



ARTIFICIAL INTELLIGENCE – A START OF FUTURISTIC ERA IN FIELD OF DENTISTRY

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INTRODUCTION

Artificial intelligence (AI) first coined by John McCarthy refers to machine that can imitate human knowledge and behavior¹. Machine learning (ML) is a subfield of AI, in which algorithms are applied to learn the intrinsic statistical patterns and structures in data, which allows for predictions of unseen data. A popular type of ML model are neural networks (NNs), which outperform more classical ML algorithms in particular on complex data structures such as imagery or language.

The main constituent of any NN is the artificial neuron, which is a mathematical non-linear model that was inspired by the human neuron.^[2]

In dentistry, the applications of AI are mostly virtual, employing AI algorithms to distinguish between lesions and normal structures, prioritize risk factors, and simulate and evaluate prospective results. According to the Barcelona Declaration for the Proper Development and Usage of Artificial Intelligence in Europe.^[3], virtual AI methodologies are fundamentally divided into knowledge-based and data-driven AI. Knowledge based AI attempts to model human knowledge and is built in a top-down fashion from the self-reported concepts and knowledge that humans use to solve problems. However, knowledge acquisition and formalization are two major bottlenecks, which consume development time and require significant initial effort.^[4] Data-driven AI, commonly known as machine learning (ML), commences in a bottom-up approach by training mathematical models with data derived from human activities. Because of the large amount of dental data available in electronic form, data-driven AI receives a lot of attention in dentistry. Data-driven AI or ML may be divided as supervised, unsupervised, and semisupervised learning.^[5]

On the supervised platform, algorithms employ manually labeled training data sets to learn the correlations between data instances and labels, yielding the desired and known outcomes.^[6] Support vector machines (SVMs), decision tree (DT), random forest (RF), and artificial neural networks (ANNs) are all ML algorithms

that can be used in supervised learning. SVMs set up an imaginary highdimensional space, place samples according to their features, and separate them by a hyperplane, resulting in data classification.^[7] ANNs are highly interconnected models inspired by vertebrate nervous systems.

In unsupervised learning, algorithms are provided with unlabeled data, and they involve recognizing hidden data patterns that investigators may not have conceived, yielding unknown results. Principal component analysis and k-means clustering are common methods used in unsupervised learning. Deep neural networks, commonly known as deep learning (DL), are a subset of ML; can also be operated in unsupervised scenarios. The term “deep” refers to multiple neural layers between the input and output layers. Convolutional neural networks (CNN) are the most widely used DL architecture in dentistry.^[8]

Semisupervised learning is an amalgamation of supervised and unsupervised learning that analyzes a collection of data while augmenting the pattern recognition abilities with a small amount of labeled data.^[8]

The various applications of Artificial Intelligence (AI) in Dentistry are as follows:

Artificial Intelligence in Patient Management

Artificial intelligence based virtual dental assistants can perform numerous tasks related to dentistry with greater precision, minimum errors and less manpower compared to humans. It can be used for various purposes ranging

from scheduling appointments, managing insurance and paper-works to assisting clinical diagnosis or treatment planning. It is very useful in alerting the dentist about patient's medical history as well as habits like alcoholism and smoking. In dental emergencies, the patient has a option of emergency tele-assistance especially when the practitioner is unavailable.

Thus a detailed virtual database of the patient can be created which will go a long way in providing best treatment for the patient.^[9]

Artificial Intelligence in Oral Medicine

Artificial intelligence can be a highly useful modality in diagnosis and treatment of oral lesions. Altered mucosa undergoing premalignant and malignant changes can also be screened and classified using this advanced system. The genetic predisposition for developing oral cancer can be accurately predicted with the help of artificial intelligence. Internal derangements of the temporomandibular joint are yet another taxing situation where the examiners' decision based on clinical and imaging data is considered as gold standard. Trained ANNs have been tested and compared with the diagnosis of a surgeon, the results have revealed high sensitivity and specificity of ANN, thereby insisting on the importance of AI in achieving correct interpretations and reducing human errors.^[10]

Käkilehto *et al.*^[11], using the data mining AI technique, analysed a large set of patient electronic dental records in order to obtain scientifically acceptable conclusions about the duration of dental restorations.

Korhonen *et al.*,^[12] using the data mining technique, have established that dentists more successfully detect caries in their new patients, compared to their old patients. The study was done using an AI system with the data obtained at general Physical examinations.

Tamaki *et al.*^[13] formed a data mining tool to identify associations, anomalies, and statistically significant patterns in large datasets, using a system of AI. The system successfully identified a high level of *Streptococcus mutans* and *Lactobacillus* as the factors of high risk for caries development in school children.

Artificial Intelligence in Dental and Maxillofacial Radiology

In the last two decades, advanced breakthroughs in image recognition using artificial intelligence systems has provided a new path in the field of radio-diagnosis. In head and neck imaging modalities AI provides added advantage owing to its distinctive ability to learn. It can be assimilated with other imaging modalities like CBCT, MRI to determine infinitesimal deviations from normality that may go unnoticed with human eye.

Logicon Caries Detector aids in detection of proximal caries, AI system aids in location of minor apical

foramen thereby strengthening the accuracy of working length determination.^[14] It can even diagnose vertical root fracture.^[15] on CBCT images of endodontically treated and intact teeth. Accurate interpretation of radiographic lesions, Cephalometric analysis and evaluation of bone architecture are added advantages which AI offers in the field of radiology.

Artificial Intelligence in Forensic sciences

With the advent of the artificial intelligence, there are several programming neural networks that can train the computers to automatically estimate the age by using pre and post treatment dental records. This advanced technique can be efficiently used in age estimation based on radiographic data of stage of tooth development.

Artificial Intelligence in Orthodontics

In the field of orthodontics AI can be used for accurately analyzing the radiographs and photographs, aiding in correct diagnosis which forms the crux of any orthodontic procedure.

A trained model in this aspect was used to assess the craniofacial skeletal and dental abnormalities in cephalometry, this was in accordance with that of an expert opinion. In addition, the model also showed contradictions presented in the data that were not noticed by the orthodontists, thereby highlighting the contribution of AI in orthodontic decision support.^[16]

With precise 3D scans and virtual models, it is easy to 3D print the aligners with customized treatment plan. As the vast data get computed, it creates an algorithm which in turn intelligently decides how a patient's tooth or teeth should be moved, with how much pressure, even identifying pressure points for that particular tooth or teeth. The AI-aided aligners not only deliver precise treatment execution but also help in monitoring the progress as well and claim to reduce treatment time as well as appointment schedules.

Xie *et al.*^[17] assisted by the ANN, have been able to use a decision-making expert system in order to identify the factors of prevailing influence in decision-making, evaluating the need for tooth extraction before orthodontic treatment of patients with malocclusion.

Artificial Intelligence in Oral and Maxillofacial Surgery

Robotic surgery simulates human body motion and human intelligence which aids the surgeon in planning surgeries with reduced operation time along with preserving the vital structures around to the smallest detail prior to the actual surgery with higher intra operative accuracy. Another tremendous utilization of AI in the surgical field is image guided surgery that confers further accurate surgical resection possibly decreasing need for revision procedures.

One of the most fruitful clinical applications of AI is bio-printing where organs and living tissues can be formulated in successive thin layers of cells which in the future may be used for regeneration of oral hard and soft tissues that are lost due to pathological or accidental reasons.^[18]

Kim *et al.*^[19] using an AI system based on the neural network model, have been able to predict toothache in 80% of the examined cases. Nieri *et al.*^[20] using the Bayesian network analysis, have been able to successfully identify several substrates with direct effect on the final outcome of treatment of impacted maxillary canines.

Artificial Intelligence in Prosthodontics

AI along with designing software's can aid the dentist to design the best possible and aesthetic prostheses considering number of factors like facial measurements, anthropological calculations, ethnicity and patient desire. AI plays a major role in identifying the type of bone, cortical thickness for making precise surgical guides for pacing implants.^[21] Another breakthrough in this field is the use of CAD/CAM

Technology which creates a 2D and 3D models has replaced the time consuming and laborious process of conventional casting thereby reducing human errors.^[22]

Virtual reality simulation (VRS) technology can be used to simulate the facial profiles post treatment. This not only enables the dentist to efficiently design the esthetics, but also acts as a motivational tool for the patient.^[23]

Artificial Intelligence in Periodontics

Deep learning analysis using radiographs can assist in diagnosing and treatment planning of periodontal diseases by enabling the early detection of periodontal changes,^[27] bone loss, and changes in bone density. Detection of peri-implantitis can also help in early intervention in implantology.^[24]

Artificial Intelligence in Dental Education System

Recently artificial intelligence has been incorporated into tutoring intelligent education system and training in dentistry.^[25] These technologies have the ability to create virtual reality that enables simulation of the practical procedures in three dimensions that enable simulation and allow access to clinical and surgical techniques.^[26] The practice sessions can be done several times till the skill set is expertise by students over the subject prior to actual handling of real clinical cases reducing the risk of iatrogenic damage. This method of training proves to be more efficient, inexpensive and reliable.

Futuristic Approach

Applications of AI in everyday life are growing leaps and bounds. As all the intelligent minds are working vehemently on AI, the day is not far when AI would be

integrated with clinical practice as much as possible. All patient medical records would be stored in digital form, adequately processed and prepared, ready to be subjected to AI algorithm analysis there would be constant processing of data sets by AI. Numerous essential correlations between the data items could thus emerge and new knowledge breakthroughs are certain without even starting individual targeted studies. This could help in saving resources and capacities, creating at the same time the basis for continual monitoring of patient health and longterm surveillance of the effects of drugs and therapeutic procedures.^[26]

CONCLUSION

In most developing countries an insufficiency of medical and dental specialists has increased the mortality of patients suffering from various diseases. Employing artificial intelligence technology, in medical and dental practice could reduce cost, time, human expertise and chances of error. This approach has the potential to revolutionize the dental scenario.

However, despite the recognized need of AI, the implementation of these systems has been limited and slow. This can be attributed to lack of formal evaluation of the systems, challenges in developing standard representations, cost and practitioner skepticism about its value and feasibility.

Increasing public awareness of safety and quality has accelerated its adoption. The application of this technical advancement in dental practice continues to develop rapidly and will hopefully contribute to reduce the morbidity and mortality of oral and maxillofacial diseases and in turn improve patient care.

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