The Limitless Potential of Artificial Intelligence in Paediatric Dentistry

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ABSTRACT

Background: The integration of artificial intelligence (AI) in paediatric dentistry has grown significantly, offering new possibilities for diagnostics, treatment planning, and patient care. AI's capacity to handle large datasets and generate accurate predictions is transforming dental practice.

Objective: This narrative review explores the potential applications of AI in paediatric dentistry, focusing on its benefits, challenges, and future implications.

Methods: A comprehensive literature review was conducted using databases such as PubMed, Scopus, and Web of Science. Relevant studies published between 2000 and 2023 were selected based on predefined inclusion criteria. The quality of the studies was appraised using the Joanna Briggs Institute tools.

Results: AI applications, including image analysis, diagnosis, treatment planning, and patient management, show significant promise in paediatric dentistry. AI-powered tools can improve diagnostic accuracy, reduce treatment inconsistencies, and enhance patient outcomes. However, challenges related to costs, complexity, and ethical concerns remain.

Conclusion: AI will not replace paediatric dentists but will serve as a valuable tool to support clinical decision-making. Future research should focus on overcoming current limitations and ensuring safe integration into clinical practice.

INTRODUCTION

The advancement of artificial intelligence has made it possible to evaluate enormous volumes of data, receive trustworthy information, and make decisions more efficiently. Artificial intelligence, sometimes known as computerized thinking, has advanced significantly in recent years. With recent progress in figure framework, digital information security (1-4), and AI technology, artificial intelligence applications have expanded into areas once thought to be the sole domain of human specialists. One such area is the understanding of patient needs, where AI holds the potential to significantly improve healthcare services, including the field of dentistry. Numerous applications of dental AI are currently under investigation, ranging from identifying normal and abnormal features to predicting treatment outcomes and diagnosing various illnesses. This overview explores the potential applications of artificial intelligence in paediatric dentistry (5-7).

Artificial intelligence, often referred to as electronic reasoning, allows machines to make decisions based on data that humans can critically analyze. An artificial neural network (ANN) is a computational model designed to mimic the workings of the human brain (7-13). Most neural networks consist of an input layer that transmits information through one or more hidden layers to produce an output. The hidden layers in this complex structure are composed of neurons, and trained artificial neural networks are capable of identifying useful patterns in raw data to achieve the desired outcome. These virtual computations improve both the precision and efficacy of dental diagnoses and are capable of simulating complex treatment protocols thanks to their robust data processing abilities (1-4). Applications of artificial intelligence in radiology and computer-aided dental procedures have become increasingly prevalent, reshaping the landscape of dental care over time. According to recent studies (5-8), automating healthcare services is critical for reducing treatment inconsistencies and enhancing the quality of care. This notion is supported by evidence demonstrating that paediatric dental professionals often experience significant physical and mental stress from long working hours while caring for children. This stress can potentially compromise the quality of care provided (7).

While advancements in AI may not seem to have a broad effect on all areas of dentistry (9-12), certain fields, particularly those involving specific diagnostic systems and image-based software for disease detection, are poised to benefit significantly (13-15). Some of the key applications of AI can be seen in automated systems designed to detect oral characteristics by analysing images (16-19). Several advancements in mechanical technology have made it feasible to offer automated dental services. Artificial intelligence

approaches are already accepted in several dental disciplines as part of the expanding paradigm of automated dentistry (17).

Historically, Plato proposed a fundamental theory of the mind's capability around 400 BC. While his conceptualization of artificial intelligence was novel for the human experience, Aristotle rejected the idea that machines could replace humans during emergencies. However, Aristotle's logic laid the groundwork for reasoning that could, in a way, substitute for human mental processes (5). Ramon Llull, a Catalan author, preacher, and scholar from the fourteenth century, developed logical rules intended to reconstruct human thought (6). Fast forward to the mid-20th century, when English mathematician Alan Turing designed a machine in 1950 that could decode complex messages. By 1955, John McCarthy coined the term "artificial intelligence," marking the formal recognition of AI as a distinct field.

MATERIAL AND METHODS

This narrative review was designed to explore the potential applications of artificial intelligence in paediatric dentistry by synthesizing existing research on the topic. An evidence search strategy was employed to identify relevant studies through a comprehensive review of scientific databases, including PubMed, Scopus, and Web of Science. The search was conducted using keywords such as "artificial intelligence," "AI," "paediatric dentistry," and "dental diagnostics" in various combinations. Studies published between 2000 and 2023 were considered, and only those written in English were included. The selection process involved screening titles and abstracts for relevance, followed by a full-text review to determine eligibility based on predefined inclusion and exclusion criteria (18).

Quality appraisal was conducted using the Joanna Briggs Institute Critical Appraisal Tools to assess the methodological quality of the included studies. Each study was evaluated based on criteria such as clarity of research questions, appropriateness of methodology, and rigor of data analysis. A synthesis of the selected studies was performed by identifying recurring themes, comparing findings, and summarizing the outcomes to draw meaningful conclusions about the role of AI in paediatric dentistry. All results were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, where applicable.

FINDINGS AND DISCUSSION

Applications of Artificial Intelligence

Computer intelligence is driven by human perception, allowing us to comprehend new concepts, adapt to changing circumstances, and learn from mistakes. It includes mental attributes such as thinking, decision-making, and the capacity to absorb large amounts of information. Human expertise can mediate various situations, and artificial intelligence benefits from this by growing more observant and adaptable. One of the most promising areas for future dental research is deep learning, which provides models derived from large datasets and aids in developing dynamic, robust networks with improved performance. Several potential applications of artificial intelligence in paediatric dentistry are expected to fundamentally alter social paediatric practice (10, 12, 13). AI is a valuable tool, clinical aid, and a means of identity verification in legal contexts (22). As larger datasets become available, AI algorithms will become increasingly sophisticated. For example, an AI framework successfully identified and counted baby teeth using comprehensive radiographs. Early orthodontic tooth development is also benefiting from specialized AI-driven technology, particularly well-suited for use with children. It is widely known that AI-enabled restorative dentistry, also referred to as computer-aided design and manufacturing (CADM), will accelerate the process and improve the aesthetics of paediatric restorations. The use of AI-powered pain-relief devices represents a more advanced and effective method for practicing pedodontics without injections. Moreover, AI can enhance the educational and learning experiences of students and patients through simulated environments (7).

Future innovations in dental software hold the potential to revolutionize the field. Dental professionals are currently gaining experience in clinical decision-making with the aid of software, and they will continue to develop and integrate AI algorithms to assist in selecting the most appropriate treatments for their patients. With significant advancements in clinical data and AI-enhanced healthcare, dentistry is on the verge of entering a new digital era. These advanced algorithms can analyse patient data, generate relevant insights, and offer efficient strategies for making therapeutic and conclusive recommendations. By collecting patient data, especially genetic information, researchers will gain a deeper understanding of each patient's unique healthcare needs. If AI programs are granted access to such data, they will be able to offer therapists the best available options for success, as well as alternative treatments. AI-based algorithms not only analyse clinical data but also help dental professionals better manage oral health issues. In 2019, researchers developed an AI system capable of comparing healthy cells to oral disease cells with precision, aiding in the understanding of disease progression and predicting survival likelihood. In some cases, neural networks are already being used to detect dental decay and periodontal disease from radiographs, and it is likely that these methods will become increasingly popular soon (17).

An electric toothbrush not only helps users brush their teeth more effectively but also provides engaging activities for children, encouraging good oral hygiene habits. Smart toothbrushes are equipped with multiple sensors in the handle, offering instant feedback on factors such as brushing pressure and technique. This information is transmitted through a companion app, helping users improve their brushing habits (18). 3D printing has gained significant attention in the healthcare industry for its ability to produce drugs, prosthetics, and even organ replicas. Its relevance was further underscored during the COVID-19 pandemic when facilities had to bypass supply chains to meet rising demands. Computer-aided design (CAD) and computer-aided manufacturing (CAM), including 3D printing, are revolutionizing dental practices by transforming them into more

efficient and cost-effective laboratories. Traditionally, dentists could not create permanent crowns without first molding the patient's tooth and making a temporary crown. With CAD and camera technology, the tooth can be prepared for the crown digitally, and a bitmap image is captured. This image is then used to manufacture the crown in the office using specialized machinery. Compared to conventional methods, 3D printers can more quickly and accurately produce orthodontic models, surgical implants, aligners, retainers, and other dental equipment. This reduces errors and staffing costs, streamlines processes, and improves both the time and cost efficiency of the technology (13).

Augmented reality (AR) is increasingly being utilized in dentistry to allow patients to preview their post-treatment results. With AR applications developed by companies like SmartTek and Kapanu, patients can use their smartphones or tablets to overlay virtual images of their enhanced teeth before undergoing cosmetic or reconstructive procedures. This allows both patients and professionals to adjust dental features, such as spacing and alignment, before entering the operating room (29).

Benefits of Developing Artificial Intelligence

Artificial intelligence enhances both diagnostic and treatment planning efficiency, making processes quicker and requiring less effort. It can standardize programs and streamline operations, which leads to faster outcomes and reduced time investment (1). Specifically in diagnostic imaging and pathology, the use of artificial neural networks (ANNs) and convolutional neural networks (CNNs) has revolutionized diagnostic accuracy and visualizations. Applications of generative adversarial networks for image correction, classification, and disease or injury detection are also emerging. From a patient's perspective, AI-based tools have the potential to address long-standing limitations in conventional dentistry. The dental profession, particularly dental academia, must ensure that AI reduces costs while benefiting patients, providers, and society at large (23). Dental professionals are increasingly using AI to help deliver better patient care by providing predictable outcomes for complex treatments (22-24).

Questions Relating to Artificial Intelligence

One major obstacle to AI is the complexity of the systems. Implementing AI solutions can be costly, and achieving accuracy in rare diseases or conditions is challenging due to the vast amount of data required for training and precision (1). As dental medicine explores the potential benefits of digital data for treatment and research, digitalization also raises ethical concerns in the biomedical context (24). These concerns include data privacy, consent, and the accuracy of AI-driven decisions in patient care.

CONCLUSION

While studies have demonstrated that artificial intelligence can be used in dentistry, these systems will not replace dental professionals in the near future. Instead, AI should be considered a valuable tool to assist dentists and medical professionals. For AI to effectively support dental care and enable patients to make informed decisions, it is crucial to organize and regulate these systems in a safe and controlled manner (17). Most institutions are currently unprepared for the integration of AI into dentistry and education. Blended reality, a new approach combining elements of virtual reality, augmented reality, and generative AI, presents an innovative method of enhancing learning and strategic planning by overlaying data onto virtual environments (32). The development of numerous AI systems for various dental disciplines, along with positive initial results, suggests that AI will play a significant role in the future of healthcare. Advancements in AI, or "man-made brainpower," have the potential to be highly beneficial for oral healthcare professionals (8). Despite the impressive benefits of AI in dental and oral hygiene applications, biological systems and education encompass much more. Complex systems and AI cannot fully replace human expertise. Humans possess critical thinking skills, proficiency, and the ability to make nuanced decisions that AI cannot replicate.

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