potential in investigating the properties of dental materials such as chemical stability, wear resistance, and flexural strength[2].

2. Oral Pathology:

The neural network may be of value for the identification of individuals with a high risk of oral cancer or precancer for further clinical examination or health education[2]. Ibragimov and Xing were the first to attempt the use of CNNs for segmentation of organs at risk from head and cancer CT images. Their results confirmed that CNNs well-generalize the intensity appearance of objects with recognizable boundaries[30]. Fuzzy sets have been used to predict cervical lymph node metastasis in carcinoma of the tongue, for the prognosis of nasopharyngeal carcinoma, outcome prediction in esophageal cancer and for the prediction of oral cancer susceptibility[31].

3. 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)[1]. It can also create a database about any relevant medical history or about any allergies that the patient may have. It can also provide emergency tele-assistance in cases of dental emergencies when the dental health care professional cannot be contacted[1].

Ethical Implications:

Healthcare decisions have been made by humans in the past, and the use of smart machines to assist with them raises issues of accountability, transparency, permission and privacy. Many AI algorithms are virtually impossible to interpret or explain. Machine learning systems in healthcare may also be subject to algorithmic bias, perhaps predicting greater likelihood of disease on the basis of gender or race when those are not actually causal factors[32]. We are

likely to encounter many ethical, medical, occupational and technological changes with AI in healthcare. It is important that healthcare institutions, as well as governmental and regulatory bodies, establish structures to monitor key issues, react in a responsible manner and establish governance mechanisms to limit negative implications[11].

Challenges Faced:

The management and sharing of clinical data are major challenges in the implementation of AI systems in health care. To integrate AI into clinical operations, systems must be adapted to protect patient confidentiality and privacy. Thus, before considering broader distribution, personal data will have to be anonymized. AI systems are also associated with safety issues. Mechanisms must be created to control the quality of the algorithms used in AI. Finally, the transparency of AI algorithms and data is a substantial issue[4]. The quality of predictions performed by AI systems relies heavily on the accuracy of annotations and labeling of the dataset used in training. Poorly labeled data can lead to poor results. Furthermore, health care professionals should possess a full understanding of the decisions and predictions made by an AI system, as well as the capability to defend them[4].

Future Trends:

We believe that AI has an important role to play in the healthcare offerings of the future. In the form of machine learning, it is the primary capability behind the development of precision medicine, widely agreed to be a sorely needed advance in care. Given the rapid advances in AI for imaging analysis, it seems likely that most radiology and pathology images will be examined at some point by a machine. Speech and text recognition are already employed for tasks like patient communication and capture of clinical notes, and their usage will increase. It

also seems increasingly clear that AI systems will not replace human clinicians on a large scale, but rather will augment their efforts to care for patients[11].

Advantages And Disadvantages of Artificial Intelligence (AI):

Advantages of AI

1. Tireless performance which saves time.

2. Logical and feasible decisions which results in an accurate diagnosis.

3. Standardization of procedures[8].

Disadvantages of AI

1. The complexity of the mechanism.

2. The costly setup.

3. Enormous data is required for training and precision[8].

Conclusion

Dentistry is a field of medicine where new technologies are developing very quickly. Nowadays, artificial intelligence and neural networks are mostly used in dental radiology to facilitate diagnosis, treatment planning, and prediction of the treatment results. Other areas of dentistry where neural networks are used are genetics, psychology, microbiology, and many others[5]. The use of AI should be viewed as a complementary asset, to assist dentists and specialists. The road to successful integration of AI into dentistry will necessitate training in dental and continuing education. AI systems show promise as a great aid to oral health professionals[4]. The advantages of this process are better efficiency, accuracy and precision, better monitoring, and time saving[33]. More research is needed with the use of neural networks in dentistry to put them into daily practice and to facilitate the work of dentist. This review

shows that artificial intelligence has developed very fast in recent years and it may become an ordinary tool in modern dentistry in near future.

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