Review Article

Artificial Intelligence-Powered Pediatric Dentistry: A Glimpse into the Future

Aditya Taiwade, Shilpi Tiwari, Shikha Mali, Suganya M
Department of Pediatric and Preventive Dentistry, People's College of Dental Sciences & Research Centre, People's University, Bhanpur, Bhopal (Madhya Pradesh)

ABSTRACT:

The rapid digitalization of various aspects of life has significantly transformed dentistry, improving the quality of dental care through advanced technologies like artificial intelligence (AI). AI, which replicates human cognitive processes, has revolutionized dental practices by automating time-consuming tasks and offering precise diagnostics and treatment plans. Despite being in early development stages, AI in dentistry signifies a disruptive technology poised to redesign clinical care. Innovations such as CAD/CAM systems, intraoral imaging, and digital radiography illustrate AI's applications in caries diagnosis, implant design, etc. Historical milestones, from conceptualization of AI to advancements in machine learning and neural networks, have paved the way for sophisticated AI models used in various dental specialties, including pediatric dentistry. AI's potential extends to patient education and practice management, promising a future where dentistry is increasingly efficient, accurate, and patient-centered. This review highlights role of AI in pediatric dentistry with special mention of review of literature.

KEY WORDS: Artificial Intelligence, Dentistry, Deep Learning, Machine Learning, Neural Networks

Address for correspondence : Dr Aditya Taiwade, Postgraduate student; Department of Pediatric and preventive dentistry, Peoples College of Dental Science, Bhopal - 462037 (Madhya Pradesh), India. E-mail: adityataiwade39@gmail.com
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INTRODUCTION:

As we all know, the world is rapidly moving toward digitalization in all aspects of life. This digital revolution has transformed dentistry in every aspect and increased the quality of dental care. The term "artificial intelligence" (AI) elicits strong feelings. For one thing, there's our fascination with intelligence, which appears to give us a unique place among living beings. Questions such as "What is intelligence?" "How can intelligence be measured?" and "How does the brain work?" arise and all these questions are relevant when trying to understand artificial intelligence.[1] AI aims to replicate human cognitive processes and achieve the same results as medical professionals in a much shorter time frame. It excels at extracting information from historical data and helps doctors by automating time-consuming tasks.[2]

Although AI development is still in its early stages, and medical tasks that modern AI can perform can almost be done by humans, the emergence of AI in dentistry signifies a new era of disruptive technology with the potential to completely redesign the landscape in which dental clinical care is practiced.[3] Over the years, man has attempted to build technology that can simulate the proper functioning of the human brain, which has resulted in the advancement of technology known as AI.[4] The exponential growth of science and technology has resulted in unique applications that are used on a daily basis, such as Siri and Alexa. These programmes are discovered at the peak of AI and its

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components. The term AI is commonly associated with robotics. It describes how technology is used to create software programmes or a system that can easily mimic human intelligence and carry out specific tasks.[5]

John McCarthy in 1955 coined the term "artificial intelligence," and he is widely regarded as the father of AI. He chose this term to explain the ability of machines to perform duties that could fall under a variety of "intelligent" activities.[6]

CAD/CAM and intraoral imaging—both laboratory and clinician controlled—are examples of how technologies are being used in dentistry. The technologies are used in caries diagnosis, in computer-aided implant dentistry, including the design and fabrication of surgical guides; in digital radiography (intraoral and extraoral), including cone beam computed tomography (CBCT); in electric and surgical/implant handpieces, lasers, occlusion, and temporomandibular joint (TMJ) analysis and diagnosis; in photography (extraoral and intraoral); in practice and patient record management, including digital patient education; and in shade matching.[7] With all of these digital dentistry implements assisting dentistry around the world, researchers and inventors are further encouraged to seek out new technologies or advancements that can be used to elevate the profession to its peak.[8] In the modern-day world, AI refers to any machine or technology that is able to mimic human cognitive skills like problem solving.[5] To understand AI, it is important to know few key aspects as depicted in (Figure1).

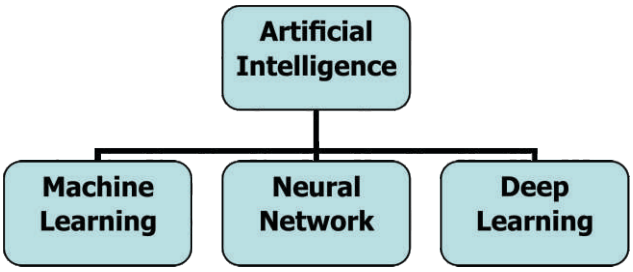

Figure 1: Key aspects of artificial intelligence.

HISTORY OF ARTIFICIAL INTELLIGENCE:

HISTORY OF NEURAL NETWORKS: 1943- Warren McCulloch and Walter Pitts published a paper in which they proposed using neural networks to mimic human brains.[9]

1951- The stochastic neural analogue reinforcement calculator developed by Minsky and Dean Edmunds is regarded as the first neural network in history.[10]

1955- For the first time in history, Allen Newell and Herbert Simon created AI applications. The Logic Theorist programme proved 38 of the first fifty-two axioms of Principia Mathematica, a work co-authored by Whitehead and Russell.[11]

Although the possibilities for implementing strong AI were unclear, the evolution of weak AI through the creation of artificial neural networks continued. Arthur Samuel extended the development of weak AI in 1959 by coining the term "machine learning."[12]

Development of Deep Learning:

The field of research and development focused on the implementation of weak AI and this trend was accelerated by Arthur Bryson and Yu-Chi Ho.[13]

In 1969, they developed the back propagation algorithm. They made a significant contribution to the current implementation of deep learning. This back propagation algorithm refines the AI execution result using a partial derivative approach, which is implemented propositionally and symbolically and is intended to improve the AI-auto-executing algorithm.[14] AI advances from the level used for Turing test implementation and mathematical and logical verification to the higher level of real-world usage through the concept of machine learning.

An early expert system emerged in 1972, which is a system that allows non-specialists to apply expertise by organising and processing expert knowledge in a specific field.[15]

MYCIN, a 1972 expert system developed at Stanford University, is designed to identify microorganisms that cause serious infections and to recommend appropriate antibiotics.[16]

In 1956, Marvin Minsky and John McCarthy (a computer scientist at Stanford) hosted approximately eight-week-long Dartmouth Summer Research Project on Artificial Intelligence (DSRPAI) at Dartmouth College in New Hampshire. This workshop, which kicked off the AI Spring and was funded by the Rockefeller Foundation, brought together people who could be considered the founding fathers of AI. Nathaniel Rochester, the computer scientist who later designed the IBM 701, the first commercial scientific computer, and mathematician Claude Shannon, who founded information theory, were among those who took part. The goal of DSRPAI was to bring together researchers from various fields in order to establish a new research area devoted to developing machines capable of simulating human intelligence.[17]

AI is a branch of computer science that aims to understand and build intelligent entities often instantiated as software programs.[18] The branches of Artificial intelligence are depicted in Figure 2.

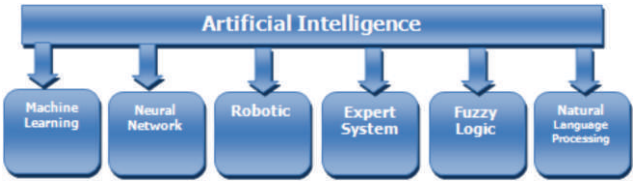

Figure 2: Branches of artificial intelligence.

MACHINE LEARNING:

Machine learning (ML) is a branch of AI in which systems learn to perform intelligent tasks without prior knowledge or hand-crafted rules. Instead, the systems identify patterns in examples from a large data sets, without human assistance.[18]

ML has an advantage that newly designed AI model enables the radiologist to develop more and increase their level of learning with a large database of new images. ML depends on algorithms to predict outcome based on data sets.

DEEP LEARNING (DL):

It is sub branch of ML that utilizes the networks with different computational layers in deep neural networks to analyse data. It utilizes varied computational layers through a deep neural network, thus analysing the input data. DL is to generate patterns to improve feature detection. DL structures referred to as convolutional neural networks (CNNs), which can extract many features from abstracted layers of filters, are mainly used for processing large and complex Images.[19]

DL is being accelerated by the development of self-learning back-propagation algorithms that progressively refine the results from the data, as well as by increase in computational power. Due to these rapid technological advances, AI, represented by deep learning, can be used for real-life problems, and is applied across all sectors of society.

The diagnostic accuracy of deep learning algorithms in the medical field is approaching levels of human expertise, changing the role of computer-assisted diagnosis from a 'second-opinion' tool to a more collaborative one.

Multiple studies have shown that deep learning algorithms performed at a high level when applied to breast histopathology analysis, skin cancer classification, cardiovascular diseases' risk prediction, and lung cancer detection.[20]

Artificial neural networks:

Artificial Neural Networks were invented keeping the structure of the brain as its basis and it has the ability to imitate human brains.[5] In 1951, Minsky and Dean Edmunds developed the stochastic neural analog reinforcement calculator, which is recognized as the very first neural network in its developmental history.[6] In 1955, Allen Newell and Herbert Simon developed programs of AI for the first time .[12]

The greatest advantage of these systems is that they have capability to solve the problems that are too complex to be solved by conventional methods. They are useful in various areas of medicinal science like diagnosis of diseases, biomedical identification, image analysis and data analysis. In dental practice also the clinical support systems are actively progressing.[9]

ROLE OF AI IN DENTISTRY:

Periodontology-Wang et al. developed a Digital Convolution Neural Network based system that consists of 16 convolution layers and two fully connected layers for detecting periodontitis of premolars and molars.[21]

DL analysis using radiographs can help in diagnosis and treatment planning of periodontal diseases by the early detection of periodontal changes. This helps in early intervention in implantology. In addition to promoting our understanding of periodontitis, this technology serves as a bridge to incorporate conventional indicators and immunologic and microbiological parameters into periodontal diagnosis.[18]

AI is being used in pediatric dentistry and periodontology to detect dental plaque and diagnose gingivitis and periodontal disease using intraoral photographs and fluorescent images. AI models have been used to detect plaque on primary and permanent teeth, predict children's oral health status and treatment needs, detect, classify, and predict dental caries, detect and categorize fissure sealants, determine chronological age, and determine the impact of oral health on adolescent quality of life. Table 1 shows findings of studies that used AI in periodontics.[22,23,24,25]

Endodontics:

In terms of detection, determination, and disease prediction in endodontics, AI has shown accuracy and precision. In order to increase the success of endodontic treatment outcomes, AI can help to improve diagnosis and treatment.

Oral Radiology:

In the fields of medicine and dentistry, many AI models have been produced to assess people's risk of getting sick, detect abnormal health data, diagnose and prognosis of diseases. Since digital images are used for

Table 1: AI in periodontics.

Author	Year of Publication	Algorithm Architecture	Objective of the study	Conclusion
K. Carter et al.	2004	Automated quantification	To assess the accumulation of plaque on teeth, a fully automated method was developed based on digital imaging of methylene blue (1% w/v) disclosed plaque.	This method has potential for automated and quantitative measurement screening of dental plaque that may be used to assess the efficacy of oral hygiene products and procedures.
J. Kang et al.	2006	Cellular Neural Network	This paper presented an approach for quantifying the dental plaque automatically based on cellular neural network (CNN) associated with histogram analysis.	The experimental results showed that this method provided accurate quantitative measurement of dental plaque compared with that of traditional manual measurement indices of the dental plaque.
Imangaliyev et al.	2017	CNN	An image classification model based on Convolutional Neural Network is applied to Quantitative Light-induced Fluorescence images.	The model directly benefits from multi-channel representation of the images resulting in improved performance when, besides the Red colour channel, additional Green and Blue colour channels are used.
You et al.	2020	CNN	To design a deep learning-based artificial intelligence (AI) model to detect plaque on primary teeth and to evaluate the diagnostic accuracy of the model.	AI model showed clinically acceptable performance in detecting dental plaque on primary teeth compared with an experienced pediatric dentist. This finding illustrates the potential of such AI technology to help improve pediatric oral health.

Table 2: AI in endodontics and oral radiology.

Author and year\	Study design	Year of publication	Algorithm Architecture	Objective of the study	Conclusion
Saghiri et al.	Experimental	2012	ANNs	ANN based AI model for determining the working length	The accuracy of ANN was more than the endodontists
Campo et al.		2015	BNNs	Bayesian networks for predicting the need for performing a retreatment	The proposed system with Bayesian networks was tested in a real environment and the results obtained are promising.
Hatvani et al		2018	CNNs	To investigate the use of CNNs for Resolution enhancement of 2-D CBCT dental images, using CT data of the same teeth as ground truth	The results suggest the superiority of the proposed CNN based approaches over reconstruction based methods
Ekert et al.		2019	CNNs	CNNs for detecting apical lesions (ALs) on panoramic dental radiographs	A moderately deep CNN showed satisfying Discriminatory ability to detect ALs on panoramic radiographs
Fukuda et al		2020	CNNs	To evaluate the use of convolutional Neural network (CNN) system for detecting vertical root fracture (VRF) on panoramic radiography	The CNN learning model has shown promising results in detecting VRFs on panoramic images
Orhan et al.		2020	CNNs	CNNs to detect periapical pathosis on cone-beam computed tomography (CBCT) images	The performance of humans and by AI systems were comparable to each other

diagnosis in the field of radiology, it is quite easy to transfer these digital data into computer language. Thus, radiology is the most suitable branch of dentistry for AI use. Table 2 shows findings of studies that used AI in endodontics and oral radiology.[26,27,28,29,30,31]

AI IN PEDIATRIC DENTISTRY:

In Pediatric dentistry, AI has many potential applications which would change the face of behavioural Pediatric practice in future. Also, with the help of larger data sets, ML algorithms will only become more sophisticated over time.

AI is also gaining pace in the early orthodontic tooth movement with customized AI driven appliances which would have better acceptability by the new generation. AI enabled restorative dentistry with computer-aided design computer-aided manufacturing technology is already established in adult dental practice and would emerge a boon to pediatric restorations in terms of time and aesthetics. Pain control with AI enabled devices is the new, smarter way towards injection-free pedodontic practice.

Also, AI can be used to enhance the teaching and learning process for students as well as patients. The various 4D goggles, movies, animations and virtual reality-based games can be used as a behaviour modification aid effectively for Pediatric patients. Thus, a dramatic improvisation of AI based Pediatric dentistry would change the way we practice as well as teach. Dentistry and oral healthcare, promisingly, is a very natural customer for artificial intelligence applications in the near future.[32]

Early childhood caries (ECC) is a multifactorial disease with host, microorganisms, diet, and oral hygiene practices as the factors that determine the risks. Children's parents/caregivers need to be engaged around these risk factors and acquire skills to self-manage risk to reduce children's risk for ECC.

To combat this ECC pandemic and overcome the barriers of lacking dental access among underserved children and lacking self-management awareness of these children's caregivers, our long-term goal is to develop a first-of-its-kind AI–powered smart phone app to be used by children's parents, which offers patient-centered caries detection and caries risk management.

FUTURE OF AI IN PEDIATRIC DENTISTRY:

AI has many potential applications in paediatric dentistry that will change the face of behavioural paediatric practise in the future. Furthermore, as larger data sets become available, machine learning algorithms will only become more sophisticated over time. The new, smarter approach toward pedodontic practice without injections is pain control with AI-enabled devices. AI can also be used to improve patient care and teaching and learning processes for students. Children patients can benefit greatly from the various 4D goggles, films, animations, and virtual reality-based games as a tool for behaviour modification. As a result, a radical improvisation of AI-based pediatric dentistry would alter both our practice and our teaching methods. A promising market for AI applications in the near future is dentistry and oral healthcare.[33]

INNOVATIONS THAT CAN TRANSFORM DENTISTRY IN FUTURE:

Use of Software in Dentistry- Currently, softwares are used by dentists to gain insights on clinical decision-making. To help physicians choose the optimum modalities for their patients, these will grow further to incorporate AI algorithms. Dental medicine is moving towards a new phase of digitization as a result of the exponential growth in clinical information and the development of healthcare AI. These clever algorithms can be incorporated into the healthcare system to analyse patient information, scientific discoveries, and therapeutic approaches to provide diagnostic and therapeutic recommendations.

Use of Tooth Brushes with Brain:

An intelligent electric toothbrush ensures that you will be brushing your teeth properly and provides children with enjoyable games to maintain the healthy habit of brushing their teeth on a regular basis. The handle of smart toothbrush is jam-packed with sensors. These provide you immediate feedback through a companion app, alerting the user if he/she is using too much force, while brushing.

Designing with Computers & 3D Printing:

In computer-aided designing (CAD) & computer-aided manufacturing (CAM), 3D printing, is gaining importance. Traditionally, a dentist must create a mould of the patient's tooth and create a temporary crown before waiting for the dental facility to create a permanent one. Using CAD/CAM technology, the tooth is drilled to prepare it for the crown, and a bitmap picture is then taken. Then, a device that receives and sends this image makes the crown in-office.

In fact, 3D printers may be used to make orthodontic models, surgical implants, aligners, retainer, etc more rapidly and precisely. This helps in

streamlining procedures and decreases errors and labor cost, which ultimately increases the technology's efficiency in terms of time and cost.

ADVANTAGES OF AI:

AI enables Diagnostic and treatment planning efficiency. It can be used for Program standardization. It is faster and takes less time. From a patient's point of view, AI could help overcome the flaws in traditional dental care that have been widely criticized. Dentistry, and specifically dental academia, has a role to play in ensuring that AI improves dental treatment while lowering costs, benefiting patients, treatment providers, and society as a whole. AI in dentistry is emerging as a benefit to clinicians in improving patients and simplifying complicated protocols by providing predictable outcomes.[16]

DISADVANTAGES OF AI:

One of the major disadvantage is that AI's mechanism is quite complicated. Costs of setup are high. Due to the large amount of data required to train and precision, it is challenging to attain accuracy in rare disorders or diseases.[1] Ethical issues in the biomedical environment are of concern.[32]

CONCLUSION:

Currently, AI has entered various areas of dentistry and has provided significant services in each of these areas. However, in many areas, there have been interesting but failed efforts and ideas, with further progress being made in using the potentials of AI. Going into the phase of investment in AI projects in pediatric dentistry can lead to facilitation of their deployment and to new developments of efficiency in the field of pediatric dentistry. According to our background review of existing dentistry AI technologies, we assume that different processes in the dental profession are largely multidimensional and require various subtleties in different areas. By looking at the types of subsets of AI and spectating their progress, it seems that AI is at the service of the dentists to augment their intelligence and efficiency, rather than being a threat for employment processes in the dentistry sector.

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Conflicts of interest
There are no conflicts of interest.

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