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Utilization of artificial intelligence in pediatric dentistry: a comprehensive literature review

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ABSTRACT

Artificial intelligence (AI) refers to the creation of computer systems capable of performing tasks that typically necessitate human intelligence. Several dental specializations, such as pediatric dentistry, increasingly utilize artificial intelligence and its components, including machine learning and deep learning. The advancement of AI in healthcare is associated with the development of AI applications designed to assist medical practitioners in diagnosing patients and determining optimal treatment strategies. Artificial Intelligence refers to the ability of machines to acquire knowledge and utilize that information to perform various cognitive functions, such as language processing, learning, reasoning, and decision-making-essentially emulating human behavior. This article provides an overview of the various applications of AI that are advantageous to pediatric dentistry.

Keywords: Artificial intelligence, machine learning, deep learning, pediatric dentistry

INTRODUCTION

Early detection, management, and prevention of these issues are crucial for optimal dental health in children. In recent years, artificial intelligence (AI) has exhibited its utility in the dental and medical sectors.[1] The process of instructing a machine to emulate human cognition is referred to as artificial intelligence, or AI.[1,2] At a Dartmouth meeting in 1956, John McCarthy coined the term "artificial intelligence" for the first time.[1,3,4] AI solutions are more vital across various dental disciplines today. The creation of AI programs designed to aid doctors in patient diagnosis, therapy selection, and outcome prediction is associated with the utilization of AI in healthcare.[2]

The domain of artificial intelligence referred to as machine learning (ML) employs algorithms to predict outcomes based on a dataset.[2] By employing data to develop algorithms, machines can address predictive challenges independently of human intervention. A set of algorithms known as neural networks (NNs) utilizes artificial neurons to process signals. Artificial neurons that mimic human neural networks are employed in neural networks, which utilize mathematical models to replicate the human brain. Neural networks provide the capability to emulate human cognitive functions, including problem-solving, reasoning, learning, and decision-making, among others. Neural networks comprise three fundamental layers: the input layer, which acquires user input; the hidden layer, which processes the data; and the output layer, where the system renders decisions.[5] Artificial neural networks (ANN), convolutional neural networks (CNN), and recurrent neural networks (RNN) are the three predominant forms of neural networks. Neural networks encompass deep learning, enabling computers to autonomously interpret data. The concealed layer of deep learning neural networks may contain anything from several thousand to several million neurons.[2,3,6] Neural networks assist in training computers to respond suitably to situations, rather than prescribing specific actions.[7] Advanced AI technologies are better suitable for application with 3D CNN in dentistry for clinical purposes, such as cone beam computed tomography (CBCT). CBCT, necessitating substantial radiation exposure, can be supplanted in endodontics by three CNNs capable of identifying anatomical structures and dental caries. They are also crucial in the domain of oral pathology.[1] Artificial narrow intelligence (ANI), artificial general intelligence (AGI), and artificial superintelligence (ASI) constitute the three primary classifications of artificial intelligence. ANI, commonly known as weak AI, possesses restricted capabilities suitable for highly specific jobs. These systems perform solely the specific function for which they were designed. Referred to as "strong" or "deep AI," AGI possesses the capability to resolve problems in a manner akin to that of a human. In dentistry, neural networks can enhance diagnostic accuracy, speed, and efficiency.[4]

AI is a contemporary technical advancement that has rapidly gained prominence in the domain of science and technology.

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AI significantly depends on imaging, which serves as a fundamental element in dentistry to a considerable degree. Artificial intelligence is exceptionally advantageous in the constant assessment and monitoring of a patient's health, comprehending the long-term impacts of pharmaceuticals, and identifying potential health-related risks in advance.[8,9] AI has the capacity to entirely eradicate the extensive hours dedicated by dental practitioners. Moreover, it is possible to enhance individuals' health at reduced expenses, deliver personalized, preventive, and predictive dental care, and unify healthcare for all. Primarily, AI possesses the capacity to enhance dental care standards, refine diagnostic accuracy and efficacy, generate superior treatment images, model outcomes, and forecast oral diseases and health conditions.[8-10] AI models have garnered attention for their role as supplementary tools, enhancing the precision and accuracy of diagnosis. AI technology has been extensively utilized in medical sciences, exhibiting exceptional efficacy in many patient care activities, including disease diagnosis and assessment of a patient's risk for disease development, among others.

A primary motivation for this study is the rapid increase in recent studies concerning neural networks in dentistry. In pediatric dentistry, artificial intelligence possesses numerous promising applications that could transform pediatric practice in the forthcoming years. The objective of this research was to investigate the several applications of AI in pediatric dentistry.

CLASSIFICATION OF AI

AI can be implemented through various methods, with different types designed to perform distinct tasks. Researchers have proposed multiple classification approaches for AI.

All non-human intelligence falls under the category of AI, which is further divided into weak AI and strong AI. Strong AI possesses intelligence and capabilities equivalent to those of humans, aiming to develop a multitasking algorithm for decision-making.

Weak AI encompasses expert systems and machine learning as separate categories. Currently, deep learning, a subset of machine learning, is one of the most actively researched fields. Convolutional neural networks (CNNs) are a type of deep learning model widely used for image generation and recognition. Among deep learning algorithms, generative adversarial networks represent an unsupervised learning approach designed to autonomously identify patterns in input data and generate new data with similar characteristics.[3,11-14]

The evaluation of existing AI applications in pediatric dentistry remains inadequate. Therefore, this review aims to provide an update on the effectiveness of AI as a diagnostic tool in pediatric dentistry.

The benefits of AI are substantial. ML and DL, as subfields of AI, have proven to be valuable tools in enhancing clinical decision-making. They improve monitoring, efficiency, accuracy, and precision while also saving time. AI helps reduce the duration of investigations and contributes to better public health outcomes while lowering costs. Additionally, it enables personalized, anticipatory, and preventive dental care.

However, AI also has its limitations. The availability of datasets remains a challenge, with only a limited number of AI-based models capable of identifying images beyond the scope of two-dimensional panoramic radiography. Furthermore, datasets from single institutions are not widely accessible, limiting the generalizability of AI applications.[3]

AI APPLICATIONS IN PEDIATRIC DENTISTRY

AI plays a significant role in diagnostics, decision-making, treatment planning, and outcome prediction. Its impact on diagnosis has been particularly notable, leading to substantial advancements in accuracy and efficiency.[15]

Dental Caries Detection

AI systems can accurately outline teeth, detect caries, and generate valuable predictions. They assist in diagnosing common pediatric dental conditions, such as tooth decay, by analyzing X-Rays and intraoral images while also playing a role in patient education.[15] Talpur et al.[16] conducted a study using DL techniques to diagnose dental caries through image analysis. Additionally, algorithms can be applied to delineate anatomical and pathological structures. An artificial neural network was specifically employed to detect the presence of caries.[4]

ML-based models utilize simple questionnaires and assessments to predict the presence of early childhood caries (ECC) in preschool-aged children. A novel caries risk prediction model incorporating genetic and environmental components was established. Key factors from the parent questionnaire are identified using a machine learning technique known as random forest throughout the COVID-19 period to predict the presence of active caries.[1] Data has been trained up to October 2023. Karhade et al.[17] employed a questionnaire and machine learning to diagnose dental caries. The results indicated that ECC can be accurately detected and classified.

Evaluation of Children's Oral Health and Management

AI identifies potential risk factors affecting children's dental health and revolutionizes the processes of data collection, organization, and utilization, ultimately enhancing the quality of care provided to pediatric and adolescent patients. Its advanced data management capabilities offer pediatric dentists a structured and standardized framework for organizing extensive medical records. This streamlined approach enables quick access to critical information regarding a child's dental history, facilitating the development of personalized, patient-centered treatment plans.[15] You et al. developed a comprehensive AI-powered toolbox for assessing pediatric dental health.[3,15] ML models and algorithms enhance dental practitioners' understanding and cognitive abilities. They analyze patient data, medical records, and other relevant information to generate predictions and treatment recommendations.[15] AI is utilized in orthodontics for treatment planning, identifying cephalometric landmarks, and predicting treatment outcomes.[11] AI has been applied to the identification of dental sealants using CNNs. An AI-driven approach demonstrated higher diagnostic accuracy compared to traditional CNN-based classification methods, enhancing the reliability of sealant detection and evaluation.[1]

Age Estimation in Children

Zaborowicz et al.[18] utilized three deep neural network models to determine the chronological age of children and adolescents aged 4 to 15. Their research indicated that neural modeling

systems could precisely ascertain metric age using proprietary dental and skeletal characteristics.

Detection of Teeth and Dental Anomalies

A single deep learning model is utilized for the diagnosis of mesiodens. This deep learning approach facilitates the identification and early detection of abnormalities in both permanent and deciduous teeth, enhancing diagnostic accuracy and clinical decision-making.[1,19] CNNs, one of the most widely used DL architectures, are commonly applied in object recognition. In pediatric dentistry, deciduous teeth are increasingly analyzed using DL techniques such as CNNs. The R-CNN inception model has demonstrated high accuracy in tooth identification. Additionally, AI has accurately detected the ectopic eruption of the first permanent molar.[1] Bulatova et al.[20] assert that the AI-based model demonstrated superior efficiency in recognizing cephalometric landmarks compared to manual tracing.

Endodontics

AI supports the assessment of root canal system anatomy, working length measurements, periapical disease and root fracture diagnosis, and retreatment outcome prediction.[4] Zheng et al.[21] reported that a multimodal CNN demonstrated high accuracy when comparing three different CNN models for diagnosing pulpitis and deep caries in intraoral periapical radiographs.

General Dentistry

AI enhances precision in shade matching, improving restorative dentistry outcomes.[4] CNN algorithms have proven effective in the automated detection of cancer and periodontal disease.[11] Research has shown that CNNs successfully identify dental plaque on primary teeth using intraoral photographs, providing clinically significant findings.[22] Additionally, AI-supervised nanorobotic techniques offer the potential for painless procedures by enabling precise local anesthetic delivery.[3]

The primary challenges in integrating AI into dentistry involve the application of AI algorithms in healthcare, particularly concerning the exchange and storage of clinical data. While AI cannot fully replace a dentist's diagnostic process, it can support general and pediatric dentists by enabling faster diagnoses with greater accuracy.[1]

CONCLUSION

Artificial intelligence has emerged as a transformative force in pediatric dentistry, enhancing diagnostic accuracy, treatment planning, and patient management. AI-driven technologies, including machine learning and deep learning models, have demonstrated significant potential in early detection, risk assessment, and personalized dental care for pediatric patients. From detecting dental caries and assessing occlusion to automating image analysis and predicting treatment outcomes, AI applications are redefining clinical workflows and improving efficiency. Despite these advancements, several challenges remain, including the need for high-quality, diverse datasets, regulatory approvals, and ethical considerations related to patient privacy and data security. Further research is essential to refine AI-based models, validate their clinical effectiveness, and integrate them seamlessly into routine pediatric dental practice.

By continuously exploring AI's capabilities, clinicians can leverage this technology to improve treatment outcomes, optimize clinical decision-making, and ultimately enhance pediatric oral healthcare. Collaborative efforts between researchers, clinicians, and technology developers will be pivotal in overcoming existing limitations and ensuring AI's safe, ethical, and effective implementation in pediatric dentistry.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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