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Artificial intelligence in pediatric dentistry: Innovations and challenges

Eloá Cristina Passucci Ambrosio[1]*; Vinicius André Coneglian[2]; Maria Aparecida Andrade Moreira Machado[3]; Thais Marchini Oliveira[1,3]

[1]Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Brazil.

[2]Department of Electrical and Computer Engineering, São Carlos School of Engineering and Institute of Mathematics and Computer Science, University of São Paulo, Brazil.

[3]Department of Pediatric Dentistry, Orthodontics, and Collective Health, Bauru School of Dentistry, University of São Paulo, Brazil.

***Corresponding author: Passucci Ambrosio EC**
Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo, Rua Silvio Marchione 3-20, Bauru 17012-900, SP, Brazil.
Email: eloacpambrosio@usp.br

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Abstract

Artificial Intelligence (AI) is a rapidly evolving field of computing with applications in various areas of knowledge, including law, finance, process automation, engineering, education, and healthcare. In pediatric dentistry, AI can have a wide range of applications in diagnosis, decision-making, and prevention. This short communication aims to explore innovative possibilities for using AI in pediatric dental care and examine the challenges associated with using these tools.

Keywords: Artificial intelligence; Deep learning; Machine learning; Dental care for children; Pediatric dentistry.

Introduction

Artificial Intelligence (AI) is a broad term encompassing a diverse set of computational tools based on algorithms capable of learning from databases, undergoing training, generating responses to questions, and performing specific tasks [1-3]. It is one of the most widely discussed technologies today, with its recent surge in popularity largely attributed to ChatGPT (OpenAI, San Francisco, CA, USA), which employs a Large Language Model (LLM) to simulate human conversation [4]. Various subsets of AI have been studied, tested, and applied across numerous fields of knowledge [1,2], offering potential benefits in advancing pediatric oral health.

Machine Learning (ML) is a subset of AI that enables algorithms to learn from data and improve their performance in executing tasks, even when not explicitly designed for a specific purpose [5]. Within the field of ML, one recently utilized technique is Knowledge Distillation (KD). This approach simplifies previously complex and robust AI models, improving their efficiency, accuracy, and ability to run on other platforms [6].

Deep Learning (DL) is an AI technique and a subfield of Machine Learning. DL utilizes artificial neural networks to recognize patterns within data sets [7,8]. These artificial neural networks consist of algorithms organized into main layers: the input layer (responsible for receiving external information, such as X-rays and photographs), the intermediate or hidden layer

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(where data processing and learning take place), and the output layer (which delivers the final result of the processing) [8]. Consequently, artificial intelligence is poised to drive significant advancements in prevention, diagnosis, and treatment planning, providing valuable support for pediatric dentists in decision-making. Therefore, this short communication aims to explore innovative possibilities for clinical care in pediatric dentistry and address the challenges associated with utilizing these tools.

Innovations and applicabilities in pediatric dentistry

Dental anxiety

Pediatric dentists must assess childhood dental anxiety, as it significantly impacts the child's behavior management during consultations. This assessment can be carried out using objective methods, such as measuring blood pressure and heart rate, as well as subjective methods, including questionnaires and visual scales [9,10].

In this context, some authors developed a smartphone application based on the Children's Dental Anxiety Scale, enhanced with Artificial Intelligence, whose validation and reliability were tested in children. The tool captured a photo of the child's face and generated five images displaying expressions: very happy, happy, neutral, sad, and crying. The child then selected the expression that best represented their emotional state during dental treatment. The authors concluded that the tool is reliable and shows promise as an alternative method for analyzing childhood anxiety, mainly because it is accessible, straightforward, and easy to implement [10].

Dental anomalies

Dental anomalies can affect both primary and permanent dentition, leading to changes in teeth' anatomy, number, and positioning. Researchers have employed Deep Learning architectures to detect mesiodens—a supernumerary tooth located in the midline region of the maxilla, between the central incisors—using imaging techniques such as panoramic radiographs and Cone Beam Computed Tomography (CBCT) [11-13]. There is no consensus on the most effective algorithm, with models such as SqueezeNet, ResNet-18, ResNet-101, Inception-ResNet-V2, Darknet-53, and DeeplabV3plus, among others, being utilized. The accuracy of these AI algorithms has been highly variable, ranging from 65% to 97.1% [11,12].

Another application of artificial intelligence lies in detecting Molar-Incisor Hypomineralization (MIH), a qualitative alteration of tooth enamel that affects permanent molars and incisors. Clinically, affected teeth exhibit opacity, porosity, and fragility [14]. Convolutional neural networks, including ResNet34, ResNet50, AlexNet, VGG16, and DenseNet121, have been utilized. Among these models, DenseNet121 demonstrated the highest accuracy (92.86%) compared to the others. In the long term, implementing AI for detecting specific dental pathologies is considered feasible and promising. Clinically, this technology holds potential for integration into the training and education of dental students, as well as enhancing the expertise of general practitioners, facilitating learning about MIH and similar dental pathologies [15].

Dental age

Dental age estimation methods are employed to evaluate the stages of tooth mineralization. Some researchers [16] determined dental age based on the development of mandibular permanent teeth using Dental Panoramic Tomographs (DPTs) of children and adolescents. This study utilized a computational approach with Artificial Neural Networks (ANN), explicitly applying the multilayer perceptron (MLP) function. The analyses demonstrated an accuracy of 93.8% [16].

Dental plaque

Dental plaque comprises bacteria, food debris, saliva, and proteins accumulating on the tooth surface. It can be a precursor to developing periodontal diseases and carious lesions [17]. Researchers used a Convolutional Neural Network (CNN) tool, trained with intraoral photographs of deciduous teeth, to compare the AI model and dentists' assessments [18]. The results revealed no statistically significant differences between the model's and the professionals' evaluations. The authors highlighted the utility of this technology, considering the difficulty of detecting dental plaque—both by adults and children—due to the similar coloration between the plaque and the tooth surface. Consequently, the AI model holds promise as a healthcare tool and an educational resource, contributing to improving children's oral health [18].

Dental caries

A study applied Deep Learning as an AI model to analyze intraoral photographs of children, aiming to detect both cavitated and non-cavitated caries. Sensitivity and specificity tests yielded excellent results, with values ranging from 88.1% to 97.1%, demonstrating a high level of diagnostic accuracy [19].

Additionally, other researchers [20] have applied Machine Learning to diagnose Early Childhood Caries (ECC), a more aggressive form of dental caries. This approach considered key factors influencing the development of ECC, including clinical, behavioral, demographic, and laboratory data (such as fluoride concentration in household water, which serves as a crucial environmental protection factor). The authors emphasized that this model could be a valuable tool for identifying predisposition to the development of ECC [20].

Challenges and limitations

It is essential to emphasize that artificial intelligence tools have predominantly been applied and tested in controlled environments. In these settings, carefully selected data, such as high-quality photographs and radiographs, are used to train these tools. However, an important next step would be to expand these tests to outpatient settings, such as dental offices or hospitals, to evaluate whether the accuracy of AI tools is maintained in real-world, less controlled scenarios.

Other factors that merit attention include the cost of acquiring and implementing these tools in clinical environments and the learning curve required for pediatric dentists to understand and adapt to the technology, which will demand time and specialized training. Lastly, a significant challenge in using AI lies in the absence of ethical regulations addressing these tools. Healthcare professionals must safeguard the privacy and security of patient data, ensuring this technology's ethical and safe use.

Future perspectives

The evolution of artificial intelligence tools has made them increasingly popular among pediatric dentists. These tools facilitate faster and more accurate diagnoses of various pathologies and contribute to developing more individualized treatment plans. Additionally, the creation of AI-based tools focused on

childhood health education and the analysis of craniofacial development has the potential to positively impact the quality of life of children and their families.

Final considerations

Artificial intelligence is a computational model that is constantly evolving and is emerging as a promising tool in child health, including pediatric dentistry. It can potentially assist in the diagnosis of dental anomalies and cavities and in clarifying professionals' doubts, among other applications. In spite of advances in artificial intelligence bring significant contributions, clinical experience, combined with visual and verbal communication with patients and their families, remains an essential and irreplaceable element in health care. Although widely used, this technology should be considered an ally to support pediatric dentists in decision-making, diagnosis and planning of therapeutic procedures.

Declarations

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