Transforming Dentistry: The role of Artificial Intelligence in Oral health care

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Abstract:

In the field of dentistry, artificial intelligence (AI) has been integrated into various dental specialties, such as oral diagnosis, endodontics, prosthodontics. The main use of AI in dentistry is for diagnosing conditions based on radiographic or digital images. However, the development of AI in dentistry is constrained by challenges related to data availability, data uniformity, and computational power, which are essential for effective data handling. Evidence-based dentistry (EBD) is considered appropriate for decision-making in dentistry, while AI machine learning (ML) models can complement expertise of humans by learning from it. Therefore, machine learning can be a valuable in assisting dental professionals in various stages of clinical cases. It is important to understand AI as a tool that can help clinicians in their routine clinical work, improving patient comfort and efficiency.

Keywords: Dentistry, Artificial Intelligence, Machine learning

Alan Turing, a mathematician, rewrote history a second time less than a decade after cracking the Nazi encryption technology Enigma and aiding the Allies in winning World War II. Turing asked himself, "Can machines think?" A few years later, IBM's Deep Blue machine stunned top chess player Garry Kasparov, marking the first notable victory of AI. Even though Kasparov prevailed in their initial meetings, Deep Blue's learning system continued to advance, enabling the computer to win more games. According to Kasparov, "the machine has reached such a high level of creativity, that goes beyond the knowledge of the player," which made the triumph conceivable. Artificial intelligence (AI) is the use of computer technology to simulate human-like intelligent behaviour, critical thinking, and decision-making[1].

Introduction

AI in the field of Dentistry approximates human cognition through software and algorithms, nearing human knowledge levels in the interpretation of complicated data. This shifts the function of computer-assisted diagnosis from a "second-opinion" tool to one that fosters more collaboration. Artificial intelligence (AI) methods, such machine learning (ML) and deep learning (DL) (Fig.1), have the capacity to carry out difficult diagnostic tasks that are currently accomplished by dental specialists, improving efficiency and accuracy of diagnosis[2]. AI works in two stages: "training" in the initial stage and "testing" in the subsequent stage. The training data establishes the parameters of the model set. In retrospect, the model uses data from previous examples, such as patient data or data from groups of data with different examples. After that, the test sets are subjected to these configurations[3]. (Fig.2)

Without the assistance of a dentist or other specialist, adequately trained AI can analyse dental radiographs to detect teeth, identify pathologies and anomalies such as dental caries, missing or lost teeth, periapical lesions, and maxillofacial abnormalities in a significantly shorter amount of time and with greater accuracy[4].

Stratified structure of Artificial Intelligence

AI adheres to fundamental machine hierarchy of Input, Processing, and Output[5]. When it comes to Dentistry, the data can be text (medical/dental records/ OPD registrations), pictorial (extra/intra-oral pictures, radiographs) or voice based (sound of handpiece, ultrasonic cleaning aids, mumbling of patients). This input data is processed by the neural networks, which then produce an output. The outcome could be a disease prediction, diagnosis, prognosis, or treatment. To make a diagnosis, it can use cephalometric analysis, clinical cue interpretation, or voxel differences to identify lesions. It makes predictions about how to handle the input by identifying typical structures, generating and assessing results, transforming speech data, or bridging the gap between data acquisition and CAD/CAM.

Integration of Artificial Intelligence in Dentistry

AI has revolutionized dental patient care by offering customized support and improving the patient's experience in the chair. Patients can get fast assistance during dental emergencies, oral hygiene advice, and answers to commonly asked issues. Artificial intelligence frees up time for dental professionals to concentrate on patient engagement and high-quality care by automating administrative activities like appointment reminders and follow-ups. As a result, patients are happier and have better overall dental experiences[6,7]. AI has the potential to completely transform oral healthcare in a number of ways, so its incorporation into dentistry is crucial.

Applications of AI in Diagnosis

Artificial intelligence can be useful in the diagnosis and treatment of ailments of the oral cavity as well as in the identification and categorization of mucosa that appears to be altered, either precancerous or malignant. The system detects even minute variations at the single-pixel resolution that the human eye might overlook. Artificial intelligence has the potential to accurately determine the genetic susceptibility of a significant number of people to oral cancer[8]. Compared to traditional approaches, AI can precisely predict the risk of oral cancer by assessing biomarkers, age, gender, and tobacco use as predisposing variables. AI outperforms current clinical techniques and conventional statistical methods like logistic regression and cox regression analysis in terms of precision and accuracy in diagnosis and incidence prognosis[3]. In order to diagnose maxillary sinusitis, artificial intelligence and deep learning were used to analyse over 200 water view radiographs with the objective to ascertain the frequency of the condition; osteoporosis was diagnosed in 200 panoramic radiographs using an artificial neural network that was coupled to a CAD system; and Sjogren's syndrome was identified in computed tomography (CT) images using artificial neural networks[9,10,11].

Applications of AI in Radiology

Artificial intelligence (AI) systems are capable of analyzing dental radiography images, including cone beam computed tomography (CBCT) scans and panoramic radiographs, to help in the identification and diagnosis of a range of dental disorders. Convolutional neural networks (CNN) have displayed promise in identifying and detecting anatomical structures. CNN's accuracy rating of 95.8-99.45 percent is comparable to clinical professionals' accuracy score of 99.98 percent when it comes to detecting and classifying teeth. CNNs can also be used to detect and diagnose dental decay[12]. Image enhancement and noise reduction are important

aspects which can improvise the radiographic analysis and overall diagnosis of the disease. The use of artefact reduction algorithms, which remove the distortion caused by radio-opaque objects on the fine details of the acquired image and help to enhance radiographic images while reducing the need for high radiation dose and large voxel sizes, is another way AI is being applied in dental radiology[13].

Applications of AI in Endodontics

In order preserve the tooth in its functioning condition and avoid additional problems, the endodontic procedure aims to deliver the highest standard of care. An artificial intelligence system analyses dental photos using sophisticated algorithms to quickly and accurately estimate the probability of dental caries for professionals. Dental clinics have observed a notable increase in the early detection of occlusal/root/smooth surface caries as a result of deploying AI, which has allowed for prompt interventions and improved patient outcomes with regard to oral health[14].

Artificial intelligence driven tools can help endodontists find and assess sophisticated root canal configurations more precisely by assisting in the identification and categorization of root canals within diagnostic images. By using patient-specific information, such as clinical characteristics, radiographic results, and therapeutic protocols, AI methodologies, such as machine learning, can be used to create prediction algorithms that determine the efficacy or failure of endodontic therapies. In addition, artificial intelligence is utilized in the evaluation of periapical lesions, root fractures, working length measurements, dental pulp stem cell viability estimation, and prognosis of retreatment procedure[15].

Applications of AI in Periodontics

Machine learning algorithms are able to recognize characteristics and signs of the severity of periodontal disease, which makes prompt diagnosis and customized treatment planning possible. By evaluating dental information obtained from patient records, such as probing depths, attachment levels, and bleeding scores, AI-based software may automate periodontal charting. When it comes to identifying and predicting the need for periodontally damaged teeth to be extracted, deep neural network (DLN) algorithms have demonstrated an impressive level of practicality and reliability[16]. A unique technique has been demonstrated to identify brushing and flossing tasks using inertial sensors worn on the wrist[17].

Applications of AI in Orthodontics

The orthodontics perspective is certainly changing due to AI. A vital component of treatment strategy, automated 3D cephalometric analysis based on sophisticated 3D CNN algorithms is currently making use of the capabilities of automated CBCT segmentations[18]. AI systems are often trained on vast datasets to recognize and classify various malocclusion categories, assisting orthodontists in treatment planning and selecting the best course of action. Software driven by artificial intelligence may create virtual 3D models of patients' teeth and replicate the treatment process and results of orthodontic therapy. By examining dental casts and forecasting ideal bracket locations based on unique tooth structure, artificial intelligence systems can automate the process of placing brackets[19]. With the use of precise 3D scans and virtual models, it becomes easy to create 3D-printed aligners in accordance with a customized treatment plan. As the massive volumes of data are analysed, an algorithm is created that effectively ascertains the appropriate amount of pressure and movement desired for each tooth, along with pressure points peculiar for that specific set of teeth.

Applications of AI in Prosthodontics

Models based on artificial intelligence are a reliable diagnostic aid for a variety of tasks, including creating partial dentures, perfecting the metal castings, mapping the tooth preparation, finish lines, selecting tooth shades, and anticipating modifications to patients' facial features who use removable prostheses[20]. Artificial intelligence systems are capable of analyzing digitized dental casts, simulating virtual articulation, and assessing occlusal relationships, interferences, and functional dynamics. When designing a prosthesis, virtual articulation and occlusion assessment can help ensure adequate occlusal contacts and harmony for the best possible functional and cosmetic results. AI tools are able to examine digital pictures of patients' natural teeth and help with suggesting shades that match and in anticipating how prosthetic restorations would look in various illumination scenarios.

Orthopantomogram images are used to classify and differentiate between the brands of various implant systems utilizing deep CNNs and transfer-learning techniques[21]. AI powered software can also assist the dentist in navigated and real-time surgeries where osteotomies are performed to put the implants in a “prosthetically driven implant placement” manner.

Applications of AI in Oral Surgery

Patient-specific information can be used by AI-based surgical planning systems to create virtual surgical simulations. Surgeons can use simulation to virtually plan complex procedures, such tumour excision or orthognathic surgery, by evaluating the likelihood of different outcomes. Artificial intelligence algorithms can help in offering information on the most effective surgical strategy, implant placement, and rehabilitation methods. This may enhance surgical accuracy and ensure the safety of patients. Machine learning has the potential to

improve surgical efficiency and precision by being incorporated into robotic-assisted surgeries and surgical navigation systems. By superimposing virtual models on the planned surgical site, Augmented reality systems can help with accurate incision, soft & hard tissue manipulation, and lower the risk of intraoperative as well as post-operative complications[22].

Limitations & Challenges of Artificial Intelligence

Security and privacy of data pose serious obstacles to the application of AI. Large volumes of data, especially highly confidential and sensitive data, are needed for AI systems to be trained and made predictions. Normally, patients give their informed consent prior to data collection. However, as AI frequently uses sophisticated algorithms and individuals might not comprehend all the implications of data usage, ensuring meaningful consent can be difficult[23]. The accuracy of the training dataset's annotations and classification has an enormous effect on how effectively AI systems anticipate things. Clinic-labeled datasets may vary in quality, which would reduce the efficacy of the AI systems that were constructed. Furthermore, healthcare practitioners must be fully cognizant of and prepared to defend the outcomes and predictions of an AI system[24]. The financial constraints involved with the AI is still a great challenge for middle- & low-income group of countries.

Is AI going to usurp the role of Dentist?

It is important to Not to misled by the name ‘AI’ there is nothing artificial about it, AI is made by humans, and ultimately to impact human lives. Data, measurements, and quantitative analytics are a crucial part of a dentist’s work. Setting up a diagnosis and treating a patient are not linear processes. No robot or algorithm could interpret complex, multi-layered challenges

– involving the psyche. While they will provide the data, interpretation will always remain a human territory. AI cannot engage in high-level conversation or interaction with patients to gain their trust, reassure them, or express empathy, all important parts of the dentist–patient relationship.

Conclusion

Dental practitioners must have sufficient training if they are to progress toward AI. There is a great deal of promise for algorithm and application breakthroughs in dentistry with AI in the future. Dental treatment can be improved even more by combining AI with other cutting-edge technologies like robotics, augmented and virtual reality. The effective and ethical application of AI in dentistry, however, depends on resolving constraints, protecting data privacy, and upholding ethical standards. To realize AI's full potential in revolutionizing oral healthcare, more research and collaborations are required.

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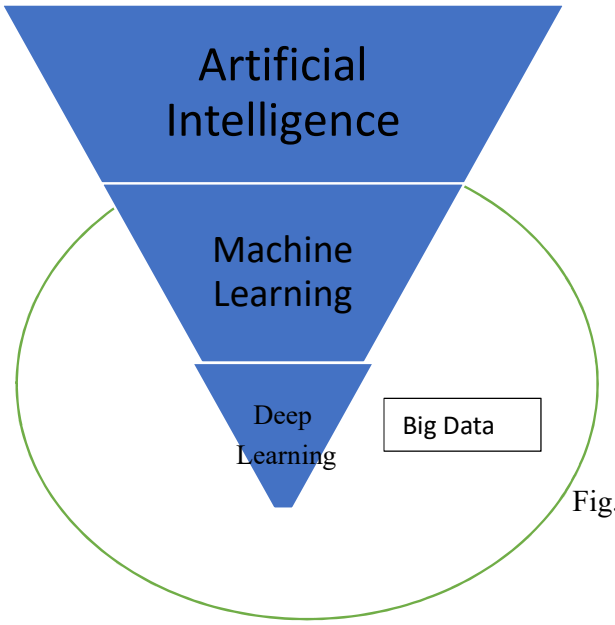

Fig. 1- Key elements of Artificial Intelligence

Fig. 2- Schematic representation of working of conventional & AI models.