OPEN ACCESS

Saudi Journal of Oral and Dental Research

Abbreviated Key Title: Saudi J Oral Dent Res
ISSN 2518-1300 (Print) | ISSN 2518-1297 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Review Article **Preventive Dentistry**

Artificial Intelligence and its Perspectives in Dentistry: A Review

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DOI: https://doi.org/10.36348/sjodr.2025.v10i01.003 | **Received:** 29.11.2024 | **Accepted:** 07.01.2025 | **Published:** 15.01.2025

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Abstract

Artificial Intelligence (AI) is the ability of machines to perform various tasks with smart work that normally requires human intelligence. It is not a new concept as it was introduced back in the 1950s. However, it has not become the practical tool until two decades ago. Artificial intelligence (AI) has obtained large interest and has long past via a transition level from being a pure statistical tool to being one of the main drivers of modern dentistry. In dentistry, the employment of synthetic intelligence continues to be at its start. Many radiographs are used to decide illnesses with the aid of using displaying the whole shape of the enamel and a few dental troubles that cannot be visible at once with the aid of using the human eye. The concepts of AI, including convolutional neural networks and/or synthetic neural networks, have proven a selection of applications in dentistry, forecasting the viability of stem cells. The dental pulp, measuring operating lengths, pinpointing root fractures and periapical lesions and forecasting the achievement of retreatment procedures. AI has established accuracy and precision in detection, evaluation and prediction. Thus, this review narrates the history, classification and its applications in dentistry.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Neural Network, Dentistry, Strong AI, Weak AI.

INTRODUCTION

The definition of AI according to Angus Stevenson is "the theory and development of computer systems capable of performing tasks typically requiring human intelligence, such as visible perception, speech recognition, decision-making, and language translation." (Banerjee M 2021). With more and more digital devices supporting people's lives on all fronts and the data those devices provide, artificial intelligence (AI) is blossoming and expanding quickly across all industries. It is capable of studying human knowledge and adopting tasks that typically need human intelligence (Ding H *et al*., 2023). Artificial intelligence (AI) is thought of as a helpful tool that machines can use to perform tasks that often require human intelligence. Additionally, it has been used to the fields of medical and dentistry, including robots, digital assistants, wearable technology, virtual medicine, drug development, clinical and dental imaging diagnostics, and choice support (Ding H *et al*., 2023). Researchers can now analyze and interpret massive amounts of data more quickly, precisely, and thoroughly than ever before thanks to these technologies (Balaji S.M 2022). In many instances, AI appeared as a valuable tool to help dentists and other healthcare professionals manage their workload. In addition to diagnosing diseases using a single information source targeted at a particular ailment, AI may learn from multiple information sources (multi-modal data) to identify diseases beyond the capacity of humans. All of those depend on quick technological advancement (as a product), processing power (hardware), algorithmic development (software), and large databases (data entry). Several radiographs, which are still routinely used to diagnose disorders, depict the entire dental anatomy as well as other oral abnormalities that cannot be seen directly by the human eye (El Joudi N.A *et al*., 2022) The use of artificial intelligence (AI) in dentistry is currently expanding to encompass voice command dental chairs, endodontics, restorative and prosthetic dentistry, orthodontic treatments, and imaging (Agrawal P *et al*., 2022). In domains including diagnosis, decision-making, treatment planning, treatment result prediction, and sickness prognosis, a number of studies on AI applications in dentistry are now being conducted

or even used. This review attempts to describe the evolution of artificial intelligence (AI) from its infancy to the present, as well as its classification, contemporary dental advancements and their limitations, and its relationship to evidence-based dentistry (EBD).

HISTORY

The term "artificial intelligence" is not new. One of the greatest thinkers of all time, British mathematician Alan Turing, demonstrated in 1936 that a common calculator known as the Turing system is feasible. The key discovery of Turing is that a computer like this can solve any problem as long as it can be modelled and resolved by an algorithm (Banerjee M 2021).

Turing characterized AI as "machines thinking" at the time because there was no context for it. He used mathematics to explore the viability of AI, the construction of intelligent devices, and the evaluation of technological intelligence. He suggested that just as humans use knowledge and inference to solve issues and make decisions, so too can machines. In his 1950 article "Computing Machinery and Intelligence," Turing suggested creating a test to determine whether a machine can develop intellect comparable to that of a person. The Turing Test is the name of this assessment. It appears on the following lines: assuming that a human judge should be able to tell a machine from a human test taker based on their use of natural language (Hastie T *et al*., 2009). The human assessor is aware that the communication is between a human and a system, and that the system, human assessor, and human cheque taker are independent entities. The vocal communication between the human examiner and the device is limited to simple text, or keyboard input, rather than speech. By doing this, the test will focus solely on the machine's capacity to answer the questions rationally rather than testing its capacity for voice interpretation. One of these devices is said to as having "machine intelligence" if the human assessor is unable to detect the difference between the human test taker and the device. (LeCun Y *et al*., 2015).

Later, in 1955, a two-month workshop called the Dartmouth Summer Research Project on Artificial Intelligence directed by John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon is when artificial intelligence was originally conceived. The field of artificial intelligence (AI) rapidly advanced between 1957 and 1974 as a result of advances in computer power, accessibility, and AI algorithms. It developed along two lines in the 1980s: machine learning (ML) and expert systems. They go against the way AI thinks in terms of their theory. ML enables computer systems to learn via experience; professional systems, on the other hand, imitate the human specialists' decision-making process. (Nam C.S *et al*., 2020).

A deep learning (DL) community that used a graphics processing unit (GPU) and had eight layers was developed in 2012; the work won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) and had a classification top-5 error of 15.3%. Compared to the runner-up, the error rate was more than 10.8% lower. SE-NET considerably decreased the top-5 error in 2017, bringing it below the human top-5 error (5.1%) to 2.25%. (Ding H *et al*., 2023).

Deep Blue, a chess-gambling expert system that defeated Gary Kasparov in 1997, is one of the more well-known examples of later AI. Recently, in late 2022, OpenAI released ChatGPT (Chat Generative Pretrained Transformer), a text-generation model that can produce responses that resemble those of humans based on text input. (Ding H *et al*., 2023).

CLASSIFICATION OF AI

There are various techniques by which AI can be achieved; unique AI types have been developed by researchers, and they are capable of performing unique jobs. Figure 1 illustrates how weak AI and strong AI might be further separated. Application trained to solve single or narrow problems is used in weak AI, sometimes referred to as narrow AI. Today's AI is primarily the weak AI. Examples include automated manipulation robots and reinforcement learning systems like AlphaGo, as well as natural language processing systems like the Amazon chatbot and Google translation. Strong AI is defined as having human-like abilities and intelligence, including its own awareness and adaptable behavior. The development of a multi-task system capable of making decisions across many areas is the aim of strong AI. Strong AI research requires extreme caution because there may be ethical concerns and dangers. As a result, there aren't any useful AI applications at the moment. (Goodfellow I *et al*., 2014).

Machine learning and expert systems are two weak AI subcategories. Based on the theory behind the approaches, ML can also be divided into supervised, semi-supervised, and unsupervised learning. Labelled datasets are used in supervised learning as the "supervisor" of the algorithm, which is used for training. (Wu J *et al*., 2016).

Contrarily, unsupervised learning operates independently to uncover the rich potential of unlabeled data. The latter of the two, known as semi-supervised learning, involves training on both a big amount of unlabeled data and a small amount of labelled data. (Choi E *et al*., 2022). To reduce labelling costs, a novel technique known as weakly supervised learning has recently gained popularity in the AI community. Deep learning, a subset of machine learning, is currently a very prominent research area. Both supervised and unsupervised learning may be involved. As seen in Figure 2, a "deep" artificial "neural network" is one that has input, numerous "hidden", and output layers as its minimum number of nodes. Expert systems, however,

require human input in order to learn. Thus, substantially less statistical data is needed. (Aubreville M *et al*., 2017).

There are other NN variations, but artificial neural networks (ANNs), convolution neural networks (CNNs), and generative adversarial networks (GANs) are the most significant forms of neural networks.

- **ANN (Artificial Neural Network)**

Layers and a group of neurons make form an ANN, as depicted in Figure 2. This model is a fundamental one for deep learning, with a minimum of three layers. The inputs are only used for forward processing. The functions of enter information are extracted by input neurons from the enter layer and sent to buried layers, where they are gradually processed. The outcomes are then compiled and shown in the output layer. (Xu B *et al*., 2015).

- **CNN (Convolution Neural Network)**

CNN is a deep learning model that is mostly used for picture production and recognition. In addition to the pooling layer and the fully connected layer in the hidden layers, CNN also consists of convolution layers, which is the primary difference between CNN and ANN. Utilizing convolution kernels, feature maps are produced from input data using convolution layers. The input image is entirely folded by the kernels. Convolution provides weight-sharing, which reduces the complexity of the images. The pooling layer is usually followed by a succession of convolution layers to reduce the dimension of feature maps and enable further feature extraction. The completely linked layer converts the 2D feature maps into 1D by connecting to all of the activated neurons in the layer above, as suggested by its name. The classification process then links 1D feature maps to class nodes. By utilizing the aforementioned useful hidden layers, CNN displayed improved efficiency and accuracy in photo identification when compared to ANN. (Alexander B *et al*., 2018).

- **GNN (Generative Adversarial Network)**

The deep learning algorithm GAN was developed by Goodfellow *et al*., in 2014. By automatically recognizing patterns from the input data, it is an unsupervised learning technique designed to generate new data having traits or patterns similar to the input data. A generator plus a discriminator neural network makes up a GAN (Goodfellow I *et al*., 2014). The ultimate goal of the generator is to generate data that the discriminator is unable to process. In GAN, the two networks compete with one another, and as a result of the fight, both networks grow. Wu *et al*., suggested a new 3D-GAN architecture based on a traditional GAN network. (Wu J *et al*., 2016). Using the most recent advancements in GAN and volumetric convolutional networks, 3DGAN generates 3D objects from a given 3D space. Unlike a typical GAN network, it can create 3D objects both directly and from 2D images. It provides a greater range of potential applications for 3D data processing compared to its 2D form. (Krois J *et al*., 2019)

AI'S PARTICIPATION IN DENTISTRY

Artificial Intelligence in Managing Patients (Shetty 2021)

- Scheduling and organising appointments in accordance with the convenience of the patient and the practitioner.
- A voice recognition system is available, enabling the dentist to carry out various tasks with ease.
- Before each appointment, informing the oral healthcare provider of any pertinent clinical records the patient may also have.
- Taking care of the paperwork, insurance, and patient records.
- Informing clients and dental professionals about checkups whenever genetic or lifestyle facts point to a higher risk of dental disorders.
- Assisting in the planning of the diagnostic and treatment for a favorable prognosis.
- Setting up daily reminders for patients to have checks on a regular basis.
- Software that can produce 3D images and a comprehensive virtual database of each patient is available.

AI in Oral and Maxillofacial Pathology:

The study of pathological conditions and the diagnosis of diseases affecting the oral and maxillofacial region are the focus of the dental specialty known as oral and maxillofacial pathology. Oral cancer is the worst kind. According to World Health Organization (WHO) statistics, over 657,000 people worldwide are diagnosed with oral cancer each year, and more than 330,000 of them pass away. (Choi E *et al*., 2011) On the basis of radiographic, microscopic, and ultrasonographic pictures, AI has been studied generally for the detection of tumours and the majority of malignancies. Additionally, radiographs can also be used to discover abnormal spots with the help of AI. (Aubreville M *et al*., 2017) consisting of parotid and salivary glands, interdigitated tongue muscles, and oral cavity nerves. The suitability of CNN algorithms as a tool for automatically identifying tumours has been confirmed. (Wu J *et al*., 2016). After histochemical and histological processing, AI can be used to scan a large number of tissue sections to find tiny details that can help with clinical diagnosis and decision-making. (Krois J *et al*., 2019).

AI in Periodontics:

AI has been applied in periodontics to classify and identify disorders related to periodontal health, including periodontitis. Additionally, CNN was used by Krois *et al*., to identify periodontal bone loss (PBL) on panoramic radiographs (Yauney G *et al*., 2019). According to Yauney *et al*., a CNN algorithm created by

their study team employing systemic health-related data may analyse periodontal problems. (Junaid N *et al*., 2022).

AI in Orthodontics:

AI is the ideal tool for addressing orthodontic issues. AI can be used in orthodontics to predict treatment outcomes and schedule treatments, including simulating the differences between the appearance of pre- and post-treatment facial images. With the use of AI algorithms, the results of orthodontic treatment, skeletal patterns, and anatomical landmarks in lateral cephalograms may be clearly apparent, substantially facilitating communication between patients and dentists (Huang Y.P. and Lee S.Y. 2021).

AI in Operative Dentistry:

Studies on the identification of dental caries, vertical root fractures, apical lesions, volumetric measurement of the pulp space, and evaluation of enamel wear have all been done in operative dentistry. A set of AI rules can examine a pattern and provide predictions for actions such as segmenting teeth and detecting cavities. A CNN method, for instance, was created by Lee *et al*., to identify dental caries on periapical radiographs (Lee J.H *et al*., 2019). A CNN method was devised by Kühnisch *et al*., to identify caries on intraoral pictures (Kühnisch J *et al*., 2022). When Schwendicke *et al*., compared the cost-effectiveness of AI with dentists' diagnoses for proximal caries, the results showed that AI was more effective and less expensive. (Rokaya D *et al*., 2022).

AI in Prosthodontics:

A dental crown is typically prepared in prosthodontics by first preparing the tooth, taking an impression, cutting the cast, and then designing, producing, placing, and cementing the restoration. Using AI in conjunction with CAD/CAM or 3D/4D printing can result in a more efficient process (Wei J *et al*., 2018) AI is also used for colour matching (Yamaguchi S *et al*., 2019) and debonding prediction of CAD/CAM restorations (Takahashi T *et al*., 2021) Current machine learning algorithms are more focused on assisting the design system of removable dentures, such as the type of dental arches (Cheng C *et al*., 2015) and facial appearance assessment in patients without teeth (Vishwanathaiah S *et al*., 2023).

AI in Pediatric Dentistry:

To detect dental plaque, early childhood caries, fissure sealants categorization, supernumerary teeth and mesiodens, chronological age assessment, identification of deciduous and young permanent teeth, ectopic eruption, etc., various applications of AI models developed for pedodontics play a crucial role. In order to help less experienced dentists make more precise diagnoses, it has been utilised frequently in paediatric dentistry. These models are very beneficial for both individuals and communities (Vishwanathaiah S *et al*., 2023). A variety of techniques, including virtual reality games, cartoons, and movies, can be utilised to help young patients change their behaviour (Baliga S.M 2019)

AI in Preventive Dentistry:

AI also has a significant impact on a number of prevention strategies, including maintaining oral hygiene, diet, assessing periodontal risk, preventing dental trauma, and combating dental caries. Additionally, it helps with early childhood caries diagnosis (Surdilovic D *et al*., 2023).

AI in Oral and Maxillofacial Surgery:

The removal of tumours and foreign objects, biopsies, and surgeries on the temporo-mandibular joint can all be effectively performed using image guidance in the cranial area. (Widmann G 2007). For the purpose of identifying and classifying patients who have a high risk of developing oral cancer or precancer, as well as for planning a treatment regimen, the ANN of AI may be very significant.

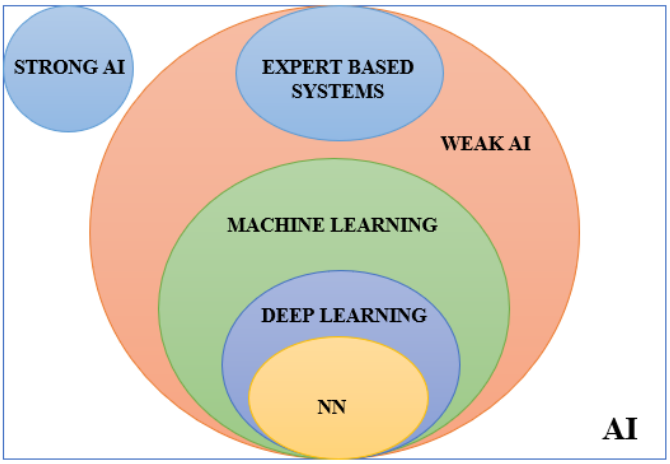

Figure 1: Schematic diagram of the relationship between AI, strong AI, weak AI, expert-based systems, machine learning, deep learning and neural network (NN).

Figure 2: Automated manipulation robot

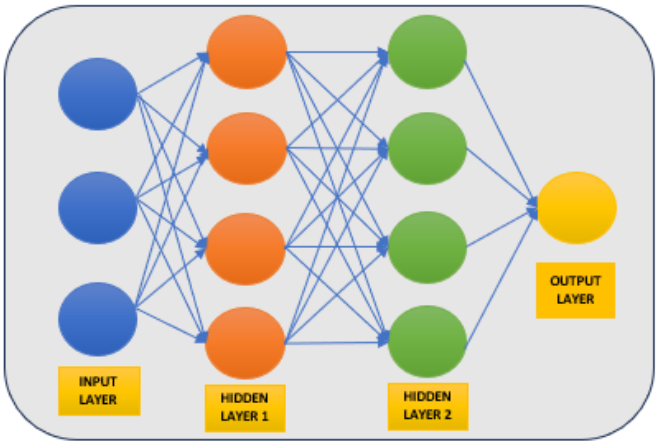

Figure 3: Schematic Diagram of Deep Learning

DISCUSSION

AI has become the expertise system that can function beyond human intellect as a result of the advancements in hardware and software. Due to AI's precision and ability to keep data under any circumstance, humans are becoming more and more dependent on these systems today. Data collection is considerably aided by the two disciplines of AI known as ML and DL. The algorithm, computing power, and training data's digitalization all play a significant role in how AI applications evolve. On the one hand, ML should assist doctors in storing and continuously updating clinical knowledge and patient-related data. ML algorithms are frequently used for identifying patterns in diagnostic data from patients, improving current clinical therapy, discovering novel medications, precision medicine, and reducing human error. EBD has a similar goal, however ML can accomplish it more quickly since it uses current data, whereas EBD often requires randomised controlled trials to achieve those goals. A more specialised subspecialty of dentistry called evidence-based dentistry (EBD) is described as ***"an approach to oral health care that requires the judicious integration of systematic assessments of clinically relevant scientific evidence pertaining to the patient's dental and medical history, the clinical expertise of the dentist, and the patient's treatment requirements and preferences."*** (Ismail, A.I. and Bader, J.D. 2004). Both EBD and ML have advantages and disadvantages unique to them. By identifying patterns and relationships between medical information, machine learning (ML) is a brand-new approach within the scientific community to improve prognosis and forecast treatment results. The inclusion of ML to EBD can also aid in the discovery of the underlying relationship between clinical statistics and disease and help provide a more accurate and unique diagnosis.

CONCLUSION

The dental industry develops new technology quickly and adopts them. AI is one of them, and if objective training data is used and an algorithm is properly trained, it has features like excessive accuracy and performance. It can be useful to dentists for quick diagnosis and treatment. Due to its accuracy and low error rate, artificial intelligence has a very promising future in the field of dentistry. Every generation of

dentists should be grateful for the technology because it lessens workload.

Conflict of Interest: No.

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