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Research Paper

Artificial Intelligence in Pediatric Dentistry: Revolutionizing pediatric dental care

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ABSTRACT:
With the goal of mimicking the structure and biological evolution of the human brain, artificial intelligence was developed to enable computers to learn and manipulate their surroundings. Real-time analysis of vast volumes of data, or "big data," is made feasible by artificial intelligence, which produces predictions that can back up the choices made by the clinician. This situation may involve pain management, diagnosis, prognosis and treatment planning in dentistry. However, to take the added advantage of AI its basics and functioning needs to be known. Thus, this review article tries to summaries the understanding and clinical applications of AI in pediatric dentistry.

KEYWORDS: *artificial intelligence, machine learning, data processing, software, deep learning*

I. INTRODUCTION

Pediatric dentistry focuses on the oral health of children from infancy through adolescence. The specialty faces unique challenges such as managing young patients' anxiety, ensuring early detection of dental diseases, and promoting long-term oral health habits. AI, defined as the simulation of human intelligence by machines, has emerged as a valuable tool in addressing these challenges. This review provides a comprehensive overview of AI applications in pediatric dentistry.[1] To get into the depth of the mechanics of the AI, the main subsets of AI are explained here

1.1 Machine Learning (ML)

Machine learning is a subset of AI that enables computers to learn from data and make decisions or predictions without being explicitly programmed for every task. It relies on algorithms that identify patterns and improve their performance as they are exposed to more data.[2] Types of Machine Learning are as follows
Supervised Learning:
The algorithm is trained on a labeled dataset, which means that the input data is paired with the correct output.Examples: Caries detection from dental X-rays (with images labeled as "caries" or "no caries").
Unsupervised Learning:
The algorithm is given data without explicit labels and tries to find hidden patterns or clusters. Examples: Grouping patients based on oral health habits or identifying new patterns in dental disease progression.
Semi-supervised Learning:
Combines both labeled and unlabeled data. Examples: Enhancing small datasets of labeled X-rays with a larger pool of unlabeled ones.
Reinforcement Learning:
The system learns by interacting with an environment and receiving feedback in the form of rewards or penalties. Examples: AI systems learning to optimize dental clinic workflows through trial and error.
Key Algorithms used are Decision Trees, Random Forests, Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Logistic Regression.[3]

1.2 Deep Learning (DL):
Deep learning is a specialized subfield of machine learning that uses neural networks with many layers (hence "deep"). These networks are designed to mimic the human brain's structure, making them powerful in handling complex tasks like image and speech recognition. DL models use artificial neural networks (ANNs), particularly convolutional neural networks (CNNs) for images and recurrent neural networks (RNNs) for sequential data. Each layer in the network extracts progressively more abstract features from the input data.[4]
Structure of a Neural Network: Input Layer: Takes in the data (e.g., dental X-ray images). Hidden Layers: Multiple layers where each neuron performs mathematical operations to detect features (edges, shapes, patterns). Output Layer: Produces the final prediction (e.g., presence or absence of caries).[5]
Key Features include - Requires large amounts of data for training, Self-learns feature extraction, unlike traditional ML, which often needs manual feature engineering, computationally intensive (needs powerful hardware like GPUs).[6]
Some of the Popular Deep Learning Models are
CNNs (Convolutional Neural Networks): Best for image analysis (e.g., X-rays, intraoral photos).
RNNs (Recurrent Neural Networks): Used for analyzing time-series or sequential data (e.g., speech recognition).
GANs (Generative Adversarial Networks): Create synthetic medical images for training purposes.[7]

1.3 Machine Learning vs. Deep Learning:
ML: An algorithm trained on patient demographics and dental records predicts the likelihood of developing early childhood caries.
DL: A CNN processes bitewing radiographs to identify tiny carious lesions that are invisible to the naked eye, improving diagnostic accuracy.[8]

II. CURRENT APPLICATIONS:

1. Caries Detection and Risk Assessment:

AI-powered imaging tools, particularly those using convolutional neural networks (CNNs), enhance the detection of dental caries on radiographs. These tools offer high sensitivity and specificity, allowing early diagnosis that is critical in children to prevent progression.

2. Orthodontic Assessment:

AI assists in orthodontic diagnosis by automating cephalometric analysis, predicting growth patterns, and planning treatment. Machine learning models are increasingly used to predict outcomes and optimize interventions in growing children.

3. Behavior Prediction and Management:

AI models are being developed to predict a child's behavior in the dental chair based on prior visits and psychosocial factors. Virtual reality (VR) and AI-powered distraction tools also help in managing dental anxiety, a common barrier in pediatric dental care.

4. Treatment Planning and Monitoring:

AI enhances precision in treatment planning by integrating clinical data, radiographs, and patient history. In interceptive orthodontics and restorative procedures, AI helps in monitoring treatment progress and outcomes.

5. Teledentistry and Remote Monitoring:

AI facilitates remote consultations and monitoring through teledentistry platforms, which is particularly useful in underserved areas. Automated diagnostic support systems assist pediatric dentists in providing timely advice and care.[9]
Improved Diagnostic Accuracy: AI reduces human error and improves the accuracy and consistency of diagnoses. Enhanced Patient Experience: AI tools like virtual assistants and behavior management systems make dental visits less stressful for children. Efficiency: Automated systems save time for both dentists and patients, allowing for streamlined workflows. Preventive Care: AI aids in identifying at-risk patients early, promoting preventive strategies that can reduce disease burden. However, the challenges faced are as follows:
Data Privacy and Security: Protecting children's sensitive health data is paramount, and AI systems must comply with stringent privacy regulations. Limited Pediatric-Specific Data: Most AI models are trained on adult data, necessitating the development of pediatric-specific datasets for optimal performance. Cost and Accessibility: The integration of AI requires significant investment in technology and training, which may not be feasible for all practices.[10]

The future of AI in pediatric dentistry is promising, with ongoing research focusing on:

- Development of robust pediatric-specific AI models.
- Integration of AI with wearable devices to monitor oral health continuously.
- Advancements in AI-driven personalized preventive strategies.
- Expansion of AI capabilities in genetic and developmental dental anomalies.

III. DISCUSSION

AI systems can be used as an additional tool to help dentists provide the best possible dental care. As a result, we can anticipate increased accuracy in diagnosis and treatment planning, as well as improved treatment outcome prediction. Although deep learning mainly helps dentists diagnose, artificial intelligence (AI) promises to increase accuracy and precision in addition to the dentist's productivity. Every area of endodontics, including root fractures, periapical lesions, dental and root caries, stem cell viability, root canal system anatomy, and more, has benefited from AI applications.

AI model-based deep learning techniques to identify plaque-affected primary teeth, a first-of-its-kind study, are under research. You, W. et al, in their study, have successfully delivered AI systems (CNN framework) that were trained on 886 tooth photos to point out plaque accumulation. The model was compared with a trained pediatric dentist and achieved clinically acceptable performance levels. A research team aimed to make use of machine learning to build oral health assessment toolkits that was well equipped to predict the Children's Oral Health Status Index (COHSI) and Referral for Treatment Needs (RFTN). Liu et al, in their study, prepared a conceptual model (oral health item bank system) guided by the PROMIS framework. The oral health conceptual model was developed by an expert panel of pediatric dentists, general dentists, social scientists, and PROMIS experts.[11]

Artificial intelligence finds its use in diagnosing mesiodens by utilizing single deep learning models. Missing the presence of supernumerary teeth on panoramic radiographs is largely due to the screening performance of young and inexperienced dental personnel. Additionally, not many general dentists are versatile in diagnosing mixed dentition in children. With such disadvantages, CNN-based deep learning could provide extensive support in screening supernumerary teeth. Ahn, Y. et al. used a deep learning model to detect mesiodens in primary or mixed dentition, implying that this method could help clinicians with limited clinical experience accomplish more accurate and timely diagnoses. They made use of multiple deep learning models (Squeeze net, ResNet , ResNet, and Inception-ResNet-V2) with the simple correlation that deeper networks provide better accuracy for classifying mesiodens. Two deep learning models were notably faster in coming up with results compared to human evaluation, but their accuracy rate was slightly lower compared to human detection, which was significantly faster.[12]

Machine leaning-based models (XG Boat, random forest, and light GBM) were compared with a regression model for detecting early childhood caries in the study by Park, Y.H. et al. Though the team used three ML algorithms to come up with a prediction model and checked the results against a logistic regression model, no strong differences were observed. With its own set of limitations, this model helps in predicting the presence of ECC in preschool children with the aid of simple surveys and examinations. It is possible to utilize the model to determine which groups are at high risk for ECC, to carry out active preventive therapies, and to formulate policies on ECC prevention. Our goals are to increase the positive impacts of oral health education on the guardians of preschool children and to contribute to a decrease in the occurrence of ECC.[13]

Dental sealants are widely used as a protective coating on the chewing surfaces of molars to protect them from cavities. For every type of dental problem present, there are different interventions, including dental restorations, sealants, and prosthodontic measures. Convolutional neural networks (CNNs) are used profoundly to classify diagnostic images and objectify pathological findings' classification, but these networks must be trained exclusively to identify each of the problems. CNN is an integral deep learning algorithm that relies on heaps of data to assist dental practitioners. Additionally, dental sealants are the first go-to solution for many dental problems and can be easily identified as they are generally white in color. Hence, fine-tuning CNN to identify dental sealants seems to be the most logical solution.

A study by Zaborowicz, M. et al. used 3 deep neural network models for assessing the chronological age of kids and adolescents aged 4–15 years and showed that neural modeling algorithms may accurately determine metric age using proprietary teeth and bone indicators. Bunyarit, S.S. et al. used an artificial neural network (ANN) computational technique to create new dental maturity ratings based on Demirjian's scores in their study. They observed that the new dental maturity scores may determine the age of Malaysian Chinese children and adolescents.[14]

CNN algorithms were employed by Caliskan, S. et al.to identify and categorize submerged molars, and the researchers found that the approach was effective. Using tooth-numbering algorithms to identify the absence of a certain tooth germ requires further studies. Dental practitioners may benefit from the identification of missing tooth germs in order to determine more accurate treatment techniques. Kilic, M.C. et al. investigated a faster R-CNN inception v2 approach for recognizing and numbering primary teeth on pediatric panoramic radiographs, and they reported good sensitivity and accuracy scores. They noticed from their study that only primary teeth were detected and numbered, which also plays a valuable role in forensic identification.[15]

IV. CONCLUSION

AI is poised to revolutionize pediatric dentistry by enhancing diagnostic accuracy, improving treatment outcomes, and transforming patient experiences. While challenges remain, ongoing advancements and increasing integration of AI into dental education and practice are expected to make it an indispensable tool in pediatric dental care.

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