Submitted: 20 July, 2023 Accepted: 18 September, 2023 Published: 03 May, 2024 DOI:10.22514/jocpd.2024.055

MINI-REVIEW

Journal of Clinical Pediatric Dentistry

Role of artificial intelligence in behavior management of pediatric dental patients—a mini review

Sonu Acharya[1,*], Brinda S. Godhi[2], Vrinda Saxena[3], Ali A Assiry[4], Noura Abdulaziz Alessa[5], Ali Azhar Dawasaz[6], Abdullah Alqarni[7], Mohmed Isaqali Karobari[8,*]

[1]Pediatric and Preventive Dentistry, Institute of Dental Sciences, Siksha 'O'Anusandhan (Deemed to be) University, 751016 Bhubaneswar, India
[2]Department of Pediatric and Preventive Dentistry, JSS Dental College, JSS Academy of Higher Education and research, 570015 Mysuru, India
[3]Department of Public Health Dentistry, Government Dental College, 452001 Indore, India
[4]Preventive Dental Science Department, Faculty of Dentistry, Najran University, 1988 Najran, Kingdom of Saudi Arabia
[5]Department of pediatric dentistry and orthodontics, dental college, King Saud University, 11454 Riyadh, Kingdom of Saudi Arabia
[6]Department of diagnostic dental sciences, College of dentistry, King Khalid University, 61421 Abha, Kingdom of Saudi Arabia
[7]Department of Diagnostics Dental Sciences and Oral Biology, College of Dentistry, King Khalid University, 61421 Abha, Kingdom of Saudi Arabia
[8]Dental Research Unit, Center for Global Health Research, Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai 600077, Tamil Nadu, India

***Correspondence:** dr.isaq@gmail.com (Mohmed Isaqali Karobari); sonuacharya@soa.ac.in (Sonu Acharya)

Abstract

The influence of behavioral science on various organizations has been experiencing remarkable growth worldwide. With the integration of recent technological advancements, behavioral science's impact has expanded into diverse fields such as finance and policy. The term "artificial intelligence" (AI) has become increasingly prevalent, but it is essential to provide clarity before proceeding. AI pertains to the theory and creation of systems capable of executing tasks that typically necessitate human intelligence. Integrating artificial intelligence (AI) in pediatric dentistry has emerged as a promising avenue to enhance patient care, improve diagnostic accuracy, streamline treatment planning, and augment patient engagement. AI-driven tools such as image analysis, natural language processing, and machine learning algorithms assist in early caries detection, orthodontic treatment planning, behavior management, and personalized oral hygiene education for pediatric patients. This paper presents an overview of AI's applications in pediatric dentistry, particularly behavior management, highlighting its potential to revolutionize traditional pediatric dental practices.

Keywords

Artificial intelligence; Behavior; Children; Management; New technology; Pediatric dentistry

1. Introduction

"Artificial Intelligence" was coined during the Dartmouth Conference in 1956 [1]. This conference brought together leading researchers in the field and laid the foundation for AI as a distinct study area. Artificial Intelligence (AI) refers to developing computer systems performing tasks that typically require human intelligence. It is a multidisciplinary field that combines computer science, mathematics, psychology, and other domains to create intelligent machines capable of simulating human thinking and decision-making processes [2]. AI systems can analyze extensive amounts of data, recognize patterns, make predictions, and learn from experience or decisions based on that information. They can also interact with humans through natural language processing, speech recognition, and computer vision.

AI has two primary types: narrow AI and general AI. Narrow AI, often called weak AI, is designed to excel in specific tasks, such as language translation, image recognition or autonomous driving. It operates within well-defined boundaries and focuses on optimizing performance within those limitations. Conversely, artificial general intelligence, often referred to as strong AI, refers to AI systems with the capacity to understand, learn, and utilize knowledge across various tasks similar to human intelligence. Despite being a theoretical concept, general AI remains an active area of research and discovery [3].

AI has experienced significant progress thanks to algorithm advancements, enhanced computing capabilities, and the abundance of extensive datasets. It has facilitated its implementation across numerous industries, such as healthcare, finance, transportation, manufacturing and entertainment. Healthcare

benefits from AI in disease diagnosis, fraud detection aids finance, autonomous vehicles utilize AI for navigation, production processes are optimized through AI algorithms, and AI systems generate personalized user recommendations [4, 5]. However, the development of AI also raises ethical concerns, such as privacy, bias, job displacement, and the potential for misuse. As AI progresses, it becomes crucial to prioritize its responsible and ethical implementation, taking into account its societal impact and implications. AI stands as a groundbreaking technology capable of transforming various industries, healthcare being a prime example. Its capacity to process vast amounts of data, learn patterns, and make informed decisions has led to its integration into various medical fields, including dentistry. In recent years, AI has garnered attention in pediatric dentistry, offering a range of possibilities to enhance patient care and clinical practices. While AI presents exciting opportunities, it also discusses its implications, limitations, and ethical considerations [6]. AI has shown promise in medical imaging analysis, diagnosis, treatment planning and patient management in healthcare. In pediatric dentistry, these capabilities open doors to improved detection of dental issues, personalized treatment plans, and innovative methods for engaging young patients. For instance, AI-driven image analysis can aid in identifying early signs of dental caries and abnormalities, facilitating timely intervention and prevention. Furthermore, AI-based algorithms can assist in predicting treatment outcomes, helping practitioners make informed decisions about orthodontic interventions or restorative procedures [7].

However, concerns about AI's reliability, transparency, and ethical usage have emerged alongside these potential benefits. The "black-box" nature of specific AI algorithms, where their decision-making processes are not easily understandable by humans, raises questions about how much trust should be given to their recommendations. Data privacy and security concerns arise when AI systems process and store patient information. Ethical considerations related to bias, accountability, and the potential for AI to replace human interactions also come into play.

2. Role of AI in dentistry

Artificial intelligence (AI) has significantly advanced in various industries, including dentistry. AI technology has been leveraged to improve diagnostic processes, treatment planning, patient care, and dental research [8]. AI has significantly advanced dentistry, transforming various aspects of oral healthcare [9]. In dentistry, AI technology improves diagnostics, treatment planning, patient care, and oral health education [10, 11]. AI algorithms can more accurately analyze dental images, namely X-rays and CT scans, to detect abnormalities, cavities, and other oral conditions. It aids in early detection and precise treatment planning. AI-powered systems also assist in designing and fabricating dental restorations like crowns and bridges, optimizing fit and aesthetics [12, 13]. Virtual treatment planning using AI simulates orthodontic outcomes, aiding decision-making. Additionally, AI chatbots and virtual assistants enhance patient education, provide personalized oral health information, and streamline administrative tasks. While AI complements dental professionals, their expertise remains vital in interpreting AI-generated results and delivering optimal care [14].

3. AI in pediatric dentistry

AI technology is increasingly integrated into various aspects of pediatric dentistry to enhance diagnostics, treatment planning, patient care and oral health education. AI has emerged as a revolutionary tool within the realm of pediatric dentistry, transforming multiple facets of care. In diagnosis, AI algorithms analyze dental images with remarkable precision, enabling early detection of dental conditions and enhancing treatment planning. AI-powered technologies like virtual reality (VR) and augmented reality (AR) alleviate fear and anxiety in pediatric patients, creating immersive and engaging experiences during dental procedures. Augmented Reality (AR) and Virtual Reality (VR) are immersive technologies that have gained prominence in various fields. Their application in pediatric dentistry has shown remarkable potential to enhance patient experiences, alleviate dental anxiety, and facilitate education and treatment planning. AR superimposes digital information onto the physical world, whereas VR generates immersive, simulated environments [15]. Pediatric dentistry stands out as one of the most demanding specialties within the dental field, largely due to the pivotal role of patient compliance in determining treatment outcomes for these young patients. Different tools, such as behavior modification and pharmacological interventions, have improved patient cooperation and compliance, ranging from the dentist's armamentarium. Pediatric patients who visit the dental practice often present with tremendous anxiety as it is their first interaction with dentists. To alleviate patient anxiety and stress, virtual reality (VR) has emerged as an innovative tool discussed in the literature, albeit to a limited extent. Several techniques are utilized to address anxiety, such as *in vivo* exposure therapy (IVET) and virtual reality exposure therapy (VRET). IVET focuses on directly exposing patients to their fears to reduce anxiety levels, frequently regarded as a gold standard approach in this context. VRET, a more recent technique, utilizes computer-generated images to simulate scenarios that allow patients to experience their fears without real-world exposure, thereby reducing anxiety [16]. A study examined the impact of virtual reality on behavioral management among children [17]. The study revealed that implementing virtual reality reduced average anxiety and behavioral scores in patients compared to the control group. Interactive and creative audiovisual representations in virtual reality are particularly appealing to children, contributing to their effectiveness in reducing anxiety [18]. Moreover, AI's ability to analyze large datasets and identify patterns contributes to personalized treatment recommendations and improved patient outcomes. While AI complements the expertise of dental professionals, its role remains essential in interpreting AI-generated results and delivering holistic care to pediatric patients. The continual advancement of artificial intelligence holds immense promise in transforming the landscape of pediatric dental care. AI is poised to contribute to more accurate diagnostics, personalized treatment plans, and innovative approaches to engage young

patients through its ability to process extensive datasets and derive actionable insights. By harnessing AI-driven tools, pediatric dentistry can potentially improve the overall experience for children, mitigate dental anxiety, and cultivate a foundation for lifelong oral health practices. However, as with any technological advancement, a careful and balanced approach is essential, ensuring that the integration of AI in pediatric dental care maintains coherence with the empathetic and human-centered aspects of patient interaction, thus realizing the full benefits while addressing potential challenges and ethical considerations [19].

4. AI in behavior management in children

Pediatric dentists play a crucial role in recognizing and treating dental diseases in children, utilizing the knowledge and skills acquired during their dental education. However, the safe and effective treatment of these conditions often involves modifying the child's behavior. It necessitates a continuum of interaction involving the dentist, dental team, patient and parent, focusing on communication and education. The ultimate goal is to alleviate fear and anxiety while fostering an understanding of the importance of maintaining good oral health and the processes involved in achieving it [20, 21].

In recent years, there have been notable advances in behavior management techniques in pediatric dentistry. Traditional methods have been enhanced with innovative approaches to reduce anxiety, foster cooperation, and promote positive oral health outcomes. Non-pharmacological techniques, such as effective communication, tell-show-do, and positive reinforcement, have built trust and allayed fears [22]. Additionally, virtual reality (VR) and augmented reality (AR) technologies have emerged as powerful tools for distraction and engagement during dental procedures. Sedation and anesthesia techniques have also evolved to ensure safe and tailored management of anxious or uncooperative children. Parental involvement and interdisciplinary collaboration with child psychologists and pediatricians contribute to practical behavior guidance. Integrating digital tools, interactive media, and educational games empowers children to actively participate in oral health care, improving cooperation and long-term dental well-being [23]. These advances collectively strive to create a positive and comfortable environment, helping children develop a lifelong positive attitude towards dental visits.

5. The process of learning in a child and AI

When considering the learning process of artificial intelligence (AI), it is helpful to draw parallels with how a child's brain develops through interactions and experiences. However, it is essential to note that the comparison has limitations since AI systems and human brains operate differently [24].

During the learning phase of an AI neural network, it is exposed to training data, which serves as the system's experiences. Through exposure to this data, the network's connections, or weights, are adjusted, leading to changes in how it processes information. It is seen as the network being "wired" in a particular way based on its interactions with the training data [25].

An AI system's inference criteria and knowledge generation are based on the patterns it learns from the training data. AI models are designed to generalize from the data they have been exposed to, allowing them to make predictions or generate outputs based on new inputs. The accuracy and reliability of these judgments depend on the representativeness and quality of the training data. However, AI systems can be susceptible to biases present in the data or biases encoded in the algorithms themselves, similar to how humans can be biased. Biases rise from various sources, such as imbalances in the training data or the inherent biases of human creators [26].

The utilization of virtual reality and other technological interventions to alleviate preoperative anxiety has been extensively documented in the medical literature, extending even to scenarios involving general anesthesia. An illustrative example is a randomized controlled trial conducted by Ryu *et al.* [27] in 2017, where children were exposed to an immersive virtual reality tour of the operating theater prior to undergoing general anesthesia. The link between heightened preoperative anxiety and adverse postoperative outcomes, encompassing escalated pain levels, increased analgesia consumption, extended recovery periods, and persistent anxiety, is well-established [28]. Furthermore, elevated anxiety is correlated with undesirable behaviors such as separation anxiety, nocturnal enuresis, and sleep disturbances. Remarkably, the study by Ryu and colleagues demonstrated that children exposed to virtual reality experienced significantly diminished preoperative anxiety compared to their non-exposed counterparts. Additionally, these children exhibited heightened compliance during the induction phase. This robust evidence underscores the potential of virtual reality as a beneficial tool in reducing preoperative anxiety and its associated ramifications, contributing to more favorable surgical outcomes and overall well-being.

AI may play a crucial role in alleviating children's fear of dental extractions and needle phobia by offering personalized and empathetic support. Through immersive technologies like virtual reality, AI can transport children to engaging and calming virtual environments during extraction, diverting their attention away from fear-inducing surroundings. AI's real-time emotion recognition capabilities allow dental professionals to monitor a child's anxiety levels and respond with comfort or pauses. Additionally, AI-powered educational tools can explain the extraction process in a child-friendly manner, reducing uncertainty and anxiety. By tailoring the dental experience to each child's unique needs and emotions, AI helps make extractions less intimidating, fostering a more positive and less fearful environment for pediatric patients. Innovative virtual reality technologies offer the potential to alleviate anxiety and minimize pain among children both before and after medical procedures and surgeries. One study found that virtual reality that induces a hypnoticstate (VRH-Virtual Reality Hypnosis) helped manage postoperative anxiety and pain in children. The subsequent study analyzed a cohort of more than 600 patients, aged between 6 and 18 years old, who were provided with an innovative virtual reality (VR) game. This game enables real-time reorientation of gameplay and allows clinicians to modify the cognitive load, enhancing

its capacity to distract patients and consequently reduce their perception of pain [29]. Using an analgesic pump with a single-chip microprocessor also has performed better in children undergoing dental treatment. The microcomputer intermittent electronic analgesia pump incorporates a timer mechanism to facilitate electronically controlled intermittent infusion while allowing for manual single administration. Thus reducing the pain of injection, which the children fear most [30]. Integrating AI in pediatric dentistry has opened up new possibilities for improved diagnostics, personalized treatment planning, and enhanced patient care. AI technology is increasingly utilized in behavior management for pediatric dental patients, offering innovative approaches to create positive and comfortable experiences. AI-powered virtual reality (VR) experiences may alleviate anxiety and fear in children during dental procedures. AI-powered virtual reality (VR) experiences are emerging as a promising avenue to relieve stress and worry in children undergoing dental procedures. This achievement is realized by immersing young patients in interactive and captivating virtual environments that serve as powerful distractions from dental treatment. By donning VR headsets, children are transported to engaging worlds where they can interact with imaginative characters, participate in games, or explore visually captivating scenarios. Through this immersion, their attention is effectively redirected away from the dental procedure, helping to mitigate feelings of apprehension. Additionally, the element of control plays a significant role; many VR experiences allow children to navigate and make choices within the virtual environment, fostering a sense of empowerment. Examples include virtual adventures where dental treatments become part of an exciting quest, interactive storytelling that envelops children in narratives, and virtual dental "games" that turn procedures into playful activities [20]. Additionally, AI algorithms may analyze facial expressions and voice tone to recognize and interpret children's emotions, aiding in understanding their reactions and tailoring communication strategies. AI chatbots and virtual assistants may provide interactive education, answering questions and explaining dental procedures, thus empowering children with knowledge and reducing apprehension. DentalVerse emerges as an innovative local mobile application, pioneering the digitalization of patient-dentist interactions. This platform seamlessly integrates functionalities that streamline processes, ensuring a comprehensive experience before and after receiving dental services. A significant highlight of DentalVerse is its emphasis on the consultative aspect, facilitated by readily accessible educational content, the provision for online consultations, and the presence of Catrinel, an intelligent virtual assistant. As a strategic vision, DentalVerse aims to progressively incorporate advanced functionalities and evolve into a pioneering teledentistry platform. Key collaborators in this transformative journey are Codestage, Gamify and DRUID, actively contributing to developing this dynamic mobile solution. By leveraging AI in behavior management, pediatric dental practices can enhance patient comfort and cooperation, promoting positive oral health experiences for children [31–33].

AI can also be applied to behavior management, specifically for children. Here are some ways AI can assist in this area:

1. Personalized learning: AI may analyze a child's learning style, preferences, and abilities to create personalized educational experiences. By adapting lessons' content, pace and delivery, AI-powered systems can help keep children engaged and motivated. It can significantly benefit children with learning disabilities or require individualized attention.

2. Gamification and rewards: AI may utilize gamification techniques to encourage positive behavior in children. AI-powered systems might make learning and behavior management more enjoyable by incorporating game-like elements such as points, badges and levels. Rewards and incentives can be tailored to each child's interests and progress, promoting a sense of accomplishment and motivation. Emerging technologies present captivating prospects to revolutionize student learning through innovative approaches. Among these technological possibilities, gamification is a compelling strategy to invigorate student motivation and participation. Gamification is succinctly defined as "the incorporation of game-design elements within non-game contexts" [34]. The prevalent mechanisms employed in gamification encompass objectives, rewards/scores, achievement badges, feedback loops, leaderboards and other elements fostering competition among users while fostering social interaction to motivate favorable actions or adopting specific behaviors. Numerous applications strategically amalgamate these mechanisms, culminating in an approach that renders sustained behavioral changes a gratifying journey for users, effectively averting discouragement [35]. Gamification presents many advantages, encompassing heightened self-awareness regarding individual capacities, improved occupational memory and focus, and augmented problem-solving aptitude and goal-oriented performance. Although gamification has gained substantial traction in personal computers, its application to smartphone apps is a relatively recent area of exploration [36]. Substantiated by evidence, a significant correlation emerges between gamification and instigating behavioral modifications within the healthcare domain [37]. Comprehensive review studies underscore that gamification exerts a constructive impact on health-oriented interventions and the embrace of affirmative behaviors [38]. Within the domain of oral health, notable instances of apps employing gamification include those that utilize games as educational tools to instruct children about a diverse array of subjects, from tooth decay awareness to promoting healthy dietary choices while cautioning against carcinogenic options [39].

3. Virtual tutors and assistants: AI-powered virtual tutors or assistants can support and guide children in various contexts. These systems can offer explanations, answer questions, and provide feedback on academic tasks. Virtual assistants can also assist in behavior management by reminding children of tasks, schedules and goals, helping them stay organized and focused. The California Dental Association (CDA) says adding a virtual assistant to the dental practice is acceptable; oral health professionals must still be aware of the risks. The most important fact to consider is that dentists remain responsible for following all Health Insurance Portability and Accountability Act (HIPAA) regulations, emphasizing the need for virtual assistants to be trained on HIPAA requirements and patient data security [40].

4. Emotional support: Patient expectations for personalized service stand as a foremost trend in dentistry, prompting

numerous practices to leverage technology in meeting these tailored care demands. In the healthcare industry, dentistry has been one of the early adopters of tools such as artificial-intelligence chatbots that can engage patients online and answer common questions around the clock. AI could provide emotional support to children by engaging in conversational interactions and offering empathy. Chatbots integrated with natural language processing capabilities have the capacity to comprehend and address children's emotions effectively. They serve as attentive listeners, offering suitable coping strategies in response. It can benefit children experiencing stress, anxiety, or other emotional challenges [41].

5. Monitoring and feedback: AI can monitor children's behavior and provide feedback to both children and parents. For example, AI-powered systems may analyze online activities, social media interactions, or device usage to identify potential risks or signs of problematic behavior. This information can then be shared with parents or guardians, enabling timely intervention and guidance [42, 43].

As AI evolves, these AI-powered VR experiences are poised to reshape the pediatric dental landscape by offering a novel and practical approach to enhance young patients' comfort and emotional well-being during their dental care journey.

6. Drawbacks of using AI in pediatric dentistry, particularly in behavior management [44, 45]

1. Lack of Personalized Interaction: AI systems need help understanding pediatric patients' unique needs and emotions. Children require a more personalized and empathetic approach, which AI might not be able to provide effectively. Building trust and rapport is crucial in pediatric dentistry, and AI might need to address these emotional aspects fully.

2. Limited Adaptability to Child's Behavior: Pediatric patients can exhibit various behaviors, from anxiety to curiosity. AI systems might be unable to adapt and respond appropriately to sudden changes in a child's behavior during a dental procedure, which a human dentist would be better equipped to manage.

3. Loss of Human Touch and Comfort: The comforting presence of a human dentist and staff plays a significant role in alleviating children's fears and anxieties during dental procedures. More reliance on AI could lead to losing the human touch essential to establishing a positive dental experience for young patients.

4. Unpredictable Reactions to AI Tools: Children might react unpredictably to AI-powered tools and robots in a dental setting. Some children might find them intimidating, leading to heightened anxiety and distress, negatively impacting the dental experience.

5. Misinterpretation of Nonverbal Cues: Pediatric patients often communicate non-verbally, and experienced dentists rely on these cues to understand a child's comfort level. AI might need help to accurately interpret these nonverbal cues, potentially leading to misunderstandings and suboptimal treatment.

6. Ethical and Safety Concerns: Implementing AI in pediatric dentistry raises ethical questions about data privacy, consent, and the potential for AI systems to harm children if not programmed and supervised correctly and inadvertently. Ensuring the safety of both the technology and the patients becomes a crucial concern.

7. Dependency on Technology: Overreliance on AI for behavioral management might hinder the development of essential communication and coping skills in children. These skills are crucial for their overall emotional and psychological growth and should only be replaced partially by technology.

8. Complexity of Procedures: Pediatric dental procedures can be intricate and vary widely based on individual patient needs. AI, while proficient in some tasks, might need help with the complexity of specific procedures, leading to subpar outcomes or the need for human intervention.

9. Parent-Child Relationship: The presence of parents or guardians during dental procedures is familiar in pediatric dentistry. AI might inadvertently disrupt the parent-child dynamic during treatments, as parents might feel less engaged or reassured by an AI presence than a human dentist.

10. Limited Learning from Experience: AI systems learn from data, but the behavioral management of pediatric patients is a nuanced skill that involves adapting to individual children over time. AI might lack the ability to learn from experiences in the same way that human dentists do.

To effectively integrate AI in pediatric dentistry, a balanced approach that combines AI's capabilities with human expertise and empathy will likely yield the best results, ensuring young dental patients' overall well-being and comfort [46, 47].

However, in pediatric dentistry and the behavioral management of young dental patients, integrating AI-powered solutions also presents specific challenges. Over-reliance on technology could compromise the essential human connection and empathetic interactions pivotal in comforting anxious children [48, 49]. Tailoring AI interactions to the diverse age groups and emotional needs of pediatric patients can be complex, as these systems might need help to adequately adapt to individual developmental stages. Moreover, while AI tools can be customized, they may need more nuanced personalization than human interactions offer. Privacy and ethical concerns become even more pronounced when dealing with children's data, necessitating stringent measures to safeguard sensitive information [50, 51]. The potential for AI to inadvertently amplify anxiety due to unfamiliarity or misinterpretation is another consideration. Ultimately, the application of AI in pediatric dental behavioral management necessitates a mindful balance that respects the uniqueness of each child's emotional journey and ensures that technology enhances rather than diminishes the human-centered care integral to successful pediatric dental practices [52, 53].

7. Conclusion

In conclusion, the potential integration of AI in pediatric dentistry offers opportunities and challenges that warrant careful consideration. While AI technologies hold promise in enhancing certain aspects of dental care, it is essential to acknowledge the complexity of pediatric dentistry and the unique needs of young patients. The preceding discussions shed light on several drawbacks and limitations of implementing AI in this field.

AI's ability to streamline administrative tasks, aid in diagnostic processes, and provide educational resources presents exciting avenues for improving efficiency and patient care. However, these advancements should be approached with a balanced perspective, considering the crucial role of human interaction, empathy, and personalized care in pediatric dental practice. While AI tools can assist in behavioral management, the nuanced nature of working with children necessitates a cautious approach. Personalized attention, understanding nonverbal cues, and building rapport with young patients remain areas where human dentists excel. Moreover, the emotional well-being of both children and their parents must be considered, as AI's role in addressing their concerns might only partially replicate the reassurance provided by human professionals. It's crucial to acknowledge that AI systems learn from data and might not encapsulate the extensive experience and judgment acquired by human dentists through years of practice. The diverse range of pediatric dental procedures, varying patient behaviors, and unexpected situations underscore the value of human adaptability and decision-making. Integrating AI should be a deliberate and informed process as pediatric dentistry evolves. Collaborative efforts that combine AI's technical capabilities with the empathetic skills of dental professionals hold the potential to achieve optimal outcomes for young patients. Rather than replacing human expertise, AI can serve as a supportive tool that complements the art and science of pediatric dental care.

In moving forward, cautious optimism should guide the integration of AI into pediatric dentistry. By acknowledging its strengths while remaining attentive to its limitations, the pediatric dental community can ensure that advancements in technology enhance, rather than replace, the vital human connections that define the practice of pediatric dentistry.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

SA—conceived the idea, collected and analyzed the data and did the writing. BSG, VS—designed the research study. AAA, NAA—performed the research. SA, AAD and AA—analyzed the data. SA and MIK—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Turing AM. Computing machinery and intelligence. Nature Machine Intelligence. 1950; 49: 433–460.
[2] Pang Z, Yuan H, Zhang Y-T, Packirisamy M. Guest editorial health engineering driven by the industry 4.0 for aging society. IEEE Journal of Biomedical and Health Informatics. 2018; 22: 1709–1710.
[3] Metz C, Smith CS. AI can be a boon to medicine that could easily go rogue. The New York Times, 2019; B5. (25 March 2019)
[4] Hengstler M, Enkel E, Duelli S. Applied artificial intelligence and trust—the case of autonomous vehicles and medical assistance devices. Technological Forecasting and Social Change. 2016; 105: 105–120.
[5] Bajwa J, Munir U, Nori A, Williams B. Artificial intelligence in healthcare: transforming the practice of medicine. Future Healthcare Journal. 2021; 8: e188–e194.
[6] Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nature Medicine. 2019; 25: 44–56.
[7] Mary-Anne Ramis, Béatrice Perrenoud.Educating future generations of health professionals: looking back and moving forward. JBI Evidence Synthesis. 2023; 21: 1348–1350.
[8] Topol E. Deep medicine: how artificial intelligence can make healthcare human again. 1st edn. Basic Books: New York, NY. 2019.
[9] Pedersen T, Johansen C. Behavioural artificial intelligence: an agenda for systematic empirical studies of artificial inference. AI & Society. 2020; 35: 519–532.
[10] Park WJ, Park JB. History and applications of artificial neural networks in dentistry. European Journal of Dentistry. 2018; 12: 594–601.
[11] Chen YW, Stanley K, Att W. Artificial intelligence in dentistry: current applications and future perspectives. Quintessence International. 2020; 51: 248–257.
[12] Rajaram Mohan K, Mathew Fenn S. Artificial intelligence and its theranostic applications in dentistry. Cureus. 2023; 15: e38711.
[13] Kühnisch J, Meyer O, Hesenius M, Hickel R, Gruhn V. Caries detection on intraoral images using artificial intelligence. Journal of Dental Research. 2022; 101: 158–165.
[14] Real AD, Real OD, Sardina S, Oyonarte R. Use of automated artificial intelligence to predict the need for orthodontic extractions. Korean Journal of Orthodontics. 2022; 52: 102–111.
[15] Reeves R, Curran D, Gleeson A, Hanna D. A Meta-analysis of the efficacy of virtual reality and *in vivo* exposure therapy as psychological interventions for public speaking anxiety. Behavior Modification. 2022; 46: 937–965.
[16] Zhang W, Paudel D, Shi R, Liang J, Liu J, Zeng X, *et al*. Virtual reality exposure therapy (VRET) for anxiety due to fear of COVID-19 infection: a case series. Neuropsychiatric Disease and Treatment. 2020; 16: 2669–2675.
[17] Evans C, Moonesinghe R. Virtual reality in pediatric anesthesia: a toy or a tool. Pediatric Anesthesia. 2020; 30: 386–387.
[18] Vishwanathaiah S, Fageeh HN, Khanagar SB, Maganur PC. Artificial intelligence its uses and application in pediatric dentistry: a review. Biomedicines. 2023; 11: 788.
[19] Böhnlein J, Altegoer L, Muck NK, Roesmann K, Redlich R, Dannlowski U, *et al*. Factors influencing the success of exposure therapy for specific phobia: a systematic review. Neuroscience & Biobehavioral Reviews. 2020; 108: 796–820.
[20] Cunningham A, McPolin O, Fallis R, Coyle C, Best P, McKenna G. A systematic review of the use of virtual reality or dental smartphone applications as interventions for management of paediatric dental anxiety. BMC Oral Health. 2021; 21: 244.
[21] Hugar S, Kohli N, Soneta S, Saxena N, Kadam K, Gokhale N.

Psychological behavior management techniques to alleviate dental fear and anxiety in 4–14-year-old children in pediatric dentistry: a systematic review and meta-analysis. Dental Research Journal. 2022; 19: 47.

[22] Nazzal H, ElShahawy OI, Al-Jundi S, Hussein I, Tahmassebi JF. The use of behaviour management techniques amongst paediatric dentists working in the Arabian region: a cross-sectional survey study. European Archives of Paediatric Dentistry. 2021; 22: 375–385.

[23] Modha B. Exploring customer journeys in the context of dentistry: a case study. Dentistry Journal. 2023; 11: 75.

[24] Hauer T. Importance and limitations of AI ethics in contemporary society. Humanities and Social Sciences Communications. 2022; 9: 272.

[25] Luczak A, McNaughton BL, Kubo Y. Neurons learn by predicting future activity. Nature Machine Intelligence.2022; 4: 62–72.

[26] Panch T, Mattie H, Atun R. Artificial intelligence and algorithmic bias: implications for health systems. Journal of Global Health. 2019; 9: 010318.

[27] Ryu J, Park S, Park J, Kim J, Yoo H, Kim T, *et al*. Randomized clinical trial of immersive virtual reality tour of the operating theatre in children before anaesthesia. British Journal of Surgery. 2017; 104: 1628–1633.

[28] Kim J, Chiesa N, Raazi M, Wright KD. A systematic review of technology-based preoperative preparation interventions for child and parent anxiety. Canadian Journal of Anesthesia. 2019; 66: 966–986.

[29] American Society of Anesthesiologists. Studies show potential of virtual reality to reduce children's anxiety, pain. Science Daily, 2018. (24 October 2018)

[30] Zhang F, Wu S, Qu M, Zhou L. Application of a remotely controlled artificial intelligence analgesic pump device in painless treatment of children. Contrast Media & Molecular Imaging. 2022; 2022: 1–6.

[31] Welbers K, Konijn EA, Burgers C, de Vaate AB, Eden A, Brugman BC. Gamification as a tool for engaging student learning: a field experiment with a gamified app. E-Learning and Digital Media. 2019; 16: 92–109.

[32] Edwards EA, Lumsden J, Rivas C, Steed L, Edwards LA, Thiyagarajan A, *et al*. Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps. BMJ Open. 2016; 6: e012447.

[33] Crawford S, Del Hagen E, Du J, Husak E, Liao Z, Santoso M, *et al*. DentalVerse: interactive multiusers virtual reality implementation to train preclinical dental student psychomotor skill. 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). 2022; 81–84.

[34] Fijačko N, Gosak L, Cilar L, Novšak A, Creber RM, Skok P, *et al*. The effects of gamification and oral self-care on oral hygiene in children: systematic search in app stores and evaluation of apps. JMIR mHealth uHealth. 2020; 8: e16365.

[35] Bryant V. Harry potter and the osteopathic medical school: creating a harry potter-themed day as a high-yield review for final exams. Medical Science Educator. 2021; 31: 819–825.

[36] Wang AI, Tahir R. The effect of using Kahoot! for learning—a literature review. Computers & Education. 2020; 149: 103818.

[37] Knösel M, Jung K, Bleckmann A. YouTube, dentistry, and dental education. Journal of Dental Education. 2011; 75: 1558–1568.

[38] You W, Hao A, Li S, Wang Y, Xia B. Deep learning-based dental plaque detection on primary teeth: a comparison with clinical assessments. BMC Oral Health. 2020; 20: 141.

[39] California Dental Association. Thinking of bringing on a virtual assistant in the dental practice? That's an option, but proceed with caution. 2023. Available at: https://www.cda.org/Home/News-and-Information/Newsroom/Article-Details/thinking-of-bringing-on-a-virtual-assistant-in-the-dental-practice-thats-an-option-but-proceed-with-caution (Accessed: 10 August 2023).

[40] Kulkarni S, Rojekar N, Bhattad D, Shukla H, Wasnik MB, Kolekar P. Acceptance of parents for behavior management technique with reference to previous dental expertise and dental anxiety. International Journal of Clinical Pediatric Dentistry. 2022; 14: S193–S198.

[41] Tai M. The impact of artificial intelligence on human society and bioethics. Tzu Chi Medical Journal. 2020; 32: 339.

[42] khan B, Fatima H, Qureshi A, Kumar S, Hanan A, Hussain J, *et al*. Drawbacks of artificial intelligence and their potential solutions in the healthcare sector. Biomedical Materials & Devices. 2023; 1: 731–738.

[43] Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. Journal of Dental Research. 2020; 99: 769–774.

[44] Mine Y, Iwamoto Y, Okazaki S, Nakamura K, Takeda S, Peng T, *et al*. Detecting the presence of supernumerary teeth during the early mixed dentition stage using deep learning algorithms: a pilot study. International Journal of Paediatric Dentistry. 2022; 32: 678–685.

[45] Gajic M, Vojinovic J, Kalevski K, Pavlovic M, Kolak V, Vukovic B, *et al*. Analysis of the impact of oral health on adolescent quality of life using standard statistical methods and artificial intelligence algorithms. Children. 2021; 8: 1156.

[46] Park YH, Kim SH, Choi YY. Prediction models of early childhood caries based on machine learning algorithms. International Journal of Environmental Research and Public Health. 2021; 18: 8613.

[47] Al-Halabi MN, Bshara N, AlNerabieah Z. Effectiveness of audiovisual distraction using virtual reality eyeglasses versus tablet device in child behavioral management during inferior alveolar nerve block. Anaesthesia, Pain & Intensive Care. 2018; 22: 55–61.

[48] Graham S, Depp C, Lee EE, Nebeker C, Tu X, Kim H, *et al*. Artificial intelligence for mental health and mental illnesses: an overview. Current Psychiatry Reports. 2019; 21: 116.

[49] Aggarwal A, Tam CC, Wu D, Li X, Qiao S. Artificial intelligence-based chatbots for promoting health behavioral changes: systematic review. Journal of Medical Internet Research. 2023; 25: e40789.

[50] Coutinho MB, Damasceno JX, Cals de Oliveira PCM, Marinho IMA, Marçal EBF, Vieira-Meyer APGF. A novel mobile app intervention to reduce dental anxiety in infant patients. Telemedicine and e-Health. 2021; 27: 694–700.

[51] Garrocho-Rangel A, Ibarra-Gutiérrez E, Rosales-Bérber M, Esquivel-Hernández R, Esparza-Villalpando V, Pozos-Guillén A. A video eye-glasses/earphones distracting method during dental treatment in children: a crossover randomised and controlled clinical trial. European Journal of Paediatric Dentistry. 2018; 19: 74–79.

[52] Kelly CJ, Karthikesalingam A, Suleyman M, Corrado G, King D. Key challenges for delivering clinical impact with artificial intelligence. BMC Medicine. 2019; 17: 195.

[53] Khan B, Fatima H, Qureshi A, Kumar S, Hanan A, Hussain J, *et al*. Drawbacks of artificial intelligence and their potential solutions in the healthcare sector. To be published in Biomedical Materials & Devices. 2023. [Preprint].

How to cite this article: Sonu Acharya, Brinda S. Godhi, Vrinda Saxena, Ali A Assiry, NouraAbdulaziz Alessa, Ali Azhar Dawasaz, *et al*. Role of artificial intelligence in behavior management of pediatric dental patients—a mini review. Journal of Clinical Pediatric Dentistry. 2024; 48(3): 24-30. doi: 10.22514/jocpd.2024.055.