

ARTIFICIAL INTELLIGENCE IN DENTISTRY

Abstract

Artificial intelligence (AI) has substantially increased its presence and relevance in numerous endeavors and application in endodontics. AI has the capacity to imitate human intelligence to conduct prediction and complicated decision making in healthcare. The objective is to discuss prospective future and existing endodontic applications of AI.

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I. 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 higher quality of life, fewer surgical complications,, better decision-making, and less wasteful operations. When used in the disciplines of medicine and dentistry, AI can significantly increase the precision of diagnoses and transform patient care. Current applications of AI in dentistry include identifying healthy and unhealthy structures, diagnosing disorders, and predicting how a treatment will proceed. Additionally, AI is widely employed in dentistry laboratories and is becoming more important in dental education.¹²

What Is Artificial Intelligence?

A branch of computer science called artificial intelligence (AI) aims to understand and produce intelligent objects, typically in the form of software. It can be characterized as a set of actions designed to complete a specific task. According to "Barr and Feigenbaum," Designing an intelligent computer system that demonstrates traits we identify with intelligence in human behavior, such as language comprehension, learning, reasoning, problem-solving, and many more, is the focus of artificial intelligence. AI is a subcategory of machine learning, which includes areas like deep learning, cognitive computing, natural language processing, robotics, expert systems, and fuzzy logic.²

Modern medicine makes use of the branch of AI known as machine learning and, more recently, deep learning.

- 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, using a big dataset and without the aid of humans, the systems find patterns in situations. A goal is set to do this, and the system's configurable functions are optimized to help the user achieve it. 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. Because patterns are combined and layered, a "deep" system is much more successful than a simple, "shallow" one. 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. An input layer, an output layer and hidden layers in between make up the neural network. A shallow neural network (SNN) may contain one or a few hidden layers, whereas a deep neural network (DNN) may have many hidden layers. Because their values are neither pre-determined or externally discernible, these levels are referred to as hidden. By building hierarchically on the data that was collected from the visible input layer, they intend to make it possible to calculate the precise value of the visible output layer. The pattern of connections between neurons determines the architecture of a certain neural network, and the weights of the neural network are the precisely programmable intensities of those connections.

- The **Convolutional Neural Network (CNN)** is one of the ANN subclasses that is most frequently employed in the fields of medicine as well as dentistry. CNN uses the mathematical technique of convolution to decode digital information, such as sound, image, and video. CNN employs a particular network of neuron connections. CNNs use a sliding window, scanning a small area of inputs at a time from left to right and top to bottom, to evaluate a broader image or signal. Due to their excellent suitability for the task of image classification, they are the most widely used approach for image recognition.⁴

II. USES OF AI IN VARIOUS FIELDS OF DENTISTRY

1. **Oral and Maxillofacial Radiology:** Numerous AI models have been created to determine the likelihood that a person would become ill, to spot abnormal medical data, to identify diseases, and to determine their prognosis.⁵ Since digital images are employed in radiology for diagnosis, it is simple to convert this digital data into computer language. As a result, the application of AI in dentistry is best suited to radiography. 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 may find extensive utility in dental surgery, including planning implantology procedures, analysing and reducing difficulties following extractions, altering bone structure, and performing orthognathic surgery. Due to the requirement for accuracy and precise planning, neural networks can be highly useful in daily practise as implantology develops very quickly. Additionally, neural networks could be able to foresee some potential difficulties during surgical therapy, allowing for their avoidance. 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
3. **Periodontics:** Deep learning can be used to categorise periodontal illnesses and ascertain the prognosis for teeth with poor periodontal health. Using a DeNTNet system built on deep learning, it may be utilised to examine the rate of periodontal bone loss. To measure periodontal pockets, needle-free and non-invasive ultrasonographic devices are being developed. It will use echo waves that an AI system can analyse via wavelet processing.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:** In endodontics, artificial intelligence can be frequently used in future. It can be used to determine working length, detect periapical lesions, detect root fractures, examine the architecture of the root and root canal systems, and make predictions about retreatment and the viability of dental pulp stem cells.¹⁰
6. **Restorative Dentistry:** The use of neural networks in conservative dentistry has grown significantly, but is still not particularly common. Artificial neural networks can be used to identify dental restorations and to identify and classify caries. With an accuracy of 99.03%, artificial neural networks have also been used to anticipate post-Streptococcus mutans prior to caries excavation.¹¹

For the purpose of detecting proximal caries and removing excessive irrelevant images from intraoral scans, artificial intelligence is incorporated into several systems, including intraoral scanners like Cerec Primescan (Dentsply Sirona) and Trios 4 (3Shape). Neural networks are capable of detecting caries with high accuracy using NILT (near-infrared illumination light transillumination) images. Another application is to employ fuzzy logic to foresee the colour change produced by the bleaching system prior to the procedure.¹²

7. **Prosthodontics:** AI aids in the creation of fixed restorations that are implant-supported. CNN models can be used to forecast the likelihood that whether a CAD/CAM composite resin crowns will debond. In prosthodontics, backpropagation of neural networks (BPNN) has been developed for computer-aided colour matching. AI is capable of creating case-specific detachable partial denture designs and can reliably predict facial soft tissue alterations that may occur in patients after using complete dentures.¹³
8. **Oral Maxillofacial Pathology:** CNN algorithms have proven to be a useful technique for cancer detection. Additionally, AI can use radiography to find tumours in aberrant sites such salivary and parotid glands, tongue muscles, and oral cavity nerves. Furthermore, it can be utilised for risk assessment, diagnosis, speech evaluation, pre-surgical orthopaedics, and cleft surgery in the management of cleft lip and palate. Other applications include the detection of oral potentially malignant disorders (OPMDs), oral squamous cell carcinoma (OSCC) in intraoral optical imaging, the differentiation between normal and abnormal head and neck mucosa, and the identification of benign, malignant, and dysplastic oral lesions.¹⁴
9. **Orthodontics:** AI is well suited to address orthodontic issues. It can be used for treatment planning, locating landmarks, and forecasting treatment outcomes, for example using facial images taken before and after therapy. Anatomical landmarks in lateral cephalograms, skeletal patterns, and the effects of orthodontic therapy can all be predicted with the use of AI algorithms. From lateral cephalometric radiographs, ANN models can also be utilised to determine whether extractions or surgery are necessary.¹⁵

10. Temporomandibular Disorders: The classification of Temporomandibular Disorders, where increased input loading is anticipated, detection accuracy could be a benefit from the use of ANN. Studies are looking into the efficacy of artificial intelligence-based Natural Language Processing (NLP) in identifying orofacial pain syndromes.¹⁶

III. ROBOTS IN DENTISTRY

1. Dental Patient Robot

- **Showa Hanako:** The Tmsuk robotics enterprises has created a lifelike robot that simulates patient motions and replies, providing dental students an almost authentic patient-care experience. In response, the more user-friendly and practical Showa Hanako 2 robot is created to replace the first one.

It has silicone skin and a mouth lining. This increases realistic feel and also arrest the water from getting into the machinery. It can sneeze, blink, roll eyes, shakes head, coughs, moves tongue and will get tired after keeping its mouth open for long duration. Moreover, it also simulat gag reflex, which is very common while doing dental procedures. To make discussion easier, speech recognition technology has also been implemented.

- **Geminoid DK:** Japan's Advanced Telecommunications Research Institute International is the company behind its development. The Geminoids have advanced motion-capture technology, which enables them to exactly replicate head movements and mimic facial emotions. They can also be operated remotely.
 - **Simroid:** The Nippon Dental University Kokoro and dental equipment producer Morita Manufacturing worked together to create a more realistic dental training robot for dentists. Simroid, according to its creators, is a modern dentistry patient simulator. It can respond with more emotive and realistic reactions. Students are made conscious of their technique via sensors put in and around the mouth that cause it to experience simulated pain and discomfort and react negatively. Additionally, it has improved communication skills and speech recognition capabilities that enable it to answer or react to requests. With two cameras that track the student's every motion as well as readings from its sensors that record during the operation, it can also rate and analyse the treatment.

2. Endo Micro Robot: It is essential to further develop endodontic technology by using cutting edge engineering as well as computer aided technology in order to decrease human error, thereby increaseing the quality of endodontic therapy.¹⁷ This computer-controlled device can be fixed to the patient's teeth. The robot or small machine will automatically drill, clean, and fill the root canal under the supervision and intelligent control. This tiny robot design has the following specific goals:

- Decreasing the dependency on dentist abilities;
- Reducing human mistake; and
- Providing a technique for accurate diagnosis and treatment.

3. **Dental Nanorobots:** For the preparation and restoration of cavities, many, invisible-to-the-human-eye nanorobots may be deployed. The dentin and demineralized enamel are the only parts of the cavity that are prepared, ensuring the maximal preservation of the healthy tooth structure. To treat any particular tooth that needs it, a colloidal suspension containing active analgesic micron-size dental robots will be applied to the patient's gingiva. This will allow the suspension to reach the dental pulp and stop any sensitivity there. Following the dental treatment, the dentist will use controlled nanorobots to restore all sensations. Additionally, restorative dental nanorobots can quickly and permanently treat patients by selectively and accurately occluding the affected tubules.
4. **Surgical Robots:** Additionally, a maxillofacial surgical robot system has also been designed. The surgeon then interactively programmes the robot during the procedure which then performs the pre-programmed duties.¹⁸
 - **Sensor-Equipped Implant Setup:** For implantology operations, including pre- and intra-operative ones, a computer-assisted surgery (CAS) programme has been developed. The 3D views are used during preoperative surgery to improve the raw images that were taken from the patient before the procedure. During the actual surgical procedure, navigation and decision-making are assisted by the intraoperative support. It aids in the 3D orientation of the position of the surgical tool and its trajectory as they are presented in real time on a monitor within the patient's 3D imaging data.¹⁹
 - **Robotic Dental Drill:** A frame is clamped to the patient's jaw, and then tiny needles are used to pierce the gums and locate the bone. This data is input into a computer, which then sets up a set of drill guides by combining it with CT scan data. These guides are then attached to a frame when the dentist clicks the button to start drilling in the precise location. When activated, the exercise is self-guiding, however the practitioner can change it whenever it is necessary. The system lessens the patient's traumas.¹⁹
 - **Dental Robot Cerec:** This robotic technician can control a Cerec device that creates a digital impression after being wheeled inside the clinic. After receiving Cerec training, the dentist will design a dental crown on a computer screen and email it to a CAD-CAM dental robot, housed in a different room. A precisely formed and coloured crown or onlay can be created in a matter of minutes and glued to the tooth in the same appointment. Another example of robotic type is orthodontic treatment with Invisalign. Malaligned teeth are digitally rebuilt, then digitally straightened, enabling the robotic fabrication of a series of dental aligners for teeth straightening.¹⁹

IV. 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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