

A Review of the Literature on Artificial Intelligence in Dentistry as a Possible Game Changer

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Abstract

The need of intelligent software for data collection, storage, analysis and helping in the treatment planning has become an important component as the amount of information and patient data has increased dramatically. Artificial intelligence (AI) is the method of programming that makes the machines with help of computers to think and behave like humans. Artificial intelligence has a variety of uses in medicine and dentistry, ranging from data analysis and identifying relevant information to using neural networks for diagnosis and the use of augmented reality and virtual reality in dental education. Dentistry is undergoing technological changes as well, thanks to artificial intelligence. Dentists in the modern age have never shied away from embracing newer innovations that have promising futures. Artificial intelligence software is assisting dentists in correctly diagnosing cases and treating patients. This technology is assisting in increasing awareness of oral and maxillofacial disorders and risk factors, as well as motivating patients to seek care as soon as possible. The integration of artificial intelligence and digitization has ushered in a new age of dentistry, with highly promising future prospects. The aim of this review is to update and emphasize the importance of artificial intelligence in dentistry.

Keywords: Artificial Intelligence, Artificial Neuronal Network, Dentistry, Image recognition, Virtual Reality.

Introduction

Industrial revolution in the 18th century has transformed predominantly agricultural based economy into modern industrialized urban society. This revolution drastically changed scientific concepts and more researches have been carried out to safeguards employees from industrial hazards and simplify their jobs.[1] On the basis of continuous research Robots were introduced in the industries. They were designed to perform only routine work and not had any analytical capacity like human. To make the machines more effective and perform multiple tasks different tasks researches were carried out for several years and they started programming the machines with the help of advancing computer sciences and micro chip science.[2,3] The word "artificial intelligence" (AI) was coined in the 1950s to describe the process of developing computers that can perform tasks that humans usually do.[4,5] It describes how technology is used to develop software or a machine that can easily mimic human intelligence and perform specific activities.

Artificial intelligence (AI) is a computer science subfield. It entails the development of computer programs to perform tasks that would otherwise necessitate human intelligence. Robotics is a technology division that deals with robots and are capable of performing a series of tasks autonomously or semi-autonomously.[6] To perform complex works AI has to be integrated with these machines. Machine learning (ML) is a part of AI, and the purpose of it is to facilitate machines to learn from data so they can resolve issues without human input. Neural networks (NNs) are a common type of machine learning model that outperforms more conventional ML algorithms in complex data structures like imagery or language.[7,8] Neural networks are a group of algorithms that use artificial neurons to compute signals. The aim of neural networks is to create networks that function in the same way that the human brain does. Fuzzy logic and Artificial Neural Networks (ANN) can learn and inspect data to perform different functions. The term "deep learning" is a reference to deep (multi-layered) NN architectures and the purpose of deep learning is to construct a neural network that automatically identifies patterns to improve feature detection.[9]

Even though researches on AI were underway for the past several decades, there was no breakthrough achievement done. However, the previous decade is remembered as the decade of extraordinary achievements in the field of artificial intelligence. Artificial Intelligence (AI) in healthcare is a game-changing force that will improve a wide range of clinical specialties as well as hospital operations.[10] AI

systems with their data mining and recognition capabilities provide appropriate patient care and effective treatment at the right time. Algorithms obtained with the aid of AI would be more precise and simpler, enabling clinicians to provide patients with unparalleled diagnosis, treatment, and care. Patients' histories and medical history will be scanned using natural language processing and predictive analytics to detect patterns, forecast progression, and chart care plans. This type of program, when combined dentist's clinical skills would have a significant effect on dental office operations. Dentists who use these new technologies will improve their accuracy, profitability, and patient confidence. Aim of this review is to update and analyse the applicability of AI and it's outcome in dental field.[11,12]

Dental education

Artificial Intelligence (AI) assists in determining what a student knows and does not know, as well as creating a tailored study schedule for each learner that takes into account information gaps. AI tailors studies to the individual needs of students in this way, increasing their productivity. Personal study plans that are constantly changing take into account the holes that students need to fill during individual lessons. Personal tutoring and counseling for students outside of the classroom assist students in staying on track with their studies.[13] Faculties save their time with AI tutors so they don't have to waste extra time explaining difficult topics to students. Students may stop being humiliated by asking for help in front of their peers by using AI-powered chatbots or AI virtual personal assistants. Virtual reality is a computer-generated simulation of a three-dimensional image or world that can be interacted with in a seemingly real or physical way by individual using special electronic equipment in a seemingly real or physical way. Students may assess their work and equate it to the ideal in the collaborative interphase, resulting in high-quality training environments.[3,6,8] Students achieve a competency-based skill level at a faster pace with these systems than with conventional simulator devices, according to a number of studies on their effectiveness. In dental education, there has been a major increase in the quality of input generated by the preclinical virtual patient as a result of the recent implementation of artificial intelligence in intelligent tutoring systems. This virtual reality system can also be used in teaching the patients for their better understanding. [14]

Patient care management

Artificial intelligence will help to take care of the hundreds of patient records and will help the dentists segregate them and it would then be able to analyze unstructured data in a patient's medical and dental history link it to larger databases to find other health issues.[11,15] Which will help dentists to understand patients' overall health and plan their treatment according to that. Based family history, lifestyle and medical history it will give an idea about potential dental risks. Based on database it can help in clinical diagnosis and treatment, as well as provide medical tele-assistance in cases of dental emergencies where the dental health care provider is unavailable. AI devices, in combination with virtual reality, have been used to not only minimize dental anxiety, but also as an effective method for non-pharmacological pain management. Based on the patients' medical records, AI technology can also help in medication selection for treatments and serve as a foundation for domain-based clinical exploration.[16] Artificial intelligence, as a whole, has the potential to estimate optimal decisions in dynamic and unpredictable circumstances. By helping dentists in making decisions and appointment managements, it will make dentists more productive than without an AI.[9,11]

AI in diagnosis and treatment plan

AI can be used in conjunction with digital imaging systems such as digital periapical radiographs, panoramic radiographs and CBCT (cone beam computed tomography) to detect minute deviations from normalcy that would otherwise go unnoticed by the naked eye. This method can also be used to precisely identify landmarks on radiographs for cephalometric diagnosis.[17] If an ML algorithm is trained by examining thousands of images labeled as normal or abnormal, it can be used to detect abnormal changes through a head and neck image. In locating, the minor apical foramen, accessory canals, fractured roots as well as proximal dental caries can be identified with the ANN embedded AI. Researcher used DCNNs (Dilated Convolutional Neural Networks) to diagnose and interpret dental radiographs and another study

conducted on classifying tooth types in dental cone-beam CT images using an automated DCNN process.[18] Both of them showed promising results. According to some researchers AI embedded diagnosis methodology detected individual lung nodules on chest scans 62 percent to 97 percent faster than a panel of radiologists.[4,7] AI enhanced dental imaging technologies would be able to scan and annotate x-rays, detecting a wide range of pathologies such as tooth decay and bone loss, as well as previous dental work and natural anatomy. This will aid the dentists in proper diagnosis, treatment planning and save time. Researchers used AI-based CNNs (Convolutional Neural Networks) for effective teeth recognition and the results showed that 95-98% of accuracy of identification.[19] According to the findings, AI innovations make it easier for clinicians to do their work. They are not required to manually enter the information. Dentists may enter their dental charts digitally using these electronic systems, resulting in increased productivity and reduced charting time. Several studies were performed in the detection of dental caries and they have given promising results even though they were modified.[11,14] They used CNN based algorithms, deep learning models and Near Infrared Light Trans illumination(NILT) images. In one study it has been that reported of applying CNNs for detection of Sjögren's syndrome (SjS) on CT images and compared the results with the performance of radiologists and showed a higher diagnostic performance. In another study the authors applied the deep learning system for diagnosing maxillary sinusitis on panoramic radiography and the diagnostic performance of was sufficiently high.[20] These results were comparable with experienced radiologists. In a study CNN with Deep Learning system was used for image classification for diagnosing lymph node metastasis on (CT) Images and showed higher diagnosing accuracy, sensitivity and specificity. In some scenarios, dentists do not have enough knowledge to make the right clinical decision in a limited period. Like that, kind of situations, AI can serve as their assistant to make better decisions in optimal period.[6,9]

According to a global survey conducted in 2019, there were 269 applications, with 99 companies developing these applications. The majority of these businesses (75%) were established after 2010. According to the research, North America (NA) is the most successful sector, followed by European and Asian firms.[] This trend of emerging AI companies clearly indicating how fast the AI space increases in diagnosis. According to market study, the global demand for AI in health care could rise at a 40% annual compound rate from \$1.3 billion in 2019 to \$10 billion in 2024. Artificial intelligence (AI) and machine learning techniques in digital pathology have emerged as a result of the ability to digitize whole-slide images of tissue, allowing for the mining of sub visual morph metric phenotypes and potentially improving patient management. The method of digitizing histopathology slides using whole-slide scanners, as well as the study of these digitized whole-slide images (WSI) using computational methods, is referred to as digital pathology.[21] It helps the pathologists to give appropriate diagnosing by providing thousands of stored or online data. Automating the detection of potentially malignant and malignant lesions in the oral cavity may result in low-cost and early diagnosis of the disease. Since in majority of the cases due to the late detections ends up in irreparable damage, it has become very important to identify in early stages. It's important to a mass a wide library of well-annotated oral lesions. Some researchers used Deep Learning and CNN based studies in detecting oral cancer and pre-cancerous lesions and conditions. But still this area needs more experiments to give more precise diagnosis. [7,22]

AI in orthodontics

Artificial intelligence (AI) has reportedly been used to assist in orthodontic care preparation for some time. Intraoral 3D scanners, cameras and radiographic images analyzing AI embedded soft ware's are available to diagnose and schedule care. This removes the need for patient impressions as well as many laboratory measures, and the findings are typically much more precise than human experience. Algorithms and mathematical analysis can be used to predict tooth movement and treatment outcome.[3,8] There have also been advancements in technology that can automatically determine whether or not a person requires braces. Not only this but things like how much pressure of the braces has to be applied to what places also have to be determined by AI. In a research, on whether to do extraction or not in orthodontic patients it has been showed that the constructed ANN in this study showed 80% accuracy in testing set. Moreover, lip incompetence and IMPA(L1-MP) were the two indices that give the biggest contribution to the output data.[9,23] An automated treatment planning and customized surgical set up planning lead to improved

diagnostic quality. Using AI in image segmentation plays an important part in orthodontic diagnostic systems and also important in volumetric medical image analysis. Software with AI algorithms are available to analyze the cephalometric based diagnosis and treatment planning.[21] Establishing of accurate diagnosis and treatment planning in orthognathic surgery is the most important step for the success of the treatment. The use of artificial intelligence has also been used to assess the growth and development of cervical vertebrae levels. One study showed that a mean accuracy of 77.02%, using artificial intelligence algorithms for determining the growth and development by cervical vertebrae stages when applied on the cephalometric radiographs.[9,11,21] In a study conducted to classify TMJOA condylar morphology (Temporomandibular Joint osteoarthritis) based on AI, it has showed the result with accuracy of 73.5%-91.2% in comparison with experts. It may also be used to provide general practitioners with orthodontic consultations for the alignment of crowded lower teeth.

AI in conservative dentistry

AI can be utilized in the diagnosis of caries detection, analyzing the depth of the caries through radiographs and based on this analysis it will help in diagnosis, designing the preparation of the tooth and optimal material for restoration or type of treatment. These can be done through storing thousands of radiographic and caries images, properties of restorative material, experts opinions and case scenarios. After capturing images with scanners and radiographs it will analyze either with the help of existing information's or searching through online it will give options for treatments. This ultimately will reduce the burden of a dentist. The success of endodontic treatment depends on properly identifying root canal morphology, presence or absence of accessory canals and assessing the working length properly.[24] According to studies conducted to evaluate the efficacy of AI in assessing the working length, it had showed that exceptional accuracy of 96% and 93% in identifying the apical foramen which is higher than the accuracy compared to professional endodontists.[14] In another study AI was used to detect vertical root fractures and the result was with an accuracy of 96.6%.[11] These studies clearly indicates that AI-based models are incredibly effective when it comes to the detection of vertical root fractures and working length measurement on radiographs.

AI in Prosthetic Dentistry

A concept assistant has combined different variables such as anthropological calculations, facial dimensions, race, and patient desires in order to provide ideal esthetic prosthesis for the patient. Using Artificial Intelligence, the computer will actually direct the dentist through the whole process of creating a digital impression and assist in making an ideal impression. It helps in analyzing arch pattern and helps in designing the partial or complete removable dentures. The advancement of virtual reality has made the process of providing cosmetic prosthetics and meeting patient needs much simpler.[3,16] The patient can try on a virtual prosthesis with the aid of AI systems and augmented reality, which can be changed until the patient is pleased, and the final prosthesis is made exactly according to these requirements. The introduction of AI in the field of implantology has made designing the prostheses to accurately and automatically and helps in identifying the exact location for implant placement. AI embedded tongue drive system is capable of analyzing tongue motions in the oral cavity and acting in accordance with the commands stated in the guidelines.[4,17]

AI in periodontics

Periodontal diseases are one of the most common oral diseases afflicting humanity. This is a well-known reality and is one of the leading causes of tooth loss in children. The disease will ultimately cause adults to lose their teeth if it continues to develop. Several studies have been conducted to determine the application of AI technology in diagnosing and predicting periodontal diseases. The outcome of one study used CAD system based on a deep convolutional neural network (CNN) algorithm for diagnosing and predicting the teeth that are compromised with periodontal health, was quite acceptable with a mean predictive accuracy of 78.9%.[16] Another study used a CNN-based AI method for correlating impaired periodontal health with systemic health effects, and found that AI can be used for automated diagnoses and screenings for other diseases.[8] AI can be used in radiographic images to analyze the periodontal

status and pre and post periodontal treatment changes through Deep Learning concepts. Based on their immune response profile, ANN can also be used to identify patients into two groups: aggressive periodontitis and chronic periodontitis. In previous study a convolutional auto encoder method used for segmenting gingival diseases from oral photos. This model effectively distinguishes between gingiva that is inflamed and gingiva that is stable. [21,25]

AI Oral surgery

AI can be used in pre surgical diagnosis and treatment planning and post surgical prognosis. It helps in identifying the relation between the tooth and nerve canals and to create 3D computed models to plan surgeries like orthognathic surgery, Lefort fractures, ridge augmentation surgery etc., AI embedded Deep Learning software helps the surgeons virtually design the surgical pattern and to predict the outcomes. Previously the have to work on 2D radiographs and plaster models to plan their surgical procedures.[8,11] Sometimes this might end up in wrong treatment. But AI software makes them work effectively. Similarly AI technology has also been used for predicting postoperative facial swelling after extraction of teeth. One study used an artificial intelligence model based on ANN for predicting the postoperative facial swelling following the extraction of impacted mandibular 3rd molars. The model produced excellent results and will be extremely useful to clinicians in predicting treatment prognosis.

Head and neck cancer:

Early detection of potentially cancerous head and neck lesions will prevent cancer in up to 88 percent of cases, but the majority of patients are diagnosed at a late stage of disease (62 percent at stage III or IV). Medical, radiological, and histopathological evaluations are used in the traditional diagnosis of suspected head and neck lesions. In the diagnosis of cancer in the head and neck AI helps in identifying and treatment planning.[19,23]A number of studies have shown that AI-based approaches can accurately predict diagnosis, prognosis, mutational status, and treatment response in a variety of cancers, including colorectal, lung, skin, and breast cancers. These studies show that AI-based methods can provide quicker, more consistent, precise, and repeatable cancer diagnosis and prognosis information, which can supplement traditional (and mostly subjective) light microscopy analysis by experienced pathologists. One study used CNNs to segment organs at risk from CT images of the head and neck. Their findings confirmed that CNNs generalize the intensity presence of objects with recognizable boundaries well, but that additional details for CNN-based segmentation of objects with poorly recognizable boundaries might be needed.[26] Another research found that when the characteristics selected were smoking, drinking, chewing, histological differentiation of SCC, and oncogene p63, genetic programming (GP) performed the best in oral cancer prognosis. In terms of oral cancer prognosis, the GP outperformed both the SVM and the LR. GP has also been shown to be useful in drug development. Fuzzy sets have been used to estimate cervical lymph node metastasis in tongue carcinoma, prognosis of nasopharyngeal carcinoma, esophageal cancer outcome prediction, and oral cancer susceptibility prediction.[16,23] Some AI-based studies used an automated nuclear phenotypic score (a-NPS) to find nuclear phenotypic changes in oral epithelial dysplasia (OED) lesions, while another study established an automated color-based feature extraction method to segment and classify OSCC stained with anti-CD34 antibody.[5,24] Because of the alarming increase in global head and neck cancers incidence and its poor prognosis, AI-based methods are well adapted to help objective diagnosis and provide useful prognostic details. Apart from all the above uses in dentistry the AI also used in Forensic odontology for identifying the victims age, gender, jaw morphology and bite marks. It can be utilized in criminal cases and mass disasters to identify the persons.[7,16]

Conclusion

In the last decade, the world of artificial intelligence has developed and it has impacted dentistry also. Several studies had been performed in dental field with the help of AI and they showed some promising results. Although developments in AI such as neural networking, natural language processing, image recognition, and speech recognition have revolutionized in many ways, still AI have a range of drawbacks and it has to be overcome. But dentists should be prepared themselves to accommodate this upcoming AI enabled dentistry.

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