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Artificial Intelligence In Dentistry: A Review

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Abstract:
The field of artificial intelligence (Al) has experienced spectacular development and growth over the past two decades. With recent progress in digitized data acquisition, machine learning and computing infrastructure, Al applications are expanding into areas that were

previously thought to be reserved for human experts. The current applications of Al in clinical dentistry were introduced and summarized in the future, the Al-based comprehensive care system is expected to establish high-quality patient care and innovative research and development, facilitating advanced decision support tools. The authors believe that an innovative inter-professional coordination among clinicians, researchers, and engineers will be the key to Al development in the field of dentistry. Al can aid in the advancement of endodontic diagnosis and therapy, which can enhance endodontic treatment results. However, before incorporating Al models into routine clinical operations, it is still important to further certify the cost-effectiveness, dependability, and applicability of these models.

Keywords: artificial intelligence, data, caries detection, future dentistry, machine learning, deep learning.

Introduction:

One of the most fascinating parts of the human body, the brain, has long piqued the interest of scientists and researchers. The scientific world has never really understood how to create a flawless model that mimics the

human brain [1]. For many years, scientists have been working tirelessly to advance "artificial intelligence" (Al) [2]. John McCarthy originally introduced this field of applied computer science known as artificial intelligence in 1956 [3]. It is, at times, called machine intelligence [2]. The "fourth industrial revolution," often known as artificial intelligence, employs computer technology to imitate critical thinking, decision- making, and intelligent behavior that is similar to that of humans [3].

Al is a branch of computer science that aims to understand and build intelligent entities, often instantiated as software programs.[4] It can be defined as a sequence of operations designed to perform a specific task.[5] Historically, artificially intelligent systems applied hand-crafted rules to the specific tasks they were meant to solve. Each task required domain-specific knowledge, engineering and manual Fine-tuning of the system by subject-matter experts. For instance, a system designed to detect lesions in medical imaging might look for abnormally coloured lumps of a given shape. The fine-tunable parts of the system might be a range of healthy tissue colours or minimum lengths and widths for a potential lump. Nowadays, medicine most commonly uses a branch of Al called machine learning[6] and, more recently, deep learning[7]

In Machine Learning (ML), a subfield of Al, algorithms are applied to perform tasks by learning patterns from data. Machine learning technique involves parameter adjustment with regards to underlying technique such as, number of neurons, layers in a neural network technique; population size, rate of mutation and crossing over rate in genetic algorithms technique etc.[8] ML models like Genetic algorithm, Artificial Neural Network (ANN), Fuzzy logic can learn and inspect the data to execute various functions. Out of these, the most popular model is **ANN.**

In Deep Learning an extremely popular class of DL algorithms is the artificial neural network (ANN), a structure composed of many small communicating units called neurons organized in layers. A neural network is composed of an input layer, an output layer and hidden layers in between.[9] It is possible to have 1 or a few hidden layers (shallow

neural network) or multiple/many hidden layers (deep neural network, **DNN) (Figure 1, a** and **b).** These layers are called hidden because their values are not pre-specified or visible to the outside. In medicine and dentistry, one of the most commonly used subclasses of ANN is the convolutional neural network **(CNN) (Figure 1c).**

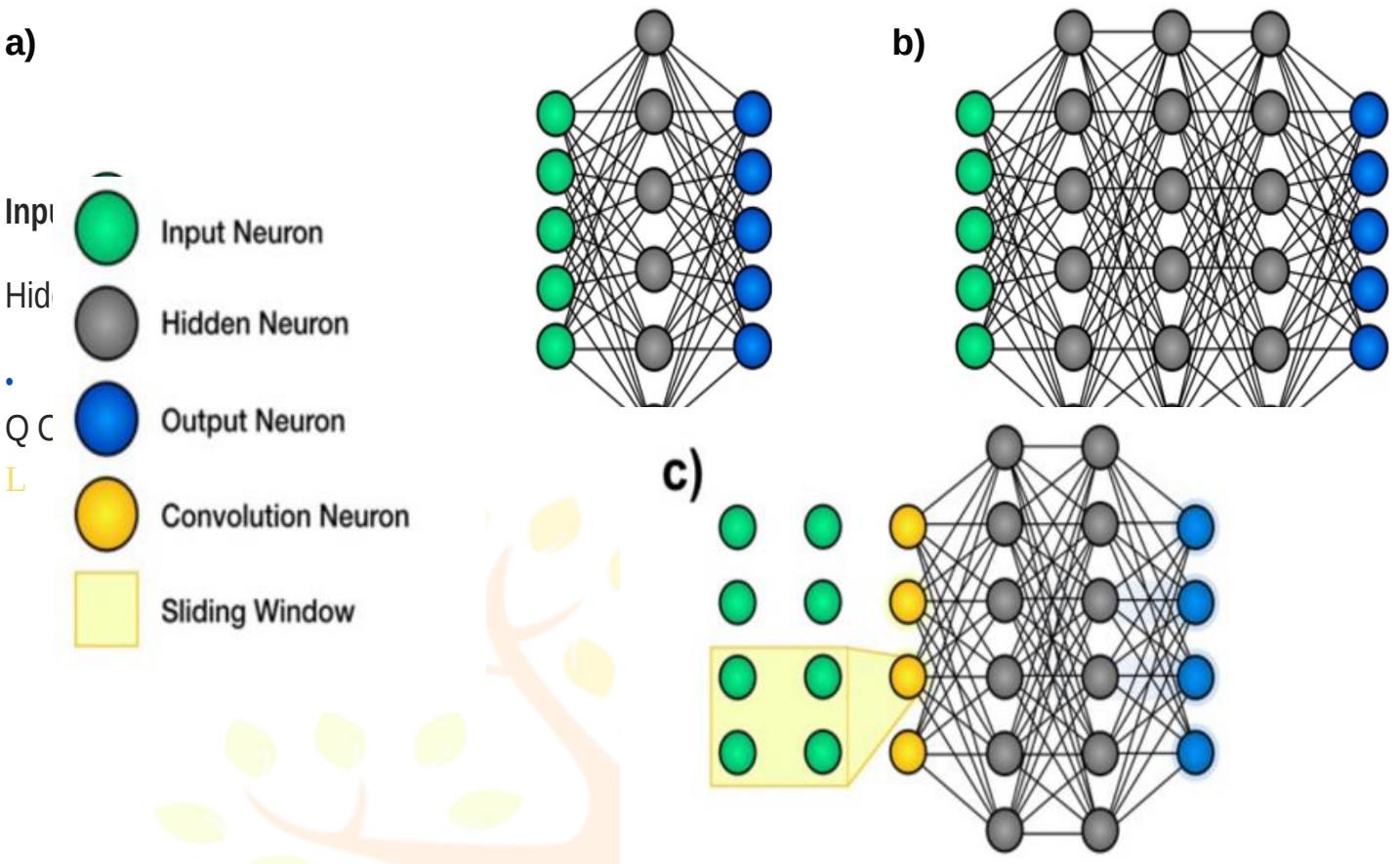


Figure 1: Schematic representation of the architecture of neural networks. Artificial neural networks are structures used in machine learning. They contain many small communicating units called neurons, which are organized in layers. **a.** Shallow neural networks are composed of an input layer, a few hidden layers and an output layer. **b.** Deep neural networks have an input layer, multiple hidden layers and an output layer. c. Convolutional neural networks use filters to scan a small neighborhood of inputs. (Source:Thomas **T. Nguyen,** DMD, MSc, FRCD(C); **Naomie Larrivee; Alicia Lee; Olexa Bilaniuk,** BASc, MSc; **Robert Durand,** DMD, MSc, FRCD(C))

Clinical Application of AI in Dentistry:

Artificial intelligence and radiology

AI provides the additional capability to learn more to be a dental professional. When integrated with imaging methods like MRI and cone

beam computed tomography it can identify even the minute deviations from normal which remains unnoticed by human eye.[1O] For example, ANN is used by dental professional teams to localize minor apical foramen thereby magnifying the precision of working length determination by radiographs and in diagnosis of proximal caries[11,12]. ML algorithms can detect an abnormal or normal lymph node in head and neck image provided a trained Radiologist who can interpret by analyzing thousands of such images which are labelled as normal or abnormal[12].

Artificial intelligence and orthodontics

ANNs have immense potential to aid in the clinical decision-making process. In orthodontic treatments, it is essential to plan treatments carefully to achieve predictable outcomes for patients. However, it is not uncommon to see teeth extractions included in the orthodontic treatment plan. Therefore, it is essential to ensure that the best clinical decision is made before initiating irreversible procedures. An ANN was used to help determine the need for tooth extraction before orthodontic therapy in patients with malocclusion.[13,14] The four constructed **ANNs,** taking into consideration several clinical indices, showed an accuracy of 80- 93% in determining whether extractions were needed to treat patients' malocclusions.[13,14]

AI can detect dental decay and periodontal disease

Typically, dental caries is detected through a clinical examination of the teeth and the inspection of dental radiographs. While radiograph analysis offers initial objective assessments, tooth morphology, margins of restorations, interproximal contacts, incipient decay, and recurrent decay are often determined by tactile sensation, which can differ among clinicians. Equally important, diagnostic capabilities can vary due to the experience level of the dental provider. AI techniques can be helpful in these scenarios because it's shown to provide a more efficient diagnostic process when used in conjunction with clinical assessment. AI can improve quality in the dental field using image detection, classification, and segmentation. For example, CNNs can detect dental decay based on

learning the location and morphology of carious lesions on radiographs; thus they're effective for diagnosing decay.[15] There are currently several AI investigational devices on the market that have been approved for use in dentistry. Dental software that can create a set of nodes and connections that accumulate and apply learning by seeing actual data is now available. It works by "emulating the structure and learning process of a human brain."[16] This software uses a cloud-based algorithm and automatically highlights areas of dental decay found on digital radiographs.[16] Essentially, it can predict caries by CNN image detection and can be easily integrated into existing workflows.

Additionally, CNN techniques can provide image classification and segmentation that can be used as an additional tool to detect periodontal disease on radiographs. CNNs can capture patterns from periodontally compromised teeth (PCT) images and perform edge detection. "Deep CNN algorithms can automatically learn hierarchical feature representations and capture regional patterns from PCT images in their multiple convolutional and hidden layers."[17] Undoubtedly, using deep CNNs on image datasets will prove to be beneficial in diagnosing and treating periodontal disease with objective accuracy.

Artificial intelligence and restorative/prosthetic dentistry

In order to provide perfect prosthesis to the patient, there are several factors which a dentist has to keep in his mind like anthropological calculations, facial measurements, esthetics and patient preferences. The use of computer aided technology for precise fit of prosthesis is yet another breakthrough of Artificial Intelligence in dentistry. Also, CAD/ CAM based systems are used in dentistry to attain finished dental restorations with great precision. Furthermore, AI based systems are used to design inlays, onlays, crowns and bridges. This system has replaced the conventional method of casting the prosthesis, reduces time and errors. [18,19]

Artificial intelligence and Oral Pathology

Detection and diagnosis of oral lesions is of crucial importance in dental practices because early detection significantly improves prognosis. As some oral lesions can be precancerous or cancerous in nature, it is important to make an accurate diagnosis and prescribe appropriate treatment of the patient. CNN has been shown to be a promising aid throughout the process of diagnosis of head and neck cancer lesions. With specificity and accuracy at 78-81.8% and 80-83.3%, respectively (compared with those of specialists, which were 83.2% and 82.9% respectively), CNN shows great potential for detecting tumoural tissues in tissue samples or on radiographs.[20,21] One study used a CNN algorithm to distinguish between 2 important maxillary tumours with similar radiologic appearance but different clinical properties: ameloblastomas and keratocystic odontogenic tumours.[21] The specificity and the accuracy of diagnosis by the algorithm were 81.8% and 83.3%, respectively, comparable with those of clinical specialists at 81.1% and 83.2%. In fact, the algorithm will have the ability to classify different oral lesions into one of three categories: benign, malignant, and potentially malignant[24]. However, a more significant difference was observed in terms of diagnostic time: specialists took an average of 23.1 minutes to reach a diagnosis, while the CNN achieved similar results in 38 s.[21] According to Garg and Karjodkar, "If premalignant or potentially malignant lesions are identified early enough, malignant changes may be prevented altogether or at least the chances of success of the treatment at an early stage is more."[22]

To assist with early diagnosis, mobile applications have been developed and used for image capture of oral lesions for remote diagnosing.[23]

Artificial intelligence in patient management

The management and sharing of clinical data are major challenges in the implementation of AI systems in health care. Personal data from patients are necessary for initial training of AI algorithms, as well as ongoing training, validation and improvement. Furthermore, the development of AI will prompt data sharing among different institutions and, in some cases, across national boundaries. To integrate AI into clinical operations, systems must be adapted to protect patient confidentiality and

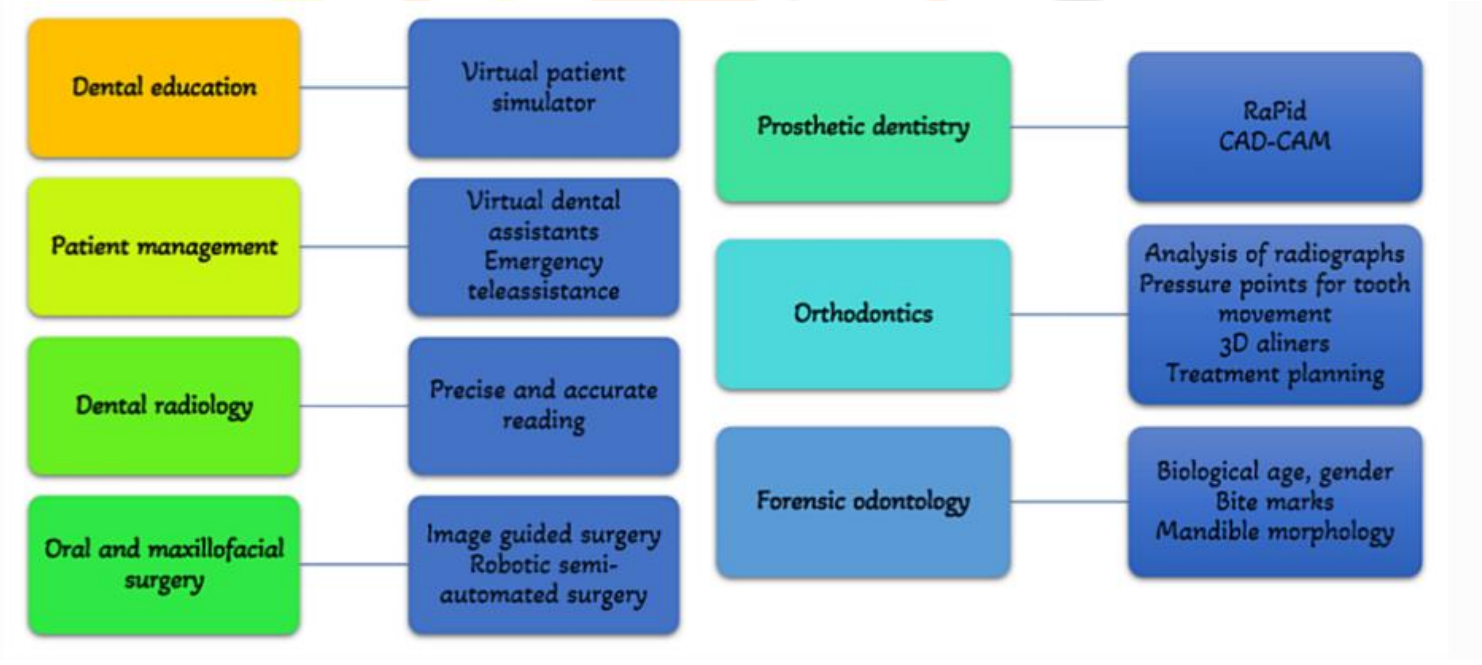
privacy.

[25] Thus, before considering broader distribution, personal data will have to be anonymized.[26] Even with the ability to take these precautions, there is skepticism in the health care community about secure data sharing. Finally, the transparency of AI algorithms and data is a substantial issue. 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.[28] Clinic-labeled datasets may be of inconsistent quality, thus limiting the efficacy of the resultant AI systems. 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.[29] interpretability of AI technology is a known problem, and major advances are required before certain classes of algorithms, such as neural networks, can make clinical diagnoses or treatment recommendations with full transparency.[27]

Other dental applications of AI

Figure describes other dental applications of AI.



(Source:Agrawal P, Nikhade P (July 28, 2022) Artificial Intelligence in Dentistry: Past, Present, and Future. Cureus 14(7): e27405. doi:10.7759/ cureus.27405)

Other applications of Artificial Intelligence in Dentistry are:

In Dental Education

The area of intelligent tutoring systems has advanced significantly since

its start in the 1980s. To generate scenarios that imitate clinical work on patients and minimize all the hazards involved with training on a live patient, AI is frequently employed in the field of dental education.

In Oral and Maxillofacial Surgery

The development of robotic surgery, in which human body motion and intellect are replicated, is the biggest use of artificial intelligence in oral surgery. The dental implant, removal of tumors and foreign objects, biopsies, and temporomandibular joint (TMJ) surgery are examples of image-guided cranial surgery procedures that have been successful in clinical settings. Surgery has undergone a revolution thanks to AI, and there are now several robotic surgeons who, with growing efficiency, carry out semi-automated surgical procedures under the supervision of a skilled surgeon [33].

In Forensic Odontology

AI is a scientific development that has been extensively applied in forensic medicine. It has shown to be quite effective in determining the biological age and gender of the healthy and ill. Additionally, it is employed for analyzing bite marks and predicting mandibular morphology [34].

For Diagnosis, Treatment, and Prognosis

The application of artificial intelligence in the diagnosis and treatment of oral cavity diseases, as well as in the detection and classification of suspiciously changed mucosa experiencing premalignant and malignant alterations can be beneficial. A useful tool for determining dental prognosis in light of the treatment strategy is an AI-based machine learning system. To determine a tooth's prognosis for long-term oral health and function, a thorough treatment strategy must be carefully reviewed [35].

Summary of dental applications of artificial intelligence

AI technologies can help professionals provide their patients with high- quality dental treatment. Dentists may employ AI systems as a supplemental tool to improve the precision of diagnosis, treatment planning, and treatment result prediction. Deep-learning technologies can provide diagnostic assistance to general dentists. Automated technology can speed up clinical processes and boost physician productivity (e.g., automatic completion of electronic dental records by identifying the tooth and numbering). The accuracy of the diagnosis can be increased by using these systems for secondary views [30].

Conclusion:

In conclusion Artificial Intelligence is not a myth but our future in dentistry. Its applications 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. Although multiple studies have shown potential applications of AI in dentistry, these systems are far from being able to replace dental professionals. Rather, the use of AI should be viewed as a complementary asset, to assist dentists and specialists. It is crucial to ensure that AI is integrated in a safe and controlled manner to assure that humans retain the ability to direct treatment and make informed decisions in dentistry. In addition, AI plays a critical role in virtual reality (VR) and augmented reality (AR). A new term, mixed reality, incorporates aspects of generative AI, VR and AR into computer-superimposed information overlays to enhance learning and surgical planning.[31] All in all, the use of AI in dentistry can assist dental providers with valuable information that can be used in real time and increase clinicians' ability to measure the effectiveness of different treatment modalities.[32]This is true despite the contentious debates surrounding the inclusion of empathy into algorithms for affective robots to convey artificial emotions. These communication pathways are intuitive and unplanned.

As various AI systems for diverse dental disciplines are being developed and have produced encouraging preliminary results, a future for AI in the health care system cannot be discounted. AI systems show promise as a great aid to oral health professionals.

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