

# Artificial Intelligence in Dentistry: The Way Forward

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## Abstract

Artificial intelligence (AI) refers to the mimicking of human intelligence in machines that are programmed to think like humans and mimic their action. The essence of artificial intelligence is its capability to rationalize and execute accordingly increase the probability of achieving a specific goal. New decade holds promising advances in healthcare system. Dentistry, with due credits to artificial intelligence is seeing revolutionary transformations too. The dentists of the modern era have never held themselves back from acclimatizing newer technologies with promising prospects. The current review aims to highlight the role of artificial intelligence in dentistry and its role in different sub-specialties.

**Keywords:** Artificial Intelligence, Artificial Neuronal Network, Fuzzy Logic, Machine Learning, Representational Learning, Clinical Disease Research System.

## 1. INTRODUCTION

Over the last decade, we witness the advent and advancement of artificial intelligence in almost every field and dentistry is no exception. Artificial Intelligence (AI) is the research field that studies and develops technological systems that can solve complex tasks in ways that would traditionally need human intelligence. The artificial intelligence can generate a huge reform in almost every industry<sup>1</sup>.

Alan Turing for the first time unraveled the mathematical prospect of artificial intelligence and formulated the Turing test to suggest that machines, like human beings can use available information and reason to solve problems. In the year 1956, John McCarthy coined the term "Artificial Intelligence"<sup>2</sup>. We are already experiencing its impact in our routine life, in terms of various office and practice management software. Various applications, such as Siri, Alexa, and voice command gadgets, have used AI technologies to build intelligent conversational interface for any device, application language, or environment<sup>3</sup>.

Artificial Intelligence is slowly but steadily invading into dentistry and revolutionizing the field. The current review aims to highlight the current and future visions of artificial intelligence in dentistry.

## Key Concepts of Artificial Intelligence

The key concept of Artificial intelligence includes machine learning, representation learning, and deep learning.

### Machine Learning

Machine learning (ML) is the scientific study of processes that computer systems use to effectively performs a specific task without using explicit instructions, relying on patterns and inference instead<sup>4</sup>. Machine learning processes build a mathematical model based on sample data, commonly called as "training data", so that it can take decisions without being explicitly programmed to perform the task<sup>4</sup>.

### Representational Learning

It is a subtype of ML, in which, the computer algorithm learn the features require for classifying the provided data. Unlike machine learning it does not require hand labeling of data<sup>5</sup>.

### Deep Learning

Deep learning is part of a broader family of machine learning methods based on artificial neural network<sup>6</sup>. Deep learning architectures such as deep neural networks, deep belief networks, recurrent neural networks and convolutional neural networks has been applied to fields

including drug designing, radiological image analysis, and histopathological diagnosis where they have produced results comparable to and in some cases superior to human experts<sup>4</sup>.

### **Artificial Intelligence Techniques**

#### **Artificial Neuronal Network (ANN)**

Artificial neural networks mimicking the neural network and the human brain is an quintessential fragment of artificial intelligence. Programming languages of Artificial intelligence are the principal tools in understanding the symbolic information<sup>7</sup>. The utmost benefit of artificial neural networks is that it resolves problems that are complicated for conventional techniques<sup>2</sup>. Artificial Neuronal Networks has been associated in diagnostic systems of healthcare to decipher findings by radiographs, ultrasound, computerized tomography, Magnetic resonance imaging etc.

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

Clinical Disease Research System (CDSS) aim to create computer programmes to simulate the human thinking by using machine techniques<sup>2</sup>. They are devised to support healthcare workers in their everyday duties, assisting with tasks that rely on the data manipulation and knowledge<sup>5</sup>.

#### **Augmented and Virtual Reality**

Augmented reality is an interactive proficiency of a real world environment where the objects that resides in the real world are augmented by computer generated perceptual information sometimes across multiple sensory modalities including visual, haptic, olfactory and somatosensory<sup>8</sup>. Virtual reality is a computer generated simulation of a three-dimensional image or environment that could be interacted in a seemingly real or physical way by a person using special electronic equipment<sup>9</sup>.

#### **Fuzzy Logic**

It is the science of reasoning, thinking and inference that recognizes for categorization of the data<sup>5</sup>. The data handling methodology permits ambiguity and hence is particularly suited to medical applications. They has been used to characterize ultrasound images of the breast,

ultrasound and CT scan images of liver lesions and MRI images of brain tumors<sup>12</sup>.

### **Evolutionary Computation**

These are speculative search and optimisation algorithms based on natural biological evolution. The most widely used form of it being used for 'genetic algorithms'. It has better application in medical field where they work by creating many random solutions to the problem at hand<sup>5</sup>.

Each AI technique has its own assets and limitations. Neural networks are mainly concerned with learning, fuzzy logic with indistinctness and evolutionary computation with exploration and optimization<sup>13</sup>.

In all areas of human activity, virtual and augmented reality technologies can provide one answer. These technologies can be used to enhance information technology and communication and thus sustain society and the knowledge-based economy. Also, to improve the competitiveness of and creativity in a nation's economy, in public administration, in research, in education and in health care and optimized disease prevention methods and public health systems and help advances in medical therapies<sup>10</sup>.

Augmented reality has a lot of applications in the field of surgical assessment such as in oral and maxillofacial surgery, implantology and orthognathic surgery<sup>11</sup>. In dentistry, Virtual reality can serve as an effective non pharmacologic analgesic for dental pain and aid in imparting dental training to budding dental professionals<sup>2</sup>.

### **Role of AI in Imparting Dental Education**

Conventional methodology comprises of theoretical and practical classes are time-consuming, costly and ineffectual. Newer tools are being inculcated in order to combat the issues with conventional method of teaching. Recent work, in which artificial intelligence has been incorporated into intelligent tutoring systems as in the Unified Medical Language System (UMLS)—used to improve the quality of feedback to students, holds promise for the future.<sup>14</sup> Various education systems based on augmented and virtual reality like DentSim, Geneva System, Virtual Dental Patient, Virtual

Dental Training Systems, Iowa Dental Surgical Simulator, HapTel, VirDenT, Moog Simodont Dental Simulator, Forsslund System has been formulated so far. Although these innovations can be costly in the beginning, they assure reduction in cost in the future for academic purpose and also improvise the quality of education manifold in dental schools<sup>15</sup>.

### **Role of AI In-Patient Management**

The breakthrough of AI in dentistry is by creating a virtual dental assistant. The virtual assistant, “D Assistant” are designed by Dentem, will hear commands, analyze data including dental images and records, and give information-driven suggestions during dental procedures. It’s designed to be the perfect helping hand for both dental practitioners and assistants, reducing errors and streamlining decision-making. Also, D Assistant can be used for appointment scheduling, dental records keeping and routine tasks reminder. Another major and crucial tasks that AI performs are big data management. AI performs this analysis at fast speeds, giving users actionable data<sup>16</sup>.

The core of dental practice “Dental Chair” has evolved from manual pumps systems, hydraulic pressure systems to electric chair with sensors. With the help of AI, the dental chairs have incorporated a newer “voice command” technology, which will function on vocal instructions eliminating the need of physical touch<sup>3</sup>.

Recently At the Consumer electronics Summit, 2020, two leading brands have released AI powered tooth-brushes, toothbrush pairs with phone via Bluetooth and Connect to an application in phone which deciphers that data. The companies’ claims that this will provide precise information in real time that is specific to each mouth. And that will neatly lead on to the distinct feedback regarding the brushing technique of every individual, based on the data collected<sup>17</sup>.

### **AI in Oral Diseases Diagnosis**

An accurate diagnosis is crucial element for successful treatment. AI driven adequately trained neural networks can be a boon to

diagnosticians. Study have confirmed that AI supported diagnosis have high sensitivity and specificity, thereby insisting on the importance of AI in achieving correct interpretations and reducing human errors<sup>18</sup>.

For instance, a clinical diagnosis of oral leukoplakia is not always a straightforward one and it might be very helpful to support the dentist-general practitioner and also other primary health care workers to arrive at a most likely diagnosis. In case of untreated oral leukoplakia, for instance in widespread otherwise asymptomatic lesions, AI-based technology may be helpful in tracking the lesion(s) over time in a reproducible fashion. Also the clinical diagnosis of oral lichen planus and lichenoid lesions is a subject of distinct clinical relevance<sup>19</sup>.

### **AI in Oral Radiology**

AI assisted interpretation of radiographic lesions and automated interpretation of dental radiographs, Computer-assisted image analysis is useful to visualize and evaluate the lesion directly from the dental panoramic radiograph and computer based digital subtraction imaging for precise and accurate diagnosis<sup>5</sup>.

### **AI in Orthodontics**

With the advent of AI, customized orthodontic treatment is easier. AI is now available for orthodontic diagnosis, treatment planning, and treatment monitoring. With precise 3D scans and virtual models, it is easy to 3D print the aligners with customized treatment plan<sup>3</sup>.

The AI-aided aligners not only delivers precise treatment execution but also helps in monitoring the progress as well and claim to reduce treatment time as well as appointment schedules<sup>3</sup>.

### **AI in Oral and Maxillofacial Surgery**

In the field of oral and maxillofacial surgery, head and neck reconstruction requires multidisciplinary communication. With the help of computed tomographic imaging and artificial intelligence technology, virtual surgical planning can be done that permit surgeons to perform virtual surgery that allow for the precise and pragmatic approach during surgery<sup>20</sup>. A recent

Development is the Voxelman system for planning and training in paranasal surgery<sup>21</sup>.

The greatest application of artificial intelligence in oral surgery is the development of robotic surgery where human body motion and human intelligence is simulated<sup>22</sup>. Successful clinical application in image guided surgery in cranial area include oral implant surgery, removal of tumor and foreign bodies, biopsy and TMJ surgery<sup>23</sup>.

### AI in Prosthodontics

AI aids in prosthodontics by the use of computer-aided design and computer-aided manufacturing technology for precision fit of prosthesis, but with innovation in generative adversarial networks, laboratories are using AI to automatically generate advanced dental restoration for custom fit and ideal function and also, improvised aesthetic appearance. This not only will help dentistry but also will have a huge potential and impact on oro-facial or craniofacial prosthesis<sup>24</sup>.

AI also can help in critical decision-making; one amongst them is to choose between fixed dentures and implants. AI can help with evidence-based decision making. AI can quickly analyze data including underlying conditions, radiological scans, and any other patient-related information. This will ultimately arm dentists with the answer to challenging situations such as these<sup>16</sup>.

Other ingenious applications of AI include “bioprinting” where living tissue and even organs can be constructed in consecutive thin layers of cells which in the future may be used for reconstruction of oral hard and soft tissues lost due to pathological or accidental reasons<sup>25</sup>.

### AI in Restorative Dentistry and Endodontics

AI Based Program Logicon Caries Detector™ program (Logicon Inc., USA) is designed to assist dentists in the detection and characterization of proximal caries<sup>26</sup>. Diagnosis of vertical root fractures on CBCT images of endodontically treated and intact teeth considered to be more accurate<sup>27</sup>. Using computer aided design and manufacturing, it helps endodontists

to identify exact apex location and thus successful root canal treatment<sup>24</sup>.

### AI in Periodontology

AI helps in alleviate pain during periodontal scaling and root planning procedures, which are usually achieved with anesthesia, alternative methods suggest that the use of immersive virtual reality distraction may be an effective method of pain control<sup>28</sup>.

In a study conducted by Shankarapillai R et al, AI has been used successfully in the periodontal risk assessment based on data from 230 patients. In their algorithm many items have been included, such as age, bleeding on probing, average pocket probing depth, presence of root calculus, and vertical bone loss as being assessed on dental films<sup>29</sup>.

### AI in Oral Pathology

Over the last decade, computerized methods have rapidly evolved in digital pathology. Whole Slide Imaging is changing the paradigm shift of histopathology and the credit goes to Artificial Intelligence. The neural network may be of value for the identification of individuals with a high risk of oral cancer or pre-cancer for further clinical examination or health education<sup>30</sup>. A study was done using artificial neuronal network on oral cancer prognosis prediction based on clinicopathological and genomic markers, such as p53 and p63<sup>31</sup>. With regard to other oral mucosal diseases the use of AI might be very helpful for the reproducibility of the clinical and histopathologic diagnosis in a selected type of lesions<sup>19</sup>.

### Conclusion

“By far, the greatest danger of Artificial Intelligence is that people conclude too early that they understand it” **Eliezer Yudowsky**

Integration of Artificial Intelligence into dentistry eases a dentist’s job and rather redefines it. It holds tremendous potential in delivering quality healthcare to the patients and improvises the arena of dentistry. The biggest limitation, however, is the requirement of huge and sound database in order to get error free results. There is

still a long way to go but hopefully the future decade will see the transformations that dentistry going to foresee owing to artificial intelligence.

## REFERENCES

1. Geuna A., Guerzoni, M., Nuccio M., Pammolli F., Rungi A. 2017. Digital disruption and the transformation of Italian manufacturing. Available at: <https://www.aspeninstitute.it/aspeniaonline/article/digital-disruption-and-manufacturing-transformation-italian-case-study>.
2. Alexander B, John S. Artificial Intelligence In Dentistry: Current Concepts And A Peep Into The Future. *Int. J. Adv. Res.* 6(12), 1105-1108.
3. Deshmukh SV. Artificial intelligence in dentistry. *J Int Clin Dent Res Organ* 2018;10:47-8.
4. Coccia M. Artificial Intelligence Technology In Oncology: A New Technological Paradigm. Available at: <https://arxiv.org/pdf/1905.06871.pdf>
5. Anisha Yaji., et al. "Artificial Intelligence in Dento-Maxillofacial Radiology". *Acta Scientific Dental Sciences* 3.1 (2019): 116-121.
6. Madabhushi A., Lee G. 2016. Image analysis and machine learning in digital pathology: challenges and opportunities. *Med Image Anal.*;33:170-175.
7. Neumann G. Programming languages in Artificial intelligence. Kaiserslautern; German Research Centre of Artificial Intelligence (LT-Lab,DFKI);2001
8. Dennis William II(2015).The Lengthy History of Augmented Reality.Huffington Post.
9. Hoffman HG,Garcio-Palaios A,Patterson DR,Jenson M et.al.The effectiveness of Virtual Reality for Dentalpain Control:A Case Study *Cyberpsychol Behav* Vol 4(40);52-35.
10. The Potential for Virtual Reality to Improve Health Care. San Diego, CA: The Virtual Reality Medical Center;2006. Available at: <http://iactor.eu/downloads/WP%20The%20Potential%20for%20VR%20to%20Improve%20Healthcare.pdf>
11. Kwon HB,Park YS,Han JS (2018).Augmented reality in dentistry:A current perspective. *Acta Odonto Scand* ;76(7):497-503.
12. Tang A., et al. "Canadian Association of Radiologists white paper on artificial intelligence in radiology". *Canadian Association of Radiologists Journal* (2018).
13. Mendonça EA. "Clinical decision support systems: perspectives in dentistry". *Journal of Dental Education* 68.6 (2004):589-597
14. Kazi H, Haddawy P, Suebnukarn S. Leveraging domain ontology to increase the quality of feedback in an intelligent tutoring system. In: *Proceedings of the 10th International Conference on Intelligent Tutoring Systems*; 2010 Jun 14-18; Pittsburgh, USA. New York: Springer.
15. Duta M et al. An overview of Virtual and Augmented Reality in Dental Education. *OHDM*. March,2011;10(1): 42-49.
16. Philip Avery. AI- Powered innovations that are Transforming Dentistry. Available at: <https://becominghuman.ai/ai-innovations-transforming-dentistry-aef03479664d>
17. AVAILABLE AT: <https://www.news18.com/news/tech/colgate-and-oral-b-are-putting-ai-where-you-least-expected-it-inside-your-mouth-2447393.html>
18. Bas B, Ozgonenel O, Ozden B, Bekcioglu B, Bulut E, Kurt M. Use of artificial Neural network in differentiation of subgroups of temporomandibular internal derangements: A preliminary study. *J Oral Maxillofac Surg* 2012; 70:51-9.
19. Waal, Issac. Skin cancer diagnosed by using artificial intelligence on clinical images. *Oral Diseases*, 2017.Doi: oral diseases. 24.10.1111/odi.12668.
20. Sohmura T, Kusumoto N, Otani T, Yamada S,Wakabayashi K, Yatani H. CAD/CAM fabrication and clinical application of surgical template and bone model in oral implant surgery. *Clinical Oral Implants Research* 2009; 20: 87-93.

21. The Voxelman System. Accessed at: [www.voxel-man.de/gallery](http://www.voxel-man.de/gallery)
22. Ruppin J, Popovio A, Strauss M, Spuntrup E, Sterner A, Stoll C. Evaluation of the accuracy of three different computer aided surgery systems in dental implantology: Optical tracking versus Stereolithographic splint systems. *Clinical Oral Implant Research*, 2008;9(7):709-716.
23. Widman G. Image guide surgery and medical robotics in cranial area. *Biomedical Imaging and Intervention Journal*. 2007; 3(1):e11:1-9.
24. Hwang JJ, Sergei A, Efros AA, Yu SX. Learning Beyond Human Expertise with Generative Models for Dental Restoration. *CoRR abs/1804.00064*; 2018.
25. Khanna SS, Dhaimade PA. Artificial Intelligence: Transforming dentistry today. *Indian J Basic Appl Med Res* 2017;6: 161-7.
26. Wenzel A. "Computer-automated caries detection in digital bitewings: consistency of a program and its influence on observer agreement". *Caries Research* 35.1 (2001): 12-20.
27. Johari M., et al. "Detection of vertical root fractures in intact and endodontically treated premolar teeth by designing a probabilistic neural network: an ex vivo study". *Dentomaxillofacial Radiology* 46 (2017): 20160107.
28. Furman E, Jasinevicius TR, Bissada NF, Victoroff KZ, Skillicorn R, Buchner M. Virtual reality distraction for pain control during periodontal scaling and root planing procedures. *Journal of American Dental Association* 2009; 140: 1508-1516.
29. Shankarapillai R, Mathur LK, Nair MA, Rai N, Mathur A. Periodontitis risk assessment using two artificial neural networks; a pilot study. *2010 Int J Dental Clinics* 2:36-40.
30. Speight PM, Elliott AE, Jullien JA, Downer MC, Zakzrewska JM. The use of artificial intelligence to identify people at risk of oral cancer and precancer. *Br Dent J* 1995;179:382-7.
31. Chang SW, Abdul-Kareem S, Merican AF, Zain RB (2013). Oral cancer prognosis based on clinicopathologic and genomic markers using a hybrid of feature selection and machine learning methods. *BMC Bioinformatics* 14:170-184