**ARTIFICIAL INTELLIGENCE IN DENTISTRY**

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**INTRODUCTION**

Researchers have been intrigued by one of the most fascinating components of the human body, the brain. For many years, they have been working tirelessly to advance "artificial intelligence" (AI). The term "AI" is used when a computer imitates the analytical skills of the human brain, such as learning and problem-solving. AI can revolutionize the field of medicine and dentistry. It has been shown to improve accuracy, efficacy and precision to the same level as medical specialists more quickly and economically. Applications of AI in dentistry are still uncommon. However, the advancement of these technologies has an impact on robotic dental assistance, radiographic diagnosis, caries detection, histopathology and electronic recordkeeping.

**HISTORY**

**1950:** The British mathematician Alan Turing, one of the founders of artificial intelligence.

**1957:** John McCarthy developed a functional programming language- LISP (List Processing Language) for artificial intelligence.

**1965- 1970:** This era is considered a dark period for AI because it did not succeed with the idea of creating intelligent machines just by uploading the data.

**1970- 1975:** Artificial intelligence achieved huge success in the field of disease diagnosis.

**1975-1980:** A new idea came up that artificial intelligence can be advanced by using other fields of research like psychology.

**1976:** One of the first examples that showed the possibilities of applying AI in medicine was the development of a glaucoma consultation program using the CASNET model at Rutgers University in Las Vegas, Nevada. This model could apply information about a specific disease to individual patients and advise doctors on how to treat patients.

**1980s:** Artificial Intelligence began to be used in large projects with practical applications.

**1986:** The University of Massachusetts released a decision support system, DXplain. This programme creates a differential diagnosis based on the inputted symptoms. When it was first released, DXplain could provide details on about 500 ailments.

**1990s:** Researchers designed computer models of human teeth using computer-aided modelling (CAM). These innovations led to the concept of building 3D models of dental crowns based on an individual's preferences simply by examining their remaining teeth.

**1997:** Gary Kasparov, the reigning world champion, was defeated by Deep Blue- a skilled chess playing expert system.

**2007:** For the first time, machine learning was used to analyse dental radiographs for diagnosis of dental caries. Computers were able to read radiographs and identify anomalies in teeth more quickly than human experts after training on sufficient datasets.

**2017:** In a Go game, Google's deep learning algorithm Alpha Go defeated Jie Ke, the top-ranked player in the world.

**2022:** A text-generation model called Chat GPT (Chat Generative Pre-trained Transformer) was introduced by Open AI. It can produce responses that resemble those of a human based on text input.

**ARTIFICIAL INTELLIGENCE**

Artificial intelligence (AI) is a field of science and engineering concerned with the computational understanding called intelligent behaviour and creation of artefacts that exhibit such behaviour. AI is concerned with the design and implementation of computer systems capable of solving problems that usually require the ability of human beings. Typically, they cannot be resolved using traditional algorithmic techniques. AI programs handle symbolic information rather than just numerical data, as is customary in computer science, to solve them.

**MACHINE LEARNING**

Machine learning (ML) is a branch of artificial intelligence that focuses on creating algorithms that let computers learn on their own based on data and prior knowledge.

* ***Supervised learning:*** A sort of machine learning system known as supervised learning predicts the outcome after being trained on a sample of labelled data that is given to the system.
* ***Unsupervised learning:*** In an unsupervised learning system, a machine learns without any human intervention.
* ***Reinforcement learning:*** It is a feedback-based learning system which learns automatically with this feedback and improves its performance

**DEEP LEARNING**

It is a subgroup of ML, referred as a special learning machine. Technically it works as the way as ML. To find and gain insights from the data, deep learning uses a variety of model layers. For eg: ‘Convolutional Neural Networks’ that can easily capture 3D frame or images

**Artificial intelligence**

**Machine learning**

**Deep learning**

**TYPES OF ARTIFICIAL INTELLIGENCE**

***Artificial Narrow intelligence:***

Artificial Narrow Intelligence (ANI) is commonly known as narrow AI. It is configured to carry out specific duties like driving a car, voice assistant speech recognition, or facial recognition. Based on a constrained set of parameters, limitations, and situations, narrow AI models simulates human behaviour.

Eg: Chatbot, Siri by Apple, Alexa by Amazon

***Artificial General intelligence:***

Artificial General Intelligence (AGI) is commonly known as strong AI. It is capable of imitating the brain's cognitive functions. The main feature of strong AI is human-like, flexible thinking and reasoning. AGL is a hypothesis, and it is assumed that it will be invented within Quantum computing.

Eg: The K computer, created by Fujitsu, is regarded as one of the world's fastest supercomputers

***Artificial super intelligence:***

Artificial Super Intelligence (ASI) is the logical progression of AGI. ASI becomes self-aware and suppresses human capacity. It is based on science-fiction. In ASI, decision-making and problem-solving skills will be better than those of humans.

Eg: Search engine algorithms like Rankbrain from Google, a multitude of the face and biometric recognition solutions

***Based on functionalities***

***i) Reactive machines:***

Reactive machines are type 1 AI that has no memory, and the task is specific. It merely employs a single predefined logic and does not take previous experience into account.

Eg: Deep Blue, the IBM chess program

***ii) Limited Memory:***

Limited memory is the type 2 AI system. It has limited memory that can be referenced to future decisions. It is one kind of machine learning model that especially learns from facts and events.

***iii) Theory of Mind:***

Theory of mind is psychological terminology. This social intelligence is applied to understand emotions. It predicts the behaviour of human reactions. Computers are equipped with all types of emotions to read the human mind.

***iv) Self-awareness:***

Self-awareness AI is the application of common sense by the machine. The system has all the predetermined data recorded, so anytime action is required, it operates automatically. This type of AI does not exist.

**APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTISTRY**

**a. Oral medicine and radiology**

***Artificial neural networks (ANN):***

Artificial neural networks (ANN) are a type of AI technology that have been widely utilised to determine how aggressively tumours are acting. It is made up of perceptron, which replicate how neurons function. The multilayer perceptron (MLP) is the one that is most frequently used. The MLP has proven to be a reliable tool for investigating the prognostic value of oral cancer biomarkers.

***Clinical Decision Support System (CDSS):***

CDSS are interactive computer programmes made to aid in decision-making for healthcare practitioners. When analysing patient data and making decisions on the diagnosis, avoidance, and treatment of orofacial diseases, these systems draw on inherent clinical knowledge. Applications for CDSS can operate alone or in conjunction with other tools like radiography systems, order entry systems or electronic dental records.

***Probabilistic and General Regression Neural Network (PNN/GRNN):***

The following decisions benefit from using these models:

* To identify the kind of cancer in patients based on demographic data, clinical symptoms, personal and medical history, and a physical examination.
* To forecast patient survival following appropriate care and follow-ups

***Dynamic Bayesian Networks:***

Time-series gene expression data gathered at the follow-up study of patients who had or had not experienced a disease relapse are taken into account by the dynamic Bayesian networks. Based on the information, one can speculate on the causal linkages between the genes within the same time-slice and between adjacent time-slices, as well as infer the related dynamic Bayesian networks.

The objectives of this programme are to:

* Evaluate patients' chances of having their oral cancer return
* Disseminate crucial knowledge about the basic mechanisms that underlie the disease.

**b. Oral and maxillofacial surgery**

***Rhinoplasty:***

Artificial neural networks, which have been considered to be a better option for detecting nasal bones because of their ability to quickly depict the interdependence between the nasal bone and facial landmark, are a key component of machine learning models, such as their ability to classify as one of its influencing factors efficiently. Artificial neural network-based fracture prediction is crucial for early detection and carefully thought-out surgery. Several machine learning methods have been applied to anticipate nasal issues, including random forests, support vector machines, and back-propagation neural networks (BPNNs) for recognising nasal bones.

***Orthognathic surgeries:***

A thorough treatment plan must be created by an orthognathic surgeon with years of clinical experience. 3D craniomaxillofacial features are automatically registered while a surgeon develops and creates surgical splints based on CT (computed tomography scan) or CBCT (Cone-beam computed tomography systems) models. To ascertain the quantity and direction of surgical interventions, it can be helpful to measure the amount and direction of hard and soft tissue movements in three dimensions prior to orthognathic surgery. It is especially helpful for treating individuals with clefts as their soft tissues differ both morphologically and behaviourally from those of non-cleft patients due to cleft-related abnormalities and scar tissue. AI may be used to quickly analyse digital cephalometric data, detect precise landmarks, and make therapeutic decisions.

**c. Orthodontics**

***Cephalometric:***

Artificial intelligence-based cephalograms are taking the place of manual land mark identification and tracing by reducing errors and saving time. The AI is primarily used to identify and assess cephalometric landmarks, make extraction decisions, analyse faces, segment teeth and the mandible, estimate bone ages, segment the temporomandibular joint, and identify bone ages.

***Facial proportions:***

To comprehend the standards of beauty and duplicate aesthetically "beautiful" proportions, surgeons and orthodontists use measurements of "perfect" face proportions. There is no established set of guidelines for facial aesthetics, and facial attractiveness is a profoundly individualised idea. At the moment, AI apps execute optical facial recognition while simulating more complicated cognitive functions, such as the analysis and interpretation of facial data.

***Extraction:***

Following are the top two reasons for tooth extraction in orthodontics:

* When there is extreme crowding, there is a need for space to align the teeth.
* The teeth may be moved (typically to retract the incisors) to correct the protrusion or hide the Class II or Class III skeletal abnormalities.

For malocclusion patients between the ages of 11 and 15, Xie et al. developed a decision-making expert system (ES) to decide whether extraction is required. Error backward propagation learning is a technique used by ANN to lessen the risk of error. The study found that an accuracy rate of 80% was achieved when determining whether extraction or non-extraction treatment was required.

***Management of impacted canine:***

The best orthodontic and periodontal outcomes for impacted canines require comprehensive treatment care. The degree of difficulty and the distance the canine is from the neighbouring teeth determine how long the therapy will last. The Bayesian Network (BN) adopts a middle ground between statistics and artificial intelligence.

***Temporomandibular joint disease:***

One of the most popular examination techniques for determining bone abnormalities in the TMJ is the orthopantomogram (OPG), and CBCT may be utilised to confirm the diagnosis if necessary. But occasionally, a patient's TMJ arthritis or other bone abnormalities may be misunderstood in the absence of a specialist. An AI system was created and trained to recognise TMJ osteoarthritis on OPGs in order to solve this issue.

**d. Paediatric and preventive dentistry**

***Dental plaque:***

A ground breaking investigation is being conducted to identify primary teeth that have been damaged by plaque using AI model-based deep learning approaches. You, W. et al., effectively supplied AI systems (CNN framework) trained on 886 teeth pictures to identify plaque build-up in their study. The model performed at clinically acceptable levels when compared to a paediatric dentist with training.

***Toolkits Designed by Machine Learning:***

In order to create oral health assessment toolkits that could accurately predict the Children's Oral Health Status Index (COHSI) and Referral for Treatment Needs (RFT), a research team looked to machine learning. Dentists, parents, and even children might utilise the outcomes of the machine learning-based toolbox to determine whether a patient needs dental care and to get a sense of where they are in terms of oral health. Dental education will need to support the adoption of clinical AI solutions by promoting digital literacy among individuals who will work in the field of dentistry in the future.

***Mesiodens and Supernumerary Tooth Identification:***

With the use of a single deep learning model, artificial intelligence can diagnose mesiodens. The detection of extra teeth may benefit greatly from CNN-based deep learning. Ahn, Y. et al. employed a deep learning model to find mesiodens in primary or mixed dentition, suggesting that this technique might aid physicians with less clinical expertise in making quicker and more accurate diagnoses. With the straightforward correlation that deeper networks offer better accuracy for classifying mesiodens, they used a variety of deep learning models (Squeeze net, ResNet 18, ResNet 101, and Inception-ResNet-V2).

***Early Childhood Caries:***

Different genes and gene polymorphisms have been identified by researchers as the cause of dental lesions in patients, however genetic variables related with the disease are rarely included in most studies. According to Zaorska, K. et al., using single nucleotide polymorphisms (SNPs) for dental caries risk prediction could be a very useful tool for clinicians to incorporate prevention strategies during a child's early years of life and for parents to instil better eating habits. To predict the presence of dental caries based on polymorphisms, the researchers used artificial neural networks in their study. By adopting the necessary precautions, implementing early treatments for affected caries, and consequently enhancing the child's overall health, the information from these forecasts may help prevent caries in children completely.

***Pit and fissure sealants:***

Convolutional neural network (CNN) is a crucial deep learning technique that helps dentists by using a tonne of data. Additionally, because they are often white in colour, dental sealants are the first line of defence for many dental issues. Therefore, it seems like the most sensible course of action to fine-tune CNN to recognise dental sealants. A deep learning-based CNN was created by a research team lead by Schlickenrieder, A. et al. to recognise these sealants from machine-readable intraoral pictures. In contrast to the typical CNN-based classifications, our AI-based system provided great diagnostic accuracy.

***Deciduous and Young Permanent Tooth identification:***

For object recognition, CNN, one of the most well-liked deep learning models, is frequently employed. Paediatric kids' deciduous teeth are increasingly being evaluated and counted using deep learning techniques like CNN. A number of models, including R-CNN, Faster R-CNN, YOLOv3, and YOLOv4, have been utilised for object identification and detection. Single-stage detectors (YOLO algorithm) and two-stage detectors (Mask R CNN, R-CNN, and Faster R-CNN) are the two main categories of object detection techniques. Two-stage detectors were used in certain studies, which led to good object detection outcomes. Even while two-stage detectors require more time and processing power than one-stage detectors, they are frequently more accurate. YOLO is a prime example of a single-stage detector that can identify and classify objects quickly and accurately. YOLO differs from previous CNN algorithms in that it can recognise objects in real-time and, on average, performs better than average across a variety of object classes.

**e. Prosthodontics**

***Computer-aided design/computer aided manufacturing (CAD/CAM):***

Following an intraoral scan in fixed prosthodontics, margin identification was finished using AI. Both permanent and removable dental prostheses are made using CAD/CAM, which stands for "computer-aided design/computer-aided manufacturing". Using data from numerous real crowns, this technique can produce the best crown design for a number of situations. Digital technologies have been employed extensively in dentistry recently to assist patients in getting the gorgeous new smiles they've always desired. These include 3D face tracking and cost-effective virtual 3D data hybrids such face, intraoral, and fragmented cone beam computed tomography (CBCT). The virtualization of a patient's anatomy is the foundation of every therapeutic intervention that alters their smile. Simple sheet drawings produced from two-dimensional printed photos of patients were used to construct the early grin designs.

***Dental Implant:***

The ideal dental implant treatment plan combines CBCT and intraoral scanning. Implant dentistry's usage of AI offers the chance to combine the two and create next-generation prosthesis. The main focus of prosthodontics is on treating temporary and removable dental prostheses, designing completing margins next to the teeth for improved longevity and alignment of the prosthesis, performing implant surgery, creating maxillofacial prostheses, maintaining ideal maxillo-mandibular relationships, and choosing the colour of teeth for better aesthetics. AI can be used in many different therapeutic methods and has a number of advantages. In a study by Lee J et al., convolutional neural networks (CNNs) based on AI were used to categorise implants using panoramic and periapical radiography. According to the study's findings, the AI-CNN system is almost as good at classifying implant procedures as humans are. Incorrect placement, subpar cementation, occlusion, and interproximal repair are examples of potential error-causing factors. Lerner et al. suggested an AI model to reduce the likelihood of these errors.

***Maxillofacial Prostheses:***

The artificial eye, which was developed in the United States, has already been used by twelve individuals with vision difficulties. These AI-powered devices can improve vision without requiring surgery. Dental professionals can construct the most attractive prosthesis for patients with the use of AI and specific designing tools, taking into account anthropological calculations, face proportions, ethnicity, and patient desire. For people who are blind or have visual impairments, there are smart reading glasses available. It is a cutting-edge voice-activated device that can be mounted on practically any set of glasses. It is primarily intended to assist those who are blind or visually impaired.

**f. Oral and maxillofacial pathology**

An innovative method to grade oral tumours using fuzzy cognitive maps (FCM) was developed. The FCM model uses eight histopathological features, and an active Hebbian learning (AHL) algorithm is utilized as the supervised learning mechanism to train and improve the model’s grading system. To test the accuracy of the FCM and AHL approach, 123 cases, including 85 normal and 38 abnormal oral tumours, were assessed. The model achieved an accuracy of 90.58% for low-grade oral tumours and 89.47% for high-grade tumours, demonstrating its potential as an important tool in the effective diagnosis and grading of oral tumours. This innovative approach has the potential to improve patient outcomes and reduce morbidity and mortality rates associated with oral tumours.

**g. Endodontics**

***Root Morphology:***

Conventional radiography is still routinely used and plays a significant role in diagnosing and planning therapy for root canal pathology, even though CBCT provides the highest-quality 3D images. As a result, limitations related to conventional radiographs—such as the superimposition and distortion of bone and dental structures—are no longer a concern. The root canal morphology was accurately assessed by the AI's deep learning algorithm. The categorization of photographs by the DL system may help inexperienced practitioners better understand them for diagnostic purposes.

***Working Length determination:***

For endodontic treatment to be successful, the working length must be accurately determined. The apical foramen can now be found with contemporary technologies like CBCT and electronic apex locators. The instrumentation must stop at the apical constriction of the root for the root canal treatment prognosis to be guaranteed. The ANN diagnosis method results in an improved radiographic working length determination and helps to improve diagnosis. Additionally, ANNs are applied as a decision-making system in a wide range of therapeutic situations. There have been a few studies that used artificial intelligence to find the apical foramen and determine whether the root canal was successful with an accuracy of 93%–95%.

**h. Periodontics**

***Haptics-based virtual reality periodontal training simulator:***

This was the first haptics-based dental simulator developed by Luciano et al exclusively for Periodontics. This simulator helps students develop the necessary skills to diagnose and treat periodontal diseases. A haptic device along with 3D images of upper and lower teeth along with gingiva can be felt by “touch”. The resulting haptic feedback replicates the clinical feel of an operator’s hand when using dental instruments.

***Halitosis:***

Artificial Olfaction, is a non-invasive technique that assesses the full spectrum of exhaled volatile compounds. It consists of an array of sensors, mainly based on nanomaterials, that semi-selectively and/or collectively assesses the composition of exhaled breath using analysis software and a database of breath patterns and then is processed toward a pattern-recognition application. A decision tree classifier then determines whether the subject suffers from oral or extra-oral halitosis and in the second case, can also draw association to different systemic diseases. Nakhleh, Amal et al, 2017 reported 20 functionalized nanomaterials-based sensors designed to successfully distinguish among 17 different systemic diseases, by analysing exhaled breath with an overall accuracy of 86%.

***Periodontal bone loss:***

Krois et al, in 2019 used AI to discover periodontal bone loss on panoramic dental radiographs. Results showed that given the limited dataset of radiographic image segments, the trained AI software showed atleast dentist like discriminating power to assess PBL on panoramic radiographs. The authors believe that the applicability and accuracy of CNNs can be improved by integrating more imaging data such as the use of intra-oral periapical radiographs and data sources such as clinical records into the analytics.

**i. Public health dentistry**

***Surveillance:***

For a long time, public health monitoring data streams have been utilised to examine trends and threats. AI approaches, particularly those based on machine learning, have been used to uncover patterns, spot abnormalities, and distinguish patterns. Strong temporal and spatial components are usually present in these data streams, demanding study in conjunction with other social, economic, and environmental data. AI opens the door to the use of a range of novel or underutilised data sources for public health surveillance, particularly ones that were not initially or intentionally designed to address epidemiological concerns.

**ADVANTAGES OF AI**

* The use of artificial intelligence is simple
* Machines don't need breaks and refreshments like people do
* The machines may be reconfigured to operate for extended periods of time without growing weary or bored.
* Precision in diagnosis
* The uniformity of practice
* Reduces time

**DISADVANTAGES OF AI**

* The mechanism's intricacy
* The expense of the setup

**CONCLUSION**

In the field of dentistry, new technologies are developed and implemented quickly. With characteristics like high accuracy and efficiency if unbiased training data is used and an algorithm is correctly trained, AI is one of the most promising ones. Dental professionals can use artificial intelligence (AI) as an additional tool to lighten their burden and increase precision and accuracy in diagnosis, decision-making, planning, and illness prognosis.

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