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Journal of Dental Specialities

Journal homepage: https://www.jdsits.in/

Review Article

A brief overview of artificial intelligence in dentistry: Current scope and future applications

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ARTICLE INFO

Article history:
Received 23-02-2023
Accepted 11-03-2023
Available online 28-03-2023

Keywords:
Artificial intelligence
History

ABSTRACT

In present times, artificial intelligence (AI) has diversified in the fields of healthcare, education, finance, and cyber security. AI is expected to eliminate behavioural and perceptive bias in human interactions and bring forth a diversification in the working ethos across industries.
Although the areas of IT, manufacturing, gaming, astronomy, data security are utilising the multitude of advantages offered by AI, there are several untapped areas where AI could be highly beneficial. Presently in healthcare, AI is in its nascent stages of development and it may take a few years for its complete integration in the field of medicine and dentistry. However, it offers promising prospects in terms of improved diagnosis, timely management, superior outcomes and cost reduction. The aim of this article is to review the current applications of AI in dentistry and its potential scope in the future.

1. Introduction

Human resources are one of the fundamental assets of the healthcare system. Therefore, the quality of results is in corroboration to the expertise and skills of the healthcare professionals. However, these do pose certain challenges in terms of upgrading of skills and capital.[1]

Artificial intelligence (AI) is a field, which is an amalgamation of computer science and extensive and elaborate datasets. In simple terms, AI is a system that enables a robot, computer or software to imitate the human brain. In 1978, Richard Bellman defined AI as the automation of activities associated with human thinking and constitutes learning, decision making and problem solving.[2] The fundamental AI categories include machine learning (ML), deep learning (DL), artificial neural networks (ANN), robotics, expert systems, speech recognition, and language processing.[3] Successful implementation of AI in the field can boost capacity increase productivity and significantly reduce the cost of treatment across the healthcare pyramid.

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2. History of AI

1950: Alan Turing published a paper titled “Computing Machinery and Intelligence” and introduced the Turing test which evaluates a machine’s ability to exhibit intelligent behaviour equivalent to or indistinguishable from that of a human behaviour.[4]

1956: The term “artificial intelligence” was coined by John McCarthy at the first AI conference at Dartmouth College. He is widely recognized as the father of AI.[5]

1966: Eliza, the first natural language processing computer programme was designed between 1964 & 1966 at Massachusetts Institute of Technology by Joseph Weizenbaum. It is considered the first chatbot in history.

1967: Psychologist Frank Rosenblatt invented the perceptron algorithm and created the first single-layer

https://doi.org/10.18231/j.jds.2023.004

perceptron which is an electronic computational device adhering to the biological principles behind how the human brain functions.

1972: Shakey, the first autonomous robot was developed at the Stanford Research Institute.

It was able to break down the simple commands into a specific sequence of actions which were needed to achieve a goal with some logic.

1997: Deep Blue, a chess-playing expert system which runs on a unique purpose-built IBM supercomputer was designed that also defeated the world chess champion Gary Kasparov in a six-match game series on May 11, 1997.

2011: A question-answering computer system named IBM Watson was developed to perform cognitive computing and data analysis.[6]

2011-2014: Siri, Alexa, Google now and Cortana used speech recognition software to answer questions & perform simple tasks.

2016: Google developed Alpha Go that combined machine learning (ML) with neural networks. It defeated professional Go player Lee Sedol in a five-game match. Presently, AlphaGo has evolved through several successive versions, like AlphaGo Master, AlphaGo Zero, and Alpha Zero which can be trained and executed faster, and has increased Go proficiency.[7]

2020: Third generation Generative Pre-trained Transformers (GPT-3) uses deep learning (DL) to produce natural human language text.

3. Machine Learning

The term machine learning (ML) was proposed by Arthur Samuel. ML employs sizeable datasets and complex algorithms to mimic the human mind. It facilitates the systems to upgrade or augment through participation without the need for human programming. The function of ML can be descriptive, predictive or prescriptive. Based on the learning mechanisms, ML algorithms could be supervised, unsupervised, semi-supervised, and reinforced.

The capability of ML is hugely dependent on the size, logicality and attributes of the of the data being fed and the execution of the algorithms.[8] The algorithms are mostly developed using TensorFlow and PyTorch. Some innovative products based on ML are Netflix recommendation engine and self-driving cars. Also, ML is behind chatbots, predictive text, language translation applications, and machine diagnosis of medical conditions based on images.

3.1. Deep learning

Deep Learning (DL) is a subcategory of ML and was introduced by Hinton et al.[9] DL algorithms are more elaborate, refined, and mathematically intricate versions of ML algorithms. DL utilises a stratified arrangement of complex algorithms called an artificial neural network (ANN). The blueprint of an ANN is based on the anatomical neuronal network of the human brain, and hence, is far more efficient than the basic ML model. DL uses complex neural networks with multiple layers to analyse more intricate patterns and relationships. Compared to ML, DL networks are self-reliant and therefore require large amounts of data.[10] This makes them well-suited to complex, real-world problems and enables them to learn and adapt to new situations. Multilayer Perceptron, Convolutional Neural Network, and Long Short-Term Memory Recurrent Neural Network are a few examples of DL algorithms.[11]

3.2. Artificial neural networks

An artificial neural network (ANN) is a computational model that simulates the human central nervous system. It comprises of several hundreds of artificial neurons, connected with nodes that mimics the synaptic connections. The ANNs consists of an input layer, transfer function and an output layer.[12] The initial research on ANNs occurred mainly in the late nineteenth and early twentieth centuries and consisted primarily of the collaborative work in the fields of psychology, physics, and neurophysiology.[13]

In recent times, ANNs have been involved in pattern recognition, image coordination, risk assessment and memory simulation.[14]

4. Applications of AI in Dentistry

4.1. AI in endodontics

AI models have demonstrated various applications in endodontics such as studying root canal system anatomy, detecting periapical lesions, root fractures, working length measurements, predicting the viability of dental pulp stem cells (DPSCs), & predicting the success of retreatment procedure.[15]

Saghiri et al. reported an accuracy of 93% in determining the apical foramen location using AI. A study conducted by Fukuda et al. for detecting vertical root fractures (VRF) using CNN showed a precision of 93%.[16]

In 2008, Devito et al. used an AI based model for proximal caries diagnosis and concluded that Artificial Neural Networks could help clinicians to diagnose dental caries more accurately.[17] This was corroborated by a study conducted by Lee et al in 2021.[18] Hung et al. reported that AI can be applied for the prediction of root caries leading to early detection and timely intervention.[19]

Setzer et al. reported a DL periapical lesion detection accuracy of around 0.93 with the specificity of 0.88, Positive predictive value (PPV) of 0.87, and Negative predictive value (NPV) of 0.93.[20]

Hatvani et al. reported superior results on using a Convolutional Neural Networks-based AI model to identify the root morphologies on Cone Beam Computerised Tomographic (CBCT) images.[21]

Aliaga et al. used ANNs to determine the type of restorative material which will be suitable for patient by predicting the longevity of the procedures by the employment of case-based reasoning systems.[22]

4.2. AI in orthodontics

In the field of orthodontics where neural networks may be used are in diagnosis, treatment planning, automated anatomic analysis, growth assessment and development, and the evaluation of various treatment outcomes.[23]

Yu et al. developed a CNN model system and found that it exhibited a sensitivity, specificity, and accuracy of more than 90% for vertical and sagittal skeletal diagnosis.[24] Sorihashi et al. developed an inference system to describe the degree of certainty for sagittal skeletal discrepancies & concluded that in almost 97% of the cases, the orthodontic experts agreed with the advice proposed by the inference system.[25]

Muraev et al. compared the accuracy of cephalometric landmark identification between ANNs and doctors and found that ANNs can achieve accuracy comparable to humans.[26]

Several studies have reported that Deep Learning networks are the most accurate method for classification of temporomandibular joint osteoarthritis.[27,28]

Suhail et al. stated that Machine Learning algorithm is able to predict the extraction procedures to an accuracy that is almost equal to that obtained from different experts of the field.[29]

4.3. AI in prosthodontics

Chen et al. developed a prototype decision model which assisted dentists in choosing appropriate removable prosthetic options. Such supportive tools in treatment planning of complex patient cases in prosthodontics helps in further development of teledentistry.[30]

Lerner et al. used AI to fabricate implant-supported monolithic zirconia crowns which are cemented on customized hybrid abutments and found a 3-year cumulative survival & success rate of 99.0% & 91.3%, respectively.[31]

4.4. AI in periodontics

In periodontology, disease progression can be evaluated while AI technology can be helpful in automatically determining clinical and radiological periodontal parameters.[30]

Farhadian et al. designed a support vector machine based decision making support system to diagnosis various periodontal diseases with an accuracy of 88.7%.[32] A biomarker comparison by Carillo et al. in 2022 between gingivitis and periodontitis using salivary gene expression profiles, reported an accuracy of 78%.[33] Lee et al demonstrated that the deep CNNs were useful for diagnosis and assessing the predictability of periodontally compromised teeth.[34] Kim et al. confirmed that CNNs can be helpful in classifying implant fixtures with high accuracy even with a relatively small network and less number of images.[35]

Lee et al. used a deep CNNs to analyse the radiographs & measure the bone loss. The percentage of bone loss, staging, and diagnosis according to CNNs were compared with the measurements made by independent examiners. The accuracy for the neural networks was found to be 85%.[23]

Cha et al. stated that a region-based CNNs can be utilized in the measurement of radiographic peri-implant bone loss ratio for the assessment of severity of periimplantitis.[36]

4.5. AI in oral surgery

Ma et al. showed that CNNs models have a promising potential in automated surgical landmark identification.[37] A study conducted by Kim et al. revealed that CNNs can assist in the prediction of paraesthesia of the inferior alveolar nerve (IAN) after wisdom tooth extraction using panoramic radiographic images.[38] A study was conducted by Liu et al. to propose a CNNs based algorithm to improve the classification accuracy of ameloblastoma and odontogenic keratocyst significantly. It was concluded that their proposed network achieved accuracy, sensitivity, specificity of 90.36%, 92.88%, and 87.80%, respectively.[39]

5. Conclusion

AI systems provides promising tools that can improve the scenario of clinical practice, as well as automate methods which will help clinicians practice more efficiently, reduce variability & subjectivity. The accuracy of most existing AI systems is significantly good, and is expected to improve in the future as sample sizes increase, more information becomes available, and more researches are conducted in the field of using Artificial Intelligence in dentistry.[40]

6. Conflict of Interest

None.

7. Source of Funding

None.

References

1. Kabene SM, Orchard C, Howard JM, Soriano MA, Leduc R. The importance of human resources management in health care: a global context. *Hum Resour Health*. 2006;4:20. doi:10.1186/1478-4491-4-20.
2. Khanagar SB, Al-Ehaideb A, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, et al. Developments, application, and performance of artificial intelligence in dentistry - A systematic review. *J Dent Sci*. 2021;16(1):508–22.
3. Thurzo A, Urbanová W, Novák B, Czako L, Siebert T, Stano P, et al. Where Is the Artificial Intelligence Applied in Dentistry? Systematic Review and Literature Analysis. *Healthcare (Basel)*. 2022;10(7):1269. doi:10.3390/healthcare10071269.
4. Turing AM. Computing Machinery and Intelligence. *Mind*. 1950;59(236):433–60. doi:10.1093/mind/LIX.236.433.
5. Bichu YM, Hansa I, Bichu AY, Premjani P, Flores-Mir C, Vaid NR, et al. Applications of artificial intelligence and machine learning in orthodontics: a scoping review. *Prog Orthod*. 2021;22(1):18. doi:10.1186/s40510-021-00361-9.
6. Lee H. Paging Dr. Watson: IBM's Watson Supercomputer Now Being Used in Healthcare. *J AHIMA*. 2014;85(5):44–51.
7. Cheng L, Yu T. A new generation of AI: A review and perspective on machine learning technologies applied to smart energy and electric power systems. *Int J Energy Res*. 2019;43(19):1928–73.
8. Sarker IH. Machine Learning: Algorithms, Real-World Applications and Research Directions. *SN Comput Sci*. 2021;2(3):160. doi:10.1007/s42979-021-00592-x.
9. Hinton GE, Osindero S, Teh YW. A fast learning algorithm for deep belief nets. *Neural Comput*. 2006;18(7):1527–54.
10. Bernauer SA, Zitzmann NU, Joda T. The Use and Performance of Artificial Intelligence in Prosthodontics: A Systematic Review. *Sensors (Basel)*. 2019;21(19):6628. doi:10.3390/s21196628.
11. Sarker IH. Deep Cybersecurity: A Comprehensive Overview from Neural Network and Deep Learning Perspective. *SN Comput Sci*. 2021;2(154). doi:10.1007/s42979-021-00535-6.
12. Agatonovic-Kustrin S, Beresford R. Basic concepts of artificial neural network (ANN) modeling and its application in pharmaceutical research. *J Pharm Biomed Anal*. 2000;22(5):717–744.
13. Lek S, Park YS. Elsevier B. V. 2008.
14. Katne T, Kanaparthi A, Gotoor S, Muppirala S, Devaraju R, Gantala R. Artificial intelligence: demystifying dentistry - the future and beyond. *International Journal of Contemporary Medicine Surgery and Radiology*. 2019;4(4):6–9.
15. Aminoshariae A, Kulild J, Nagendrababu V. Artificial Intelligence in Endodontics: Current Applications and Future Directions. *J Endod*. 2021;47(9):1352–7. doi:10.1016/j.joen.2021.06.003.
16. Saghiri MA, Asgar K, Boukani KK, Lotfi M, Aghili H, Delvarani A, et al. A new approach for locating the minor apical foramen using an artificial neural network. *Int Endod J*. 2012;45(3):257–65.
17. Devito KL, de Souza Barbosa F, Filho WNF. An artificial multilayer perceptron neural network for diagnosis of proximal dental caries. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2008;106(6):879–84. doi:10.1016/j.tripleo.2008.03.002.
18. Lee S, Oh SI, Jo J, Kang S, Shin Y, Park JW, et al. Deep learning for early dental caries detection in bitewing radiographs. *Sci Rep*. 2021;11(1):16807. doi:10.1038/s41598-021-96368-7.
19. Hung M, Voss MW, Rosales MN, Li W, Su W, Xu J, et al. Application of machine learning for diagnostic prediction of root caries. *Gerodontology*. 2019;36(4):395–404.
20. Setzer FC, Shi KJ, Zhang Z, Yan H, Yoon H, Mupparapu M, et al. Artificial Intelligence for the Computer-aided Detection of Periapical Lesions in Cone-beam Computed Tomographic Images. *J Endod*. 2020;46(7):987–93. doi:10.1016/j.joen.2020.03.025.
21. Hatvani J, Andras H, Jérôme M, Basarab A, Kouamé D, Gyöngy M, et al. Deep learning-based super-resolution applied to dental computed tomography. *IEEE Trans Rad Plasma Med Sci*. 2019;3(2):120–8.
22. Aliaga IJ, Vera V, De Paz J, García JF, Mohamad MS. Modelling the longevity of dental restorations by means of a CBR system. *Biomed Res Int*. 2015;p. 540306. doi:10.1155/2015/540306.
23. Ossowska A, Kusiak A, Świetlik D. Artificial Intelligence in Dentistry-Narrative Review. *Int J Environ Res Public Health*. 2022;19(6):3449. doi:10.3390/ijerph19063449.
24. Yu HJ, Cho SR, Kim MJ, Kim WH, Kim JW, Choi J, et al. Automated Skeletal Classification with Lateral Cephalometry Based on Artificial Intelligence. *J Dent Res*. 2020;99(3):249–56.
25. Sorihashi Y, Stephens CD, Takada K. An inference modeling of human visual judgment of sagittal jaw-base relationships based on cephalometry: part II. *Am J Orthod Dentofacial Orthop*. 2000;117(3):303–11.
26. Muraev AA, Tsai P, Kibardin I, Oborotistov N, Shirayeva T, Ivanov S, et al. Frontal cephalometric landmarking: humans vs artificial neural networks. *Int J Comput Dent*. 2020;23(2):139–48.
27. Bianchi J, Ruellas ADO, Gonçalves JR, Paniagua B, Prieto JC, Styner M, et al. Osteoarthritis of the temporomandibular joint can be diagnosed earlier using biomarkers and machine learning. *Sci Rep*. 2020;10(1):8012. doi:10.1038/s41598-020-64942-0.
28. de Dumast P, Mirabel C, Cevidanes L, Ruellas A, Yatabe M, Ioshida M, et al. A web-based system for neural network based classification in temporomandibular joint osteoarthritis. *Comput Med Imaging Graph*. 2018;67:45–54. doi:10.1016/j.compmedimag.2018.04.009.
29. Suhail Y, Upadhyay M, Chhibber A, Kshitiz. Machine Learning for the Diagnosis of Orthodontic Extractions: A Computational Analysis Using Ensemble Learning. *Bioengineering (Basel)*. 2020;7(2):55.
30. Bernauer SA, Zitzmann NU, Joda T. The Use and Performance of Artificial Intelligence in Prosthodontics: A Systematic Review. *Sensors (Basel)*. 2019;21(19):6628. doi:10.3390/s21196628.
31. Lerner H, Mouhyi J, Admakin O, Mangano F. Artificial intelligence in fixed implant prosthodontics: a retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients. *BMC Oral Health*. 2020;20(1):80. doi:10.1186/s12903-020-1062-4.
32. Farhadian M, Shokouhi P, Torkzaban P. A decision support system based on support vector machine for diagnosis of periodontal disease. *BMC Res Notes*. 2020;13(1):337. doi:10.1186/s13104-020-05180-5.
33. Carrillo-Perez F, Pecho OE, Morales JC, Paravina RD, Bona D, Ghinea A, et al. Applications of artificial intelligence in dentistry: A comprehensive review. *J Esthet Restor Dent*. 2022;34(1):259–280.
34. Lee JH, Kim DH, Jeong SN, Choi SH. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. *J Periodontal Implant Sci*. 2018;48(2):114–23.
35. Kim JE, Nam NE, Shim JS, Jung YH, Cho BH, Hwang JJ, et al. Transfer Learning via Deep Neural Networks for Implant Fixture System Classification Using Periapical Radiographs. *J Clin Med*. 2020;9(4):1117. doi:10.3390/jcm9041117.
36. Cha JY, Yoon HI, Yeo IS, Huh KH, Han JS. Peri-Implant Bone Loss Measurement Using a Region-Based Convolutional Neural Network on Dental Periapical Radiographs. *J Clin Med*. 2021;10(5):1009. doi:10.3390/jcm10051009.
37. Ma Q, Kobayashi E, Fan B, Nakagawa K, Sakuma I, Masamune K, et al. Automatic 3D landmarking model using patch-based deep neural networks for CT image of oral and maxillofacial surgery. *Int J Med Robot*. 2020;16(3):2093. doi:10.1002/rcs.2093.
38. Kim BS, Yeom HG, Lee JH, Shin WS, Yun JP, Jeong SH, et al. Deep Learning-Based Prediction of Paresthesia after Third Molar Extraction: A Preliminary Study. *Diagnostics (Basel)*. 2021;11(9):1572. doi:10.3390/diagnostics11091572.
39. Liu Z, Liu J, Zhou Z, Zhang Q, Wu H, Zhai G, et al. Differential diagnosis of ameloblastoma and odontogenic keratocyst by machine learning of panoramic radiographs. *Int J Comput Assist Radiol Surg*. 2021;16(3):415–22.
40. Buschang PH, Asiri SN. The present, past and future of orthodontic research. *Semin Orthod*. 2019;25:326–38.

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Cite this article: Choudhary A, Malik A, Kaul R, Sharma A, Gupta A. A brief overview of artificial intelligence in dentistry: Current scope and future applications. *J Dent Spec* 2023;11(1):12-16.