# Artificial Intelligence and Machine Learning: The new Frontier of Digital Dentistry

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**Abstract**

The field of medicine and dentistry has been witnessing tremendous transformation in the last decade with the adaptation of Artificial Intelligence (AI). AI deals with developing self-learning computer technologies which can mimic the functioning of human brain. The quick, effective and efficient nature of these applications leads to their wide usage in education, diagnostic and clinical aspects of modern dental practice. This article highlights the basic concepts of AI and Machine Learning, with some of the applications in the current digital dental era.

**Keywords:** Artificial intelligence, Artificial Neural Network, Image Analysis, Intraoral Scanners, Clear aligners

## 1. Introduction

Human brain is a complex network of millions of neurons. Intelligence can be defined as a general mental ability for reasoning, problem-solving, and learning.[1]Artificial intelligence, sometimes termed machine intelligence, is revolutionizing the field of science and technology. They were introduced in the early 1950s with the aim to develop computational technologies that can mimic human intelligence. Since then they have been rapidly permeating the day to day life of human beings in different ways. Health care system has been adapting and benefitting substantially from integrating Al technologies into their practice in the past decade. AI has gained its foothold in dentistry and raised the benchmark for standards of patient care as they provide reliable, in depth information, ultimately to render better, quick service to those in need.

This article discusses basic concepts of AI and some of the important applications of AI and machine learning in dentistry.

## 2. Basic Concepts in AI

Encyclopedia Britannica defines the "artificial intelligence" (AI) as the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. Unique ability of adapting to changing circumstances separates intelligent beings from others. The earliest research probably dates back to the work of McCulloch and Pitts (1943) who explained the operation of neurons to be a switching binary fashion, indicating how neurons either fire or do not fire (are 'on' or 'off'). They proposed such neurons could learn and hence change their action with respect to time.[2] The term artificial intelligence was coined by John McCarthy in 1956. AIstarted gaining importance with the advent of data computing as well as cloud computing ability and availability of vast amount of data collected.

Machine learning (ML) deals with programs or algorithms which help the machines to learn on their own through data and observations without being explicitly programed.[3] The ML algorithm evolve as they are exposed to more and more new data. The algorithms developed to detect dental caries on bitewing radiographs (BTW) is an example of such programs. They analyze a large number of BTW which are previously labeled as carious or normal by clinicians. Here they learn to analyze the pattern of pixel data of radiographs which can then be used to diagnose new BTW radiograph.

## 3. Neural Network

Artificial neural network (ANN) is the essential part of AI. Analysis and learning of thestructure,

mechanism and function of biological neural network forms the foundation for the construction of ANN. During nerve conduction, only if the intensity of the stimulus or the sum of stimuli (input) exceeds its threshold, only then the message will be transmitted into the next neuron across the synapse.

Similarly, basic design of ANNs consists of a set of simple units, also termed neurons. These neurons are linked to each other by weighted connections which are called synapses, and are organized in layers: Information is fed to neurons of the input layer, and then processed in the hidden layer and finally exits to the neurons of the output layer. ANNs can be adaptive to external or internal changes and ‘‘learn’’ from the data entered into them. ANN models provide better results when intuition and concrete thinking information are processed, in comparison to the traditional processing modalities. Training a neural network involves prompting the algorithm to guess, compare, change weights for a better guess, and compare again, for thousands or millions of incrementally better guesses, finally reaching a point where more guesses either cease to improve results, or the change in improvement becomes too small to matter.[3] Mathematically, the algorithm tries to maximize the number of right answers. ANN algorithms are commonly use for image analysis today and are considered handy in such complex, tedious, time consuming decision making tasks.

## 4. Clinical Decision Support System

Clinical decision support systems (CDSS) are basically computer programs designed to give expert support for the clinician during diagnosis and treatment planning procedures in patient care. They use embedded clinical knowledge to analyze patient data and make decisions in regards to the clinical diagnosis, treatment plan.4 They are mainly composed of three basic components: The user interface where the clinician enters a questionnaire pertaining to the signs and symptoms experienced by the patient, The set of data describing the clinical knowledge in the domain of the program, and an inference engine to analyze the input data using the data set to arrive at a diagnosis or suggest a treatment plan.[4]

CDSS systems can be standalone or may be integrated with other applications such as the electronic health record or radiology software. In such scenarios they can provide with some valuable insights, recommendations to be incorporated into the treatment plan. A simple example would be in patients needing surgery the algorithms can analyze medical history and give recommendations such as need for antibiotic prophylaxis, allergies etc. Currently used CDSS are primarily based on Fuzzy logic, ANN or Bayesian networks for the data analysis.[5]

## 5. Applications of AI

### I. Integrating AI into Electronic Health Records

Electronic dental Records are now replacing the old paper based record storage systems. Office and practice management softwares such as Dentrix, Open Dental, and Eaglesoft are becoming integral components of dental practice. Their main significance is standardization in dental charting with addressing the administrative and clinical aspect of patient care under a single platform.[6]

Introducing AI applications into these softwares are a new breakthrough (cloud dental software products like Dovetail). They can provide relevant key insights to the clinician, which will in turn be very promising in delivering quality healthcare effectively and efficiently.

Speech recognition systems would be helpful in the hands-free documentation process. This can avoid contamination in the patient-dentist-chart triad, achieving better infection control.6Voice controlled perio charting and dental chair operations are some of the newer inventions.

Virtual nurse assistants such as Care angel’s virtual nurse assistant are gaining popularity. They can provide wellness checks between regular visits using voice and AI, answer post-operative queries effectively such as post op instructions and how to recognize emergencies.

## II. Application of AI into Radiology

The advantage of ANN account to their unique ability of self-learning. These programs have demonstrated remarkable progress in image-recognition tasks and can detect minute deviations from normalcy which can go unnoticed by the human eye. Hence they are becoming popular to be used along with MRI and cone beam computed tomographies. AI applications have well established their use in radiology per se as in early detection breast cancers.

Oral Radiographic Differential Diagnosis (ORAD) is one of the earliest programs developed by Stuart C.White with the purpose to assist in generating a differential diagnosis for radiographic lesions of the jaws. This program was designed to recognize upto 98 lesions of the jaws. On recognition of a jaw lesion, patient specific informations are entered through a questionnaire to characterize the lesion.The program output is a list of the lesions in order of their estimated probability. In addition, an estimate of the extent of match between the lesion in question and the typical appearance of each lesion in the knowledge base can be calculated. Preliminary trials indicate that ORAD is useful in assisting clinicians in formulating a differential diagnosis.[7]

Logicon Caries Detector™ program (Logicon Inc., USA) is designed to assist dentists in the detection and characterization of proximal caries. LCD enabled dentists to find 20 percent more cases of caries penetrating into dentin than they were able to find without it, while not causing them to mistreat any additional healthy teeth.[8]

Digital subtraction radiography (DSR) tools in few softwares allows practitioners to distinguish small differences between subsequent radiographs, taken few weeks/months apart, that otherwise would have remained unnoticed because of overprojection of anatomical structures or differences in density that are too small to be recognized by the human eye. [9]

The fully automated cephalometric analysis programs are found to be less time consuming with a high reliability and reproducibility when compared to the traditional manual or computer aided analysis techniques.[10]

ANN can act as a decision making systems in various clinical scenarios as in locating the apical foramen thus enhancing the accuracy in working length determination[12], detection of vertical root fractures[13], estimating bone density to predict osteoporosis.

## III. Application of AI into Prosthodontics and Restorative Dentistry

CAD-CAM(Computer Aided Designing and Computer Aided Manufacturing): CAD/CAM is cutting edge technology for the delivery of high-quality restorations/appliances in all fields of dentistry. They have evolved from machine copy milling to fully computer controlled system, which made the automatic production of crowns and bridges feasible. The entire process involves 3 major steps, beginning with digitization of the model using digitization tools/intraoral scanners. This 3D model is then used to design the intended product using specific softwares. At last the product is milled to the final product.[13]

Digitization of Dental Impressions can be accomplished by direct or indirect methods. Intraoral scanners (IOS) are devices for capturing direct optical impressions in dentistry. Hence they capture the digital data directly from the mouth. The basic principle is projecting a light source (laser, or more recently, structured light) onto the dental arch to be scanned, including prepared teeth and implant scanbodies (copings). The images of the dentogingival tissues captured by imaging sensors are processed by the scanning software, which generates point clouds. These point clouds are then triangulated by the same software, creating a 3D surface model (mesh). The 3D surface models are the 'virtual' alternative to traditional plaster models, cause less patient discomfort, time-efficient and convenient for communication with the dental technician. [14, 15] Their use has drastically reduced the total time for production of the ceramic restorations leading to the development of chair side CAD-CAM units.(CEREC).

The newer systems (Cerec, Cercon, Lava and Everest) are efficient in producing restorations which are superior in aesthetic, precise, cheaper and quick compared to the ones manufactured through conventional lab techniques. Applications such as Virtual articulators and facebows have further improved the the design by adding kinematic analysis to the process.[16]

### IV. AI Driven Customized Orthodontic Treatment

In 1999, Align Technology Inc introduced an esthetic alternative to braces. Clear aligners are probably the most debated infusion of AI to the field of orthodontics, they now account for 15% of orthodontic appliances in the market. They are the "invisible" method of moving teeth with the use of a series of computer generated, clear removable aligners. 17

With precise 3D scans and virtual models, it is easy to 3D print the aligners with customized treatment plans. As vast data gets computed, it creates an algorithm which in turn intelligently decides how patient's teeth should be moved with how much pressure, even identifying pressure points for that particular tooth. The AI aided aligners not only deliver precise treatment execution but also help in monitoring the progress as well and claim to reduce the time as well as the appointment schedule. A variety of clear aligners treatment have been introduced in the past, Invisalign, Clearconnect, Clearpath, Clingers, K-line and Orthocaps.[18] Invisalign is the most widely used and preferred modality of complex clear aligner treatment system in recent years. The advantages of clear aligners compared to the conventional orthodontic treatments include: Better oral hygiene, less irritation to the soft tissues, good periodontal health maintenance and comfort.

### V. Computer-Designed Stereolithographic Surgical Guides for Implant Placements

The placement of dental implants no longer relies on traditional "mental navigation" but rather on precise, computer-guided implant positioning that is planned pre-surgically. 19 Implant simulation softwares can use the data from computed tomography (CT), cone beam computed tomography (CBCT) or magnetic resonance imaging , visualize the anatomical landmarks in relation to a scanning template representing future restoration. Virtual implant surgical procedures can be performed with emphasis to the the anatomical and restorative requirements. These planned position can be later transferred during surgical procedures.

Guided implant surgeries have shown to be extremely useful in patients where the bone volume is critical, anatomy demands ideal location of the implant to enhance esthetics. They ensure more precise placement with a high degree of reproducibility. [19]

Today, there are three practical ways to apply this technique in a clinical setting: guided surgery using drill guides processed by stereolithographic rapid prototyping, computer-milled templates or computer navigation systems. Computer-milled templates are fabricated by drilling the final position of the implants in the scanning template itself using a drilling machine. Computer navigation systems allow an intraoperative real-time bur tracking according to the preoperative planned trajectory.[20] This technology has potential to minimize inter-operator error, resulting in minimally invasive surgery and can establish a standard collaborative accountability between the surgeon and restorative clinician.[19]

Surgical robot system for maxillofacial surgery are being developed with which the surgeon interactively programs the robot during the surgery after which the robot performs the preprogrammed tasks.[20] Yomi is robotically assisted dental surgical system, cleared by FDA, for implant placement. It is used to plan a procedure based on patients' CT scan.[21]

## 6. Conclusion

To summarize, AI is transforming dentistry like never before. Introducing AI and ML in dental practice can increase the confidence level of dentist in decision making thus ensuring more data driven diagnosis, efficient and effective treatment. Allowing the development of programs which are more economical, need for

extensive training, proper validation and standardization of programs, reduce logistical barriers in implementation are some of the challenges to be overcome over the next few years. AI and ML undoubtedly are revolutionary breakthrough in modern dentistry and look promising in reducing the workload of dentist, cost reduction of the treatment with greater patient satisfaction.

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