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Pediatric Dentistry and Artificial Intelligence – A Review

Abishek CB, Daya Srinivasan, Asvitha Babu, Pragadesh Ganesh

Department of Pedodontics and Preventive Dentistry, Chettinad Dental College and Research Institute, Kelambakkam, Chengalpattu, India.

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ABSTRACT:

Artificial intelligence (AI) has revolutionized pediatric dentistry by enhancing diagnostic accuracy, personalizing treatment, and improving patient management. AI seeks to address problems and acquire knowledge in ways that resemble human thought. The field of AI has experienced remarkable growth and development over the past two decades, partly due to advances in digital data collection, machine learning, and computing infrastructure. AI in dentistry is a rapidly expanding area of research and development and has the potential to significantly enhance patient care and drive major advances in healthcare. Advances in AI technology have the potential to offer significant healthcare benefits such as reducing postoperative complications, improving quality of life, and reducing the number of unnecessary procedures. AI algorithms analyze dental images and historical data, enabling the early detection of dental issues and customized care plans tailored to individual patient needs. Predictive analytics assists in identifying potential problems before they arise and promotes preventive care. Additionally, AI facilitates tele dentistry, allowing remote consultations that expand access for underserved populations. Behavioural management tools engage young patients through interactive applications, making dental visits less intimidating. Despite these advancements, challenges, such as data privacy, integration into practice, and the need for professional training must be addressed. Overall, AI holds significant promise for improving outcomes and promoting better oral health in children.

1. Introduction

Artificial Intelligence (AI) is becoming a revolutionary force in healthcare, including dentistry. This cutting-edge technology is changing the way dental professionals work, from diagnosis and treatment planning to boosting efficiency and precision in their daily tasks. In dentistry, AI's two main branches, Convolutional Neural Networks (CNN) and Machine Learning (ML), are widely used and hold great promise for the future of dental practice [1].

Convolutional Neural Networks (CNN), a part of deep learning, are particularly useful for handling complex and large dental images. CNNs are excellent at detecting patterns, structures, and anomalies in dental images, improving the efficiency and accuracy of diagnoses, especially in intricate cases involving X-rays and 3D scans. Machine Learning (ML) is another vital branch of AI in dentistry. ML models and algorithms enhance the cognitive abilities of dental professionals by analyzing patient data, medical records, and other pertinent information to make predictions and treatment recommendations. This aids in decision-making and improves the precision of treatment plans.

2. Application in Dentistry

Artificial Intelligence (AI) has swiftly advanced in dentistry, offering various applications in diagnosis, decision-making, treatment planning, and outcome prediction. AI has notably enhanced diagnostic accuracy and efficiency, easing dentists' workload. Increasingly, dentists rely on AI-powered computer programs for decision support, with these applications becoming more intelligent and reliable. However, the lack of standardized reporting and study design in dental AI research has prompted the proposal of the MI-CLAIM (Minimum Information about Clinical Artificial Intelligence Modelling) checklist to improve transparency and utility [2].

In dentistry, AI is used in several areas. It facilitates the early detection of dental caries, even in challenging cases, by analyzing radiographic and image data. AI algorithms can segment teeth, identify caries, and

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provide valuable predictions. AI also improves periodontitis diagnosis by addressing clinical evaluation limitations and aiding early detection. In orthodontics, AI assists in treatment planning and predicting outcomes, streamlining the decision-making process for orthodontists and patients.

AI has significantly advanced oral and maxillofacial pathology (OMFP), especially in detecting tumours and cancers using radiographic, microscopic, and ultrasonographic images. It also supports managing cleft lip and palate, aiding in risk prediction, diagnosis, orthopaedics, speech assessment, and surgery. In prosthodontics, AI has transformed crown design by generating custom designs for individual patients, enhancing efficiency in the restoration process. AI is also used in shade matching and predicting debonding in CAD/CAM restorations.

In pediatric dentistry, AI offers comprehensive preventive and therapeutic oral health care, consultation, and diagnosis for children from infancy to adulthood. AI helps resolve discrepancies in growth data analysis, and augmented reality (AR) methods have been developed to educate patients and families about growth disorders and treatments.

3. In Diagnosis and Treatment Planning

Artificial Intelligence (AI) has become a transformative technology in pediatric dentistry, providing tailored benefits for young patients. AI fundamentally changes how data is gathered, structured, and utilized, thereby enhancing the quality of care for children and adolescents. Its role in pediatric dental practices is pivotal, particularly in efficient data management. AI enables pediatric dentists to organize extensive medical records in a structured and centralized manner, ensuring rapid access to critical information about a child's dental history [1.3]. This capability supports the development of personalized and child-centered care plans.

Automation of routine tasks is another significant advantage of AI in pediatric dentistry, where the well-being of young patients is paramount. AI-driven chatbots streamline administrative tasks such as appointment scheduling, billing inquiries, and parent communications within dental practices. Moreover, AI aids in diagnosing common pediatric dental issues like cavities by analyzing X-rays and intraoral images, providing valuable decision support to dentists. By leveraging a child's dental and medical history, AI can recommend suitable treatments and preventive measures, considering the unique needs and sensitivities of children.

AI excels in educating young patients and parents alike, generating child-friendly educational materials that facilitate understanding of dental conditions, treatment options, and the importance of oral hygiene. This empowerment encourages active participation in oral health care and promotes good dental habits among children. Additionally, AI's predictive analytics identify trends and potential risk factors in pediatric oral health, enabling early intervention to prevent common dental issues like cavities and orthodontic problems.

Remote monitoring through AI-driven devices, such as smart toothbrushes, allows parents and dentists to closely monitor a child's oral health between visits by providing real-time data on brushing habits and oral hygiene. In research and development, AI accelerates advancements in pediatric dental care by analyzing data from child-specific clinical trials, facilitating the development of innovative treatments and preventive measures tailored to their needs [3].

Overall, AI fosters a collaborative approach in pediatric dental care by engaging both young patients and parents. By providing access to health data, age-appropriate educational resources, and decision support tools, AI ensures that children and their parents are well-informed partners in maintaining optimal oral health.

4. In Assessing Child's Oral Health

An advanced toolkit that utilizes Artificial Intelligence (AI) for assessing children's oral health comprehensively have been found recently. Central to this toolkit is a concise form (SF) aimed at helping parents evaluate their children's oral health status and determine the need for dental treatment. This innovative approach views health holistically, encompassing physical, mental, and social well-being. The toolkit's accuracy depends on several crucial factors. Firstly, the formulation of questions posed to parents and caregivers is critical, influencing the quality and relevance of the collected data. Additionally, the understanding of both children and parents is pivotal, ensuring that responses offer meaningful insights into the child's oral health [4,5]. The timing of the survey also plays a significant role, as the child's condition and

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parental responses may vary throughout the day. Hence, conducting the survey at an appropriate time is essential for obtaining reliable data.

Above all, the success of the toolkit hinges on the development of a robust machine learning algorithm. This algorithm must effectively process and analyze data from parents and caregivers, identifying patterns and correlations to accurately assess a child's oral health and treatment needs. Importantly, the toolkit is designed to complement rather than replace the role of dentists during dental examinations. While AI enhances data collection and analysis, the clinical expertise and judgment of dentists remain essential for diagnosing and treating specific oral health issues. Therefore, the AI-powered toolkit aims to collaborate with dental professionals, augmenting their ability to deliver comprehensive and personalized care for children's oral health. This collaborative approach ensures that children receive optimal care, with AI supporting and enhancing the diagnostic and treatment process.

5. In Detecting Deciduous Teeth

In the field of dental diagnostics, the identification and numbering of teeth using dental radiographs are fundamental tasks. Over time, various image-processing algorithms have been developed to achieve precise tooth classification and segmentation, tailored to different types of radiographs and employing diverse techniques. Automated dental identification system based on Bayesian classification has been pioneered, achieving high accuracy in tooth classification and numbering on bitewing radiographs [6].

Similarly, a tooth classification and numbering approach using image enhancement techniques has been created, demonstrating effectiveness even with challenging images. Recent advancements in tooth localization have increasingly utilized deep learning, particularly Convolutional Neural Networks (CNNs). A recent study developed a Faster R-CNN model with the Google Net Inception v2 architecture to detect and number deciduous teeth in pediatric panoramic radiographs, representing the first model to accurately detect and number each primary tooth in children, demonstrating high performance and significant potential for advancing pediatric dental diagnostics [7].

6. In Assessing Chronological Age

Researchers in the field of artificial intelligence (AI) have achieved noteworthy advancements in estimating the chronological age of children and adolescents aged 4 to 15. This ground-breaking approach employs digital pantomographic images and a novel set of tooth and bone parameters to create an innovative age assessment methodology. By integrating these parameters, the method demonstrates AI's potential to transform age estimation techniques [8]. The methodology effectively and accurately determines the chronological age of individuals within the specified age range, with significant implications for healthcare and forensic applications. The models are specifically designed for ages 4 to 15 and use dimensionless measurements based on proportions, enhancing their adaptability across various pantomographic imaging systems. Future research should explore deep learning methodologies, compare network features with the new models, and conduct sensitivity analyses of key variables for age determination. This commitment to innovation ensures that AI remains at the forefront of age assessment technology.

7. AI in Early Childhood caries

The incorporation of Artificial Intelligence (AI) in early childhood caries (ECC) exhibits considerable potential for precise prediction and diagnosis. Research studies have demonstrated that machine learning algorithms can accurately forecast ECC and caries risk across diverse populations, displaying high levels of accuracy, sensitivity, specificity, and area under the curve (AUC) values. The implementation of these tools is crucial for initiating targeted preventive measures and optimizing clinical decision-making in dental caries management.

A deep learning-based screening system has been developed to detect ectopic eruption of maxillary permanent first molars, potentially enhancing clinical diagnosis and management in pediatric patients. Similarly, machine learning models have been created to predict ECC, effectively identifying high-risk groups among children aged 1 to 5, suggesting the feasibility of AI in enhancing oral hygiene education and dental care [9,10].

For teenagers, a caries risk prediction model has been developed that considers environmental and genetic

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factors with high discrimination ability, aiding early identification in high-caries-rate populations. An automated machine learning (AutoML) system has been designed to classify children based on their ECC status, showing effectiveness in resource-limited settings when including age and parent-reported oral health status.

Machine learning algorithms have been employed to predict tooth decay by analyzing oral bacterial communities and incorporating demographic and environmental factors to improve prediction accuracy. These multifactorial models offer potential for personalized preventive interventions targeting specific bacterial species and individual risk factors.

8. AI in Pediatric Restorative Dentistry

AI is rapidly transforming pediatric restorative dentistry, offering numerous benefits such as increased efficiency, precision, and improved aesthetics. Central to this transformation is computer-aided design and computer-aided manufacturing (CAD/CAM) technology, which has become essential in restorative procedures for children. Powered by AI, CAD/CAM technology allows dental professionals to design and create restorations with remarkable accuracy and speed [11].

One of the main advantages of AI-enabled CAD/CAM technology in pediatric restorative dentistry is the significant reduction in treatment time. Young children often struggle with lengthy dental procedures, and shorter treatment sessions are better tolerated. AI-driven CAD/CAM systems streamline the restoration process, enabling faster and more efficient treatments [12]. Additionally, this technology helps create custom-made restorations that perfectly fit a child's dental anatomy, enhancing treatment outcomes, reducing discomfort, and minimizing the need for multiple visits.

Moreover, AI, particularly through deep learning, represents a transformative subset of machine learning. Deep learning models can extract complex and subtle patterns from dental images and radiographs. These models can identify essential features such as lines, edges, corners, and larger patterns in a hierarchical manner. In pediatric restorative dentistry, this capability is especially promising for conservative caries excavation and precise tooth preparation for restorations.

9. AI in Detection of Plaque

AI-based deep learning techniques for identifying plaque-affected primary teeth is a major leap forward in pediatric dentistry was implemented. Using a Convolutional Neural Network (CNN) framework, their research is poised to transform plaque detection and management in primary teeth [13]. This innovative AI model has been trained on an extensive dataset of 886 tooth photos, enabling it to accurately detect and identify plaque accumulation.

A significant advantage of AI in plaque detection is its ability to rapidly analyze a large number of tooth images, saving valuable clinical time and allowing for more frequent and thorough examinations. Early detection and monitoring of plaque progression enable the implementation of effective preventive measures. Additionally, the continuous monitoring of plaque and dental health is a potential area for further expansion. AI can track changes in plaque status over time, allowing dentists to provide personalized recommendations for improved oral hygiene and preventive care

10. AI in Endodontics and Orthodontics

The integration of Augmented Reality (AR) into dentistry is heralding a new era of improved visualization and patient engagement. This cutting-edge approach leverages data from various diagnostic imaging methods, such as periapical radiographs, CT scans, and MRI scans, to provide dentists with valuable real-time information, enhancing both the diagnostic and treatment processes [14].

AR technology in dentistry offers numerous benefits. It allows dentists to overlay detailed anatomical structures, like root canals, directly onto the patient’s oral cavity in real-time, eliminating the need to constantly reference separate screens. This enhances treatment precision, maintains the dentist’s focus on the procedure, and leads to better treatment outcomes with reduced risks. Additionally, real-time, three-dimensional visualizations on the patient’s body improve communication between dental practitioners and patients, helping them better understand dental conditions, treatment options, and expected results.

Orthodontics, in particular, has significantly benefited from the combination of AI-driven appliances and AR technology. Personalized AI-driven appliances, designed

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to be more appealing to younger patients, are becoming increasingly popular. These appliances are customized to meet individual needs, making orthodontic treatment more engaging [15]. AI algorithms combined with AR technology create personalized treatment plans and appliances, enhancing efficiency and patient-centered care. AI ensures precision and predictability in orthodontic treatment planning and appliance design by analyzing extensive datasets and recommending tailored treatment strategies. AR complements this by allowing orthodontists to visualize expected treatment outcomes and communicate them effectively to patients. It also supports remote monitoring, enabling patients to use AR-powered apps to capture images of their teeth, allowing orthodontists to assess progress and provide remote guidance, thus reducing the need for frequent in-person visits [16].

11. AI in Local Anesthesia

AI technology can significantly improve the quality of sonographic images used in guiding local anesthesia procedures. By processing and enhancing images, AI algorithms can increase the clarity and visibility of anatomical structures, making it easier for medical professionals to accurately identify the target area for anesthesia. Enhanced image quality results in more precise injections, reducing the likelihood of complications [17,18]. The integration of AI in local anesthesia not only aids medical professionals but also enhances the overall patient experience. AI-guided procedures tend to be more accurate, leading to less discomfort, quicker recovery times, and fewer complications. Consequently, patients can feel more assured about the safety and effectiveness of local anesthesia, fostering a more positive view of pediatric dentistry procedures.

12. Prediction Models

Genetic Algorithms (GA) and Artificial Neural Networks (ANN) have proven useful in predicting and interpreting biological activities, such as dental caries. With a properly established training database representing values for a specific population, GA and ANN can be utilized to predict the sizes of unerupted teeth. In one study, an artificial neural network model was developed to predict toothache based on factors like toothbrushing time, daily toothbrushing frequency, toothbrush replacement patterns, use of dental floss, scaling, and other epigenetic factors such as diet and exercise [19]. This resulted in a highly accurate toothache predictive model that identified oral hygiene, proper eating habits, and stress prevention as crucial factors in preventing toothaches.

13. Advantages and Challenges

AI-driven systems can analyze extensive datasets of pediatric oral health information, enabling early and accurate diagnoses of dental conditions, which leads to timely interventions and improved treatment outcomes. These AI tools aid dental professionals by streamlining routine tasks like image analysis, patient management, and appointment scheduling, thereby enhancing overall practice efficiency [22]. Additionally, AI can improve patient engagement through interactive educational tools and personalized treatment plans, allowing children and their parents to better understand their oral health conditions and become active participants in their care.

AI can also predict and identify potential oral health issues, facilitating proactive preventive measures—crucial in pediatric dentistry where early intervention is key. It enables precise treatment planning and customized interventions, ensuring that pediatric patients receive care tailored to their unique needs. However, using AI in pediatric dentistry necessitates the collection and storage of sensitive patient data, posing significant challenges in maintaining patient privacy and data security, especially for minors. Dental professionals must undergo training to effectively use AI tools, which can be time-consuming and require adaptation to new workflows. Resistance to adopting AI technology can also hinder its effective utilization.

AI solutions often involves significant upfront costs for equipment, software, and training, which can be challenging for small pediatric dental practices to afford. Moreover, pediatric dentistry involves the care of minors, raising ethical concerns about informed consent, patient autonomy, and the role of AI in decision-making for young patients. AI systems also require continuous updates and maintenance to remain effective and compliant with changing regulations, adding to the operational workload of dental practices.

Implementing Artificial Intelligence (AI) in pediatric dentistry holds significant promise but also presents several notable challenges. A primary concern is the

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necessity for specialized and extensive datasets tailored to the unique dental and oral health needs of children [20]. Gathering such data, especially from a pediatric population, can be both time-consuming and resource-intensive. Additionally, ensuring the ethical use of AI in pediatrics, maintaining patient privacy, and obtaining informed consent from parents or guardians are critical challenges. The integration of AI into clinical workflows requires a shift from traditional practices, necessitating those dental professionals adapt to and trust AI-driven tools for diagnosis and treatment planning. Furthermore, ongoing updates and maintenance of AI systems, along with ensuring compliance with evolving regulations, can be cumbersome [21]. Despite these challenges, AI's potential benefits in pediatric dentistry, such as improved diagnostics and more efficient treatments, make it a field of significant interest and ongoing development. Pediatric dentists and researchers must collaborate to address these challenges and fully harness AI's potential in promoting the oral health and well-being of young patients.

14. Conclusion

The integration of artificial intelligence (AI) and machine learning is gaining traction in various fields, including pediatric dentistry. AI has the potential to address deficiencies in traditional dental care practices that have been criticized. In dentistry, AI is becoming a valuable tool for clinicians, improving patient care and streamlining complex procedures by delivering consistent results. However, it's important to acknowledge that AI's underlying mechanisms can be complex, and the initial setup costs are high. While AI in pediatric dentistry is still in its early stages, it is advancing quickly through ongoing research and development. Despite these technological advancements, it is crucial to recognize that AI can never fully replace the essential role of human professionals in delivering quality healthcare.

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