**ARTIFICIAL INTELLIGENCE IN DENTISTRY**

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INTRODUCTION

In every element of our everyday life, digital technologies are now becoming increasingly significant. Almost all currently operating industries, already have a significant impact, and that impact is only increasing. The economic sector that could most profit from the advent of digital technologies is the dental industry. In order to provide an effective treatment system and enable the dentist, patients, and dentistry students to save a lot of time and money while also reducing human error, it is also necessary to integrate emerging technologies properly in dentistry.1

The phrase "**artificial intelligence**" (AI) refers to the use of technology and robots to carry out tasks that would typically be completed by humans. Fast-evolving technology known as artificial intelligence (AI) makes it possible for computers to carry out formerly human-only functions.2

AI developments provide a glimpse of potential benefits for health care, including fewer surgical complications, higher quality of life, better decision-making, and less wasteful operations. When applied to the fields of medicine and dentistry, AI can play a crucial role in improving diagnosis accuracy and revolutionizing care. AI is currently used for a variety of purposes in dentistry: identification of normal and abnormal structures, diagnosis of diseases and prediction of treatment outcomes. Furthermore, AI is used extensively in dental laboratories and is playing a growing role in dental education.12

**What Is Artificial Intelligence?**

 The goal of artificial intelligence (AI), a subfield of computer science, is to comprehend and create intelligent things, frequently in the form of software. It can be described as a series of actions intended to carry out a particular task. According to “Barr and Feigenbaum,” AI is the part of computer science concerned with designing an intelligent computer system that exhibits characteristics we associate with intelligence in human behavior- understanding language, learning, reasoning, problem solving, and many more. Machine learning and its related topics, such as deep learning, cognitive computing, natural language processing, robotics, expert systems, and fuzzy logic, are subcategories of artificial intelligence (AI).2.

Nowadays, the branch of AI known as machine learning, and more recently, deep learning, is used in medicine.

In **machine learning (ML),** a subfield of artificial intelligence, systems learn to carry out intelligent tasks without the aid of predetermined information or prewritten rules. Instead, without assistance from humans, the systems identify patterns in cases from a vast dataset. A goal is set to do this, and the system's configurable functions are optimized to help the user achieve it. An ML algorithm learns by exposure to random instances and incremental tuning of the "tunables" in this process, which is referred to as training. The system thus finds patterns that it then applies to fresh photos.3

**Deep learning (DL)** is a sub-branch of ML wherein systems attempt to learn a pattern and a hierarchy of composable patterns that build on each other. A "deep" system is far more effective than a simple, "shallow" one due to the combination and layering of patterns. The **artificial neural network (ANN),** a structure made up of numerous microscopic communicative units called neurons grouped in layers, is one of the most well-known classes of DL algorithms. A neural network is composed of an input layer, an output layer and hidden layers in between. It is possible to have 1 or a few hidden layers (shallow neural network) or multiple/many hidden layers (deep neural network, DNN). Because their values are neither pre-determined or externally discernible, these levels are referred to as hidden. They want to make it possible to compute the accurate value of the visible output layer by building hierarchically on the data that was obtained from the visible input layer. The architecture of a particular neural network is defined by the pattern of connections between neurons, and the finely tunable intensities of those connections are referred to as the weights of the neural network.

The **convolutional neural network (CNN)** is one of the ANN subclasses that is most frequently employed in the fields of medicine and dentistry. Convolution is a mathematical technique used by CNN to interpret digital data including sound, picture, and video. CNN uses a specific neuron connection architecture. CNNs employ a sliding window to evaluate a larger image or signal by scanning a small area of inputs at a time from left to right and top to bottom. They are the most used algorithm for image recognition because they are very well suited to the task of image classification.4

**USES OF AI IN VARIOUS FIELDS OF DENTISTRY**

1. **ORAL AND MAXILLOFACIAL RADIOLOGY**

Many AI models have been developed to assess the risk of people getting sick, to detect abnormal health data, diagnose and predict the prognosis of diseases.5 As Digital images are used for diagnosis in radiology, it is quite convenient to transfer these digital data to computer language. Hence, radiology is the most suitable branch of dentistry for the use of AI. Other uses include the use of deep CNN based AI models for diagnosing osteoporosis in dental panoramic radiography (DPR) images. AI has also been found helpful in oral cancer prediction.6

**2. ORAL AND MAXILLOFACIAL SURGERY**

Neural networks in dental surgery may fine wide use in many aspects starting from the orthognathic surgeries, changes in the bones, assessing and minimizing post extraction complications, and planning implantology treatment. Implantology is developing very rapidly and the use of neural networks can be very helpful in daily practice because of the prerequisite of precision and meticulous planning. Neural networks may also help predicting some complications that might occur during surgical treatment and hence avoiding them.One such machine learning system (clinical decision support system) developed by Polášková et al. (2013), provides recommendations in implant treatment. This uses referencing anamnesis and medical examination and provides information pertaining to treatment planning.7

1. **PERIODONTICS**

Deep learning can be used to asertain the prognosis of periodontally compromised teeth and for classification of periodontal diseases. It can be used for examining the periodontal bone loss using a deep learning-based DeNTNet system. Painles and non-invasive ultrasonographic probes are being developed to mesure periodontal pockets. It will apply echo waveforms that AI can evaluate with wavelet transformation technique.8

**4. PEDIATRIC DENTISTRY**

AI customized appliances can be used for early orthodontic movements. AI based devices can be used in pediatric dentistry for pain control.9

**5. ENDODONTICS**

Artificial Intelligence finds wide use in Endodontics. It can be used for detection of periapical lesions, root fractures, working length determination, to study root and root canal system morphology and also for predictions for retreatment and dental pulp stem cells viability.10

**6. RESTORATIVE DENTISTRY**

Neural network use in conservative dentistry has developed quickly, but is not very widespread yet.Artificial neural networks can be used to detect caries,and also to detect and classify dental restorations. Artificial neural networks have also been used to predict the post-Streptococcus mutans prior to excavation of dental caries with an accuracy of 99.03% 11

Artificial intelligence is incorporated into many systems like intraoral scanners such as Cerec Primescan (Dentsply Sirona) , Trios 4 (3Shape) for detecting proximal caries and removal of the excessive images of intraoral scan (my.cerec.com, 2020) Neural Network are capable of high-accuracy caries detection with Near-Infrared- Light Transillumination (NILT) images. Schwendicke et al., 2020).16-17 Another use is to predict the color change obtained by the bleaching system before the procedure by the using fuzzy logic.12

**7. PROSTHODONTICS**

AI helps in producing implant-supported fixed restorations.CNN models can be used to predict the probability of debonding of CAD/CAM composite resin crowns.Backpropagation of neural networks (BPNN) has been introduced for computer color matching in prosthodontics.AI can predict accuratelyfacial soft tissue changes that may occur in patients after complete denture use and can make case specified removable partial denture designs.13

**8. ORAL MAXILLOFACIAL PATHOLOGY**

CNN algorithms shown to be a suitable tool for the detecting cancers. Moreover, tumors on abnormal locations such as nerves in oral cavity, tongue muscles, parotid and salivary glands can be detected via radiography by AI. It can also be used in management of cleft lip and palate for risk prediction, diagnosis, speech assessment, pre-surgical orthopaedics and cleft surgery. Other uses include detecting oral potentially malignant disorders (OPMDs), oral squamous cell carcinoma (OSCC) in intraoral optical images,to identify benign, malignant and dysplastic oral lesions and to find difference in normal and abnormal head and neck mucosa.14

**9. ORTHODONTICS**

AI is most suitable for solving orthodontic problems. It finds application in treatment planning, landmark identification and predicting treatment results such as through pre- and post-treatment facial photographs. AI algorithms can help to foresee impact of orthodontic treatment, anatomic landmarks in lateral cephalograms and skeletal patterns.ANN models can also be used for evaluation of the need of extractions or surgery from lateral cephalometric radiographs.15

**10. TEMPOROMANDIBULAR DISORDERS**

 ANN could help in the classification of Temporomandibular Disorders, were more input loading is likely to increase accuracy in detection. There are studies that have tried to search the effectiveness of AI-based Natural Language Processing (NLP) in the diagnoses of orofacial pain disorders.16

 **ROBOTS IN DENTISTRY**

1. **DENTAL PATIENT ROBOT**

1**. SHOWA HANAKO**

Tmsuk robotics company has manufactured realistic robot designed to simulate patient gestures and responses, giving dental students close to real experience of working on a patient. In advancement to this, Showa Hanako 2 is developed that is more user friendly and functional replacement the earlier robot.

It has silicone skin and mouth lining. This increases the realistic feel and also prevents the water from getting into the machinery. It can blink, roll eyes, sneeze, shakes head, coughs, moves its tongue and even getting tired after keeping its mouth open for too long. Moreover, the robot is also capable enoough of simulating a gag reflex, which is quite frequent while doing dental procedures. A speech recognition technology has also been to facilitate conversation ability.

1. **Geminoid DK**

It is developed by Advanced Telecommunications Research Institute International, Japan. The Geminoids can be controlled remotely, are equipped with advance motion-capture technology which allows the machine to mimic face expressions and also precisely imitate head motions.

**Simroid**

It is a more realistic dental training robot for dentists developed by The Nippon Dental University Kokoro in collaboration with dental equipment maker Morita Manufacturing. Its manufacturers claim that Simroid is a next-generation dental patient simulator. It can react with more real life and emotional responses. Sensors placed in and around the mouth, which allow it to feel simulated pain and discomfort, that will make it react negatively, making students conscious of their technique. Also equipped with better communication skills, speech recognition capabilities which allow it to respond and react to questions or commands. Additionally it can also rate and evaluate the treatment, with two cameras that monitor every move of the student and also readings from its sensors that record throughout the procedure.

 **B) ENDO MICRO ROBOT**

To reduce the human error and improve the endodontic treatment quality, it is imperative to develop advancement in endodontic technology by applying advanced engineering and computer aided technology.17 This computer-controlled machine can be mounted on teeth within the patient mouth. With monitoring and intelligent control, the robot or micro machine will perform the automated drilling, cleaning, and filling of the root canal. Specific objectives for this micro robot design include:

(1) Reducing the reliance on the dentist skills,

(2) Minimizing human error,

(3) Providing method for precise diagnosis and treatment.

**C) DENTAL NANOROBOTS**

Multiple Nanorobots working on the teeth together, invisible to naked eye, may be used for the cavity preparation and restoration. Cavity preparation is very precisely controlled and restricted to the demineralized enamel and dentin, providing maximum conservation of the sound tooth structure. A colloidal suspension with active analgesic micron-size dental robots will be put on the patient gingiva to reach the dental pulp, where it will shut down the sensitivity in any particular tooth that requires treatment. After the oral procedure is completed, the dentist contolled nanorobots will restore all sensations.37 Also, reconstructive dental Nanorobots can selectively and precisely occlude the specific tubules within minutes, thus offering patient a quick and permanent cure

**D) Surgical Robots**

Surgical robot system for maxillofacial surgery has also been developed. With this system the surgeon programs the robot interactively during the surgery after which the robot delivers the pre-programmed tasks.18

**SENSOR-EQUIPPED IMPLANT SETUP**

Computer-assisted surgery (CAS) application has been developed for implantology which includes pre- and intra-operative procedures. The preoperative surgery uses 3D views provided to enhance raw images obtained from the patient prior to operation. The intraoperative support is used during the real surgical procedure for navigation and decision aid purposes. It helps in 3D orientation of position of surgical instrument and trajectory displayed on a monitor in real-time within patient 3D imaging data.19

**ROBOTIC DENTAL DRILL**

It consists of clamping frame onto a patient jaw and then very thin needles penetrate the gums to ascertain the bone location. This data is transmitted to a PC, that combines it with data of CT scan to configure a set of drill guides. These guides are then attached to a frame and when the dentist presses the button to start drilling in the precise location. On activation the drill is self-guiding and also the practitioner can alter the drilling process at any required time. The system minimizes traumas to the patient.19

**DENTAL ROBOT CEREC**

This robot technician is wheeled into clinic and can command a Cerec machine that takes a digital impression .The Cerec trained dentist will then designa dental crown on a computer screen and emails the design to a CAD-CAM dental robot located in another room. Within minutes a precisely shaped and colored crown or onlay is produced which can be bonded to the tooth in the same visit. Invisalign orthodontics is another example of robotic type. Malaligned teeth are digitally recreated and then straightened digitally, allowing a series of tooth straightening dental aligners to be fabricated robotically.19

**CONCLUSION**

AI is rapidly progressing and finds potential applications wide spectrum of areas like diagnosis, treatment planning and prognosis. Although present scenario limitations include data acquisition, interpretability, ethical considerations, yet AI holds a promise for serving as an excellent adjunct to dentists for improved oral healthcare.

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