

AI-DRIVEN DECISION SUPPORT SYSTEMS IN PAEDIATRIC DENTISTRY

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ABSTRACT

Artificial intelligence (AI) is transforming paediatric dentistry by enhancing diagnostic accuracy, streamlining treatment planning, and improving behaviour management. 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. The ultimate ability to improve patient care and make precise diagnoses of illnesses has revolutionized the world of healthcare.

AI algorithms analyse 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. Paediatric dentistry benefits from various applications of artificial intelligence, and the aim of this systematic review was to evaluate the effectiveness of AI as a diagnostic tool in Pediatric Dentistry.

Keywords: artificial intelligence, behaviour management, paediatric dentistry

INTRODUCTION

Artificial intelligence, also referred to as the “fourth industrial revolution,” leverages computer systems to mimic human-like rational analysis, judgement and intelligent behaviour.¹ Artificial intelligence (AI) is becoming an important part of our lives owing to increased data availability and improved power of computing.² AI methods have shown remarkable aptitudes and capacities for detecting meaningful data patterns, which has prompted extensive experimentation with these methods as tools in clinical trials, notably to support every stage of diagnosis, treatment and prognosis.¹ 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.³ The development of AI in health care has been related to the development of AI programs intended to help the clinician to formulate a diagnosis, make therapeutic decisions, and predict the outcome.⁴ 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.³

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 is a subset of AI that uses statistical models and algorithms to identify patterns within large datasets, enabling predictive analysis and decision-making based on the data.⁵ 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.³

AI is feasible to improve people's health at lower costs, provide customized, preventative, and predictive dentistry, and integrate healthcare for everyone. Above all, AI has the potential to increase the standards of

dental care, fine-tune the accuracy and effectiveness of diagnosis, come up with better visuals for treatment, simulate results, and predict oral diseases and health and accuracy of diagnoses.⁶ The various 4D goggles, movies, animations and virtual reality based games can be used as a behaviour modification aid effectively for pediatric patients.⁷ Dental age estimation represents another important pediatric application.⁸ AI technology has been widely applied in the field of medical sciences and has demonstrated excellent performance in a variety of tasks related to patient care, including disease diagnoses and identification of a patient's risk for developing a disease, among many other tasks.⁶ Artificial intelligence (AI) powered chat bots are the virtual interfaces that replicate human communication through audio, text, and visual cues with users.⁹ In paediatric dentistry, AI has many promising applications that might change paediatric practice in the coming years. The integration of AI must therefore be done purposefully, to protect providers and patients from harm.¹⁰ Thus, the aim of this review was to explore the multitudinous possibilities of using AI in paediatric dentistry.⁶

APPLICATIONS OF AI IN PAEDIATRIC DENTISTRY

Artificial intelligence (AI) is transforming healthcare, with growing impact in pediatric dentistry. Applications include diagnostic support, caries risk assessment, behavior management, treatment planning, and preventive care. By combining data-driven models with clinical expertise, AI enhances diagnostic accuracy, efficiency, and overall quality of care for children. The following sections highlight its main applications in pediatric dentistry.¹¹

1.) 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.³ Using AI, the computer can guide the dentist as they

create a digital impression, optimize the final scan by eliminating the unwanted frames during scanning, automatically detect the margins of the preparations and develop a restoration design that imitate the anatomy of the lost tooth structure.¹² AI-driven chatbots streamline administrative tasks such as appointment scheduling, billing inquiries, and parent communications within dental practices.³ AI is highly effective in analyzing dental images such as Xrays, photos, and 3D scans. Algorithms can be trained to detect cavities, monitor tooth growth, and predict orthodontic issues early on and this advanced detection means that Paediatric dentists can intervene sooner, often leading to less invasive treatments.¹³ 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. 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.³

2.) TREATMENT PERSONALIZATION:

AI can help create personalized treatment plans for children including aligning orthodontic treatments using clear aligners that are custom-fitted using 3D models of the child's teeth or predicting how a child's teeth will move over time, making treatments more efficient and reducing the number of dental visits required.¹³

3.) DENTAL PLAQUE DETECTION:

Dental plaque consists of bacterial masses on tooth surfaces; these masses usually occur at the gingival margin and in the interproximal areas.¹⁴ Dental plaque, a complex bacterial biofilm, often presents challenges in detection, even for experienced dental practitioners. Traditional methods of plaque assessment are frequently regarded as either cumbersome or expensive, although the introduction of digital imaging has contributed to improvements in plaque quantification and monitoring. In an experimental study, Young et al. trained a Convolutional Neural Network (CNN) with 886 tooth images, demonstrating diagnostic performance comparable to that of a Paediatric Dentist. While factors such as image quality

and interpretability remain limitations, these AI-based tools highlight the potential to assist not only clinicians but also parents in tracking and supporting children's oral hygiene practices.¹¹

4.) ECC DETECTION:

Early childhood caries (ECC) is a common complex disease that persists as a clinical and public health problem, despite major advances in the science and practice of dentistry.¹⁵ 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.³

Early Childhood Caries (ECC) is a multifactorial condition shaped by genetics, behavior, and environment. Zaorska et al. used artificial neural networks (ANNs) with SNP data to predict caries susceptibility, highlighting preventive potential. Machine learning (ML) models such as XG Boost, Random Forest, and Light GBM showed accuracy comparable to logistic regression, supporting their role in ECC risk screening and preventive planning.¹¹

5.) SUPERNUMERARY TEETH DETECTION:

Panoramic radiographic screenings conducted by less experienced or younger dental practitioners may occasionally overlook the presence of supernumerary teeth. Despite these limitations, convolutional neural network (CNN)-based deep learning models have shown considerable promise in assisting with their detection. Ahn et al. demonstrated the application of a deep learning approach for identifying mesiodens in primary and mixed dentitions, suggesting that such models can enhance diagnostic accuracy and efficiency, particularly for less experienced clinicians.⁹ Additionally, Kuwada et al. reported on two deep learning algorithms designed to detect impacted supernumerary teeth in the maxillary region using panoramic radiographs. Nonetheless, challenges in

precise identification persist, particularly in cases involving incomplete eruption of permanent teeth.¹

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.³

7.) 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. 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.³

8.) 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. Recent advancements in tooth localization have increasingly utilized deep learning, particularly Convolutional Neural Networks (CNNs).³

9.) AI ASSISTED CHILD BEHAVIOUR GUIDANCE:

AI offers considerable promise in the domain of behaviour management for paediatric dental patients by enabling individualized support and engagement strategies. Through personalized learning approaches, AI systems can adapt to each child's cognitive style and developmental needs, which is particularly beneficial for children with learning disabilities. The incorporation of gamification elements such as reward

systems, points, and progression levels further enhances motivation and transforms the dental experience into a more positive and enjoyable one.¹¹

10.) AI IN LOCAL ANAESTHESIA:

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. The integration of AI in local anesthesia not only aids medical professionals but also enhances the overall patient experience.

Consequently, patients can feel more assured about the safety and effectiveness of local anesthesia, fostering a more positive view of paediatric dentistry procedures.³

ADVANTAGES AND CHALLENGES:

AI-driven systems can analyze extensive datasets of paediatric 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. AI can also predict and identify potential oral health issues, facilitating proactive preventive measures crucial in paediatric dentistry where early intervention is key. It enables precise treatment planning and customized interventions, ensuring that paediatric patients receive care tailored to their unique needs. However, using AI in paediatric 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.

AI solutions often involves significant upfront costs for equipment, software, and training, which can be challenging for small paediatric dental practices to afford. Moreover, paediatric 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 paediatric dentistry holds significant promise but also presents several notable challenges. A primary concern is the necessity for specialized and extensive datasets tailored to the unique dental and oral health needs of children. Gathering such data, especially from a paediatric population, can be both time-consuming and resource-intensive. Additionally, ensuring the ethical use of AI in paediatrics, maintaining patient privacy, and obtaining informed consent from parents or guardians are critical challenges.³

CONCLUSION:

The integration of artificial intelligence (AI) and machine learning is gaining traction in various fields, including paediatric 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 paediatric 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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