GRADUATION PROJECT

Degree in Dentistry

USE OF NEW TECHNOLOGIES FOR BEHAVIOR MANAGEMENT IN PEDIATRIC PATIENTS

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ABSTRACT

Introduction: Behavior management is essential in pediatric dentistry, as children's anxiety and cooperation directly influence treatment success. Traditional non-pharmacological techniques may be insufficient in modern clinical settings, leading to increased interest in digital technologies as alternative approaches. **Objective:** The aim of this study was to evaluate whether new technologies, such as virtual reality and artificial intelligence, provide greater reductions in anxiety and improved behavioural outcomes in pediatric dental patients compared with traditional techniques, as well as to analyse their advantages and their impact on pain perception and treatment acceptance. **Material and Methods:** A documentary research study was conducted using electronic databases including Medline, Scopus, Cochrane and PubMed. The search was limited to English-language randomized controlled trials published within the last five years. After applying inclusion and exclusion criteria, 17 studies were selected for analysis. **Results:** Most digital interventions, particularly virtual reality, were associated with significant reductions in dental anxiety and improvements in behavioural cooperation. Compared with conventional techniques, immersive and interactive technologies demonstrated greater effectiveness, especially during invasive procedures. **Conclusions:** New technologies are effective adjuncts to traditional behaviour management strategies in pediatric dentistry. Virtual reality and artificial intelligence show significant potential in reducing anxiety, improving cooperation, and enhancing treatment acceptance; however, further research is required to standardize their clinical application and evaluate long-term outcomes.

KEYWORDS

Dentistry ; pediatric dentistry; virtual reality; dental anxiety; behavior management

RESUMEN

Introducción: El manejo del comportamiento es fundamental en odontopediatría, ya que la ansiedad y la cooperación de los niños influyen directamente en el éxito del tratamiento. Las técnicas tradicionales no farmacológicas pueden resultar insuficientes en los entornos clínicos actuales, lo que ha generado un creciente interés por las tecnologías digitales como enfoques alternativos. **Objetivo:** El objetivo de este estudio fue evaluar si las nuevas tecnologías, como la realidad virtual y la inteligencia artificial, proporcionan una mayor reducción de la ansiedad y mejores resultados conductuales en pacientes odontopediátricos en comparación con las técnicas tradicionales, así como analizar sus ventajas y su impacto en la percepción del dolor y la aceptación del tratamiento. **Material y métodos:** Se realizó un estudio de investigación documental utilizando bases de datos electrónicas como Medline, Scopus, Cochrane y PubMed. La búsqueda se limitó a ensayos clínicos aleatorizados en inglés publicados en los últimos cinco años. Tras aplicar los criterios de inclusión y exclusión, se seleccionaron 17 estudios para su análisis. **Resultados:** La mayoría de las intervenciones digitales, especialmente la realidad virtual, se asociaron con reducciones significativas de la ansiedad dental y mejoras en la cooperación conductual. En comparación con las técnicas convencionales, las tecnologías inmersivas e interactivas demostraron mayor eficacia, especialmente durante procedimientos invasivos. **Conclusiones:** Las nuevas tecnologías son complementos eficaces a las estrategias tradicionales de manejo del comportamiento en odontopediatría. La realidad virtual y la inteligencia artificial muestran un gran potencial para reducir la ansiedad, mejorar la cooperación y aumentar la aceptación del tratamiento; sin embargo, se requieren más investigaciones para estandarizar su aplicación clínica y evaluar sus efectos a largo plazo.

PALABRAS CLAVE

Odontología, odontopediatría, realidad virtual, ansiedad dental, manejo del comportamiento

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1. INTRODUCTION

1.1. History and Relevance of Behavior Management techniques in pediatric dentistry

Behavior management has always been an important part of pediatric dentistry because the outcome of a dental treatment depends as much on the child's cooperation as it does on the dentist's technical abilities. In pediatric dentistry there is a certain level of trust that is required to minimize a child's anxiety and induce a positive attitude in the child that can continue into adulthood. The most common behavioural management methods used in children the last decades include strategies such as tell-show-do, positive reinforcement, modeling and distraction as ways to achieve cooperation (1). These options have been the cornerstone of behavioral management in pediatrics and are rooted in classical conditioning, where learning is emphasized through reward and duplication.

Throughout history, the first methods used for behavior guidance in children were developed in the 20th century, mirroring the progression with child psychology. Famous psychologists such as Erikson and Piaget described stages of development related to autonomy and cognitive function. Throughout the years dental professionals have used different sets of communication techniques aimed at each age group. Young children were more adept to responding to sensory tools and visual modeling, while older children benefitted from a more collaborative approach such as discussing the steps in a treatment. These key differences in approach between age groups remain a fundamental part of achieving effective care. The importance of communication with the patient cannot be understated in the clinical setting because it has a direct correlation to their behavior and attitude during the treatment process. If communication is clear, simple, direct and adjusted for their age group then their cooperation will in turn be better.

In modern times, there has been a shift to more contemporary approach that have begun to challenge the traditional behavior management systems. The digital age has transformed how children nowadays interact with technology daily, including tablets, phones, gaming consoles. This everyday exposure to technology has changed a lot of children's ability to pay attention for long periods of time, have patience, and even changed their preferred ways of learning (2). Therefore, traditional methods such as reassurance through explanation or audio-visual distractions have failed to maintain a child's full attention throughout the dental treatment.

Dental fear and anxiety in children have had an increasing prevalence throughout the years and there is a need for innovation. Years ago, parents often sided with the dentist in situations, even though the child had anxiety about the dental treatment they had an even higher fear about the consequences they would deal with at home if they did not cooperate. Nowadays, it seems the child and parents are on the same team, as a result the child is more inclined to express their discomfort and anxiety which in turn causes them to cooperate less knowing there will be no consequences for their behavior at home. Globally there are estimates that around 20-30 % of pediatric patients are experiencing substantial fear and anxiety when visiting the dentist, so much so that even having a mild anxiety has a direct correlation to avoiding preventative appointments and a worsening of oral health (3). Children have a lot of new sensory information when they visit the dentist including new noises and items put in their mouth that they have never seen before. This coupled with previous painful experiences can lead a child down a path of avoidance of the dentist for the rest of their lives. To combat this, modern dentistry has taken a new approach that is now more patient-centered and highlights emotional well-being in addition to treatment outcomes.

This technological evolution has brought about the opportunities to enhance the non-pharmacological side of behavior management. With the use of new tools such as virtual reality (VR), artificial intelligence (AI), social robotics, augmented reality (AR), and phone applications dentists are able to give an interactive, sensory, and personalized approach that can regulate anxiety while preserving a safe/efficient environment (4,5). Understanding how these technologies can shape the future of child clinical treatment is essential, knowing the advantages and limitations of each are essential for a correct assimilation into pediatric dentistry

1.2. Virtual Reality in Pediatric Dentistry

Virtual reality has garnered a vast amount of attention from the dentistry community and can be seen as one of the most promising digital tools to add in pediatric dental treatments. The VR headset system is used to immerse children into a three-dimensional environment while they are being treated, and it replaces the clinical stimuli with comforting virtual landscapes. This virtual approach can be explained by the limited-capacity model of attention which states that human attention is finite can be fully absorbed with enough immersive stimuli. There is also the gate-control theory of pain which proposes that having an extreme cognitive focus can dissipate the nociceptive signals of pain that travel throughout the body (6,7). VR

Influences pain perception by shifting the attention from the nociceptive input to multi-sensory stimuli. From a psychological perspective, VR gives the patient the ability to feel like he is in control and that he is in a predictable environment which together are key factors of reduced fear.

VR's effectiveness in reducing anxiety and perceived pain during a dental treatment has been confirmed numerous times with randomized clinical trials. Ran et al. 2021 portrayed that children who were using VR during a dental procedure showed a lower heart rate along with a significantly less amount of self-reported anxiety compared to the control group in the same trial (1). Bagher et al. 2023 validated these results as well with his or study that resulted in lower pain perception and improved cooperation from patients who were anxious (2). Another randomized clinical trial also reported finding that 90 % of patients preferred treatment with a virtual reality headset compared to traditional methods of distraction (3).

Children with special communication needs have also benefitted from VR, a 2024 trail integrated sign language into their virtual reality videos and reported a significant decrease in anxiety for the hearing-impaired children (4). Children with special needs have also been treated with VR, during which they were able to play a VR game while being treated and the results showed reduced patient stress and smoother clinical transitions (5). These studies portray how beneficial VR can be not only for children in general but even patients with special needs and communication.

While VR does have its advantages there are also a list of limitations alongside it as well: hygiene for headset, high cost of equipment and some patients reporting a high degree of motion sickness when using it (6). The dentist must always be present to verbally assure the child of any questions and although it is a great supplement it cannot replace human reassurance. When applied in the proper situations VR can change a child's dental experience for the better, resulting in less overall anxiety and fear. It is an ethical choice and there is substantial evidence-based research that supports its use in pediatric dentistry.

1.3. Mobile Applications and Gaming Tools

Smart phones and tablets are in nearly every child's hand when growing up in this new generation. This revolution has paved the way for a new approach to behavior management using these devices. The method is based on self-determination and operant conditioning theory but uses mobile apps/games to improve cooperation, decrease anxiety, and reinforce oral hygiene techniques.

Carmen et al. 2023 showed that during a treatment the use of a mobile application that had animated dental story lines and objectives resulted in a substantial decrease in anxiety compared to traditional verbal direction (6). Another study from Mayer et al. 2023 showed similar decrease in anxiety when using a mobile based audio distraction application during the use of a dental turbine (7).

Mobile applications unlike VR can be used outside of the dental clinic and they have the ability to reduce anxiety and fear through these applications. Long term oral health can be promoted by mobile phones as well through reminders of daily brushing and timers to ensure proper cleaning in children. Mobile phones have the ability to be a portable and to most people an affordable option that can be used to enhance a child's oral health in the long term in both high- and low-income populations (8).

Dental Gaming applications also hold a strong proposition for improving overall oral health outcomes by requiring the parents to be involved with the process. Parents who are engaged with their child's dental health progress have a strong correlation to better oral hygiene outcomes in children.

Mobile applications are an inexpensive and effective way to promote good oral health in children and have been shown to decrease the anxiety they experience during a dental treatment. They are great learning tools and promote good habits that children can carry on into their future. Aligning well with the new methods of behavioral management in pediatric dentistry.

1.4. Artificial Intelligence and Augmented Reality

Artificial intelligence (AI) is a new technology that has the ability to read and interpret facial expression, tone of voice, and other physiological facts to determine the anxiety levels of a patient in real-time. Adabdokht et al. 2025 showed an 85 percent harmony between

professional psychological assessments and AI emotion-recognition outcomes (8). Another study from Rathod et al. (2022) showed that live video streams used with deep-learning analysis can predict with a high accuracy the signs and levels of distress in dental settings (9). With the help of these models' dentists can make real-time adjustments to improve the treatment process for the child. A clinician can adjust the pace of treatment, amount stimuli and even the tone of his or her voice to be able to accommodate their patient better and reduce anxiety.

Augmented reality (AR) is another new technology can be used interactively with a superimposed layer on the real environment typically through glasses. With AR the child is still able to see the clinical environment and has visual contact with the dentist. A randomized controlled trial in 2025 showed that using AR in the delivery of anesthesia had a significant reduction in perceived pain as well as anxiety when comparing it to traditional methods (10). AR is a great in-between option when a child cannot handle full-immersion and is more comfortable being able to see the environment that he/she is in. It like VR can be used as both an educational tool as well as a distraction for the patient.

Chahartrangi et al. 2025 emphasized AR's educational role in oral health, showing that virtual-patient simulations improved learners understanding and empathy (11). Relating this to dentistry, AR is can accurately envision the oral anatomy and virtually simulate the dental procedures, this can clarify the treatment for young patients while teaching dentists in their communication skills as well.

AI and AR are key tools in advancing the behavior management techniques in pediatric patients. They are important advancements for the concept of adaptive emotional regulation, and they are the next step beyond traditional passive distraction techniques.

1.5. Social Robotics

Social robotics use humanoid robots that have the ability to portray human emotions, speech patterns, and human emotions which in turn creates an empathetic and supportive environment for the patient. Kasimoglu et al. 2023 discovered that using a humanoid robot for guiding a child through a simple prophylaxis treatment reduced the amount of saliva being

produced (a stress biomarker) and improved patient cooperation compared to traditional assistance (12).

Takata et al. 2025 used numerous humanoid robots to trains children with autism and special needs, the study observed a high improvement in communication and engagement from these children (13). The results show how useful and important a robot can be for special needs patients; they seem to respond better to a more predictable and unprejudiced stimuli compared to a human who can give off more negatively perceived cues.

Use cases for robots in a dental clinic can include pre-treatment orientation along with explaining what certain instruments are. This can set the tone for a calm demeanor and environment that a child is able to feel relaxed in. There are risks to having an over-reliance on social robots in the dental field, mainly due to the loss of human empathy if the clinician is not engaged enough. There must be a balance between the two, but if found it can be a valuable aid to the dental treatment procedure.

1.6. Ethical and Clinical Considerations

When introducing new technology into pediatric dentistry there must be extensive oversight into every tool. The data of the patient that is stored and interpreted needs to have compliance with the legal and ethical standards, including consent, privacy and accountability. The European Union has its own standards with data protection called the General Data Protection Regulation (GDPR) it is mandatory for digital health applications. Parental consent, anonymity, having a secure encryption of data as well as transparency about how AI processes and stores information is mandatory (12).

Pediatric dentistry is a more sensitive area where additional ethical standards are put into place because of the general vulnerability of children and their limited self-sufficiency. Obtaining consent in this case is the process of getting both parental authorization as well as child approval. Procedures must be explained to the child in a developmentally suitable language to ensure comprehension. When using technology with immersion such as VR the dentist must fully explain what the tool does and confirm that the patient wants to participate.

Psychological stress and mistrust can arise without first confirming with the child if they want to use this type of technology during their treatment.

Richter et al. 2025 emphasized how frameworks for AI in pediatric medicine needs to comply with explainability to the patient, fairness, and clinician responsibility (14). These same frameworks can be applied to pediatric dentistry as well; the dentist should always remain ethical and legal in their actions. If they are interpreting data from AI or other new technologies, they need to have the responsibility to not solely rely on the systems interpretations but instead take both the AI interpretation and their own professional judgement into account.

One critical issue with these new technologies is the accessibility to them due to the high cost of equipment. VR headsets and robotic assistants may only be available is specialized clinics which are more often than not privately owned. This entails that privately owned clinics will be much better suited to treat pediatric patients compared to a publicly owned clinic due to their much lower budget. An ethical approach to this problem will require cost analysis and distribution strategies to community dentistry settings.

Dentists must also take into account that these technologies must only be used when needed, so they must understand the abilities and limitations of their uses. Training and developing a skillset for implementing these new types of technologies is a crucial part of professional ethics. Schools and training programs need to emphasize how these technologies are allowed to be used and the main areas of ethical consideration including informed consent, privacy and bias mitigation. Principles such as autonomy, beneficence, non-maleficence and justice must always be used as a guideline when integrating new technologies into a pediatric dental clinic.

1.7. Justification and Evidence Gaps

Although there are very positive outcomes across these studies, there is still gaps in the current evidence. The biggest limitation includes methodological heterogeneity meaning that all the studies vary significantly in design, number of participants, and measurements for outcome. Most clinical trials that include VR or AR has relatively small sample sizes of less than

60 coupled with treatments that are short in duration (13). The types of anxiety assessment tools also vary significantly and are difficult to compare directly to one another (15).

These technologies are a recent introduction to the field of pediatric dentistry and therefore they lack long term follow-ups. There is no proof of a permanent behavioral change in these pediatric patients that undergo AI, VR or AR based treatment, only proof of short-term improvement.

Another limitation from the studies includes the cultural and contextual disparities that limit the ability to generalize the results. Most of the studies were conducted in middle to high income areas and did not account for low-income areas who may have trouble accessing these technologies due to equipment cost. To avoid this inequality in the future, new studies must tackle this problem with cost-effective and culturally compliant models.

The Cost to benefit ratio of using these new technologies also needs to be better assessed for economic analysis. Clinical outcomes were the focus of these studies, but they did not consider the parental satisfaction which needs ethical analysis as well.

The justification for this documental research is to first review the evidence from the last five years to create a summary of which new technologies can produce repeatable benefits for the behavioral management of pediatric patients. Secondly, by evaluating the ethical, educational and practical aspects to offer suggestions that are safe and appropriate to use in the pediatric dental field, aiming to connect technological innovation with everyday dental care.

1.8. Theoretical Framework Summary

Psychology has a deep root in the foundation of technological behavior management in pediatric dentistry. There are four interconnected psychological frameworks that can explain how the new digital tools today influence anxiety, attention span and patient cooperation.

Behavioral learning theory which stemmed from Skinner's operant conditioning states that any behavior can be influenced and shaped by reinforcement. Mobile applications and social

robots have the ability to use positive feedback loops including rewards and tracking progress to encourage cooperation from the patient (7).

Cognitive-distraction theory states that a patient's attention is a finite resource. VR or AR has the ability to distract the patient's attention from painful stimuli by immersing them into a virtual environment or producing significant sensory stimuli (6).

Social-learning theory is a framework from Bandura and underlines observational learning. Bandura states that children model behavior displayed by role models. Social robots can act as a type of role model towards children and because these robots are calm and cooperative, children will emulate this same behavior (11,16).

Self-efficacy theory is a later framework from Bandura that emphasizes how important it is to has belief in one's ability to complete a task successfully. Mobile applications that are educational and AR experiences that teach a child about a certain treatment can give them a sense of control and competency which will in turn calm them down reducing anxiety (17, 18).

The theoretical framework offers an organised description for why introducing digital tools into pediatric dentistry can be useful. these technologies incorporate the psychological principles to minimize fear, anxiety, increase trust and encourage trust in the relationship between patient and clinician.

1.9. Current state and Research context

During the last 5 years the landscape for new technologies being used for behavioral management in pediatric patients has expanded substantially. The number of articles regarding this subject has more than doubled, which shows the junction between dental research and fields such as biology, psychology and computer science.

Quantitative analysis's overwhelming show reduced levels of anxiety and across most of these interventions. VR has taken the biggest chunk of this effect size by reducing pain perception and anxiety from between 40 % to 60 % compared to the control states (15). Mobile

applications have average benefits but seem to be useful in maintain an oral hygiene routine. AI and AR have shown in early trials that there is promise with their use in pediatric dentistry with their use in emotion recognition and educational guide (11).

Overall parental and dentist scores are high in terms of satisfaction, with parents reporting a greater trust in the use of these technologies when explained with transparency and dentists reporting increased treatment efficiency. Still, methodological standardization is a missing ingredient in this recipe.

In the past 2 years there has been collaboration between dental schools, psychologists and engineers creating an interdisciplinary approach. These groups have started to research the merging of VR and AI together to adjust stimuli in real time (14). Early findings suggest a higher level of engagement and patient cooperation.

The current state of evidence behind this topic reinforces the clinical practicality and psychological effectiveness of these technologies, but it also shows the need for more standardization protocols and long-term data results.

1.10. Integrative Summary and Study Purpose

In a nutshell, pediatric dental anxiety continues to be a worldwide issue and has a direct effect on quality of treatment, patient and parent satisfaction as well as productivity. Traditional behavioral management techniques such as tell-show-do, positive reinforcement and modeling still are a foundational aspect of pediatric dental treatment, but they have their insufficiency's. They lack sufficient sensory stimulation and cannot grab the attention of this day and ages digitally innate children. Emerging technologies like VR, AR, AI, mobile applications and social robots show real promise as the next series of steps leading into modern era pediatric dental care.

Fairness, accessibility, clinical accountability, and compliance with privacy regulations are all necessary for ethical integration. Human empathy and communication must be supplemented by these instruments, not replaced. To guarantee safe, equitable, and informed adoption in a variety of healthcare situations, education and training are essential.

The current documentary research critically examines how these technologies can improve pediatric dentistry practice while reviewing current information from the past 5 years. This work attempts to add to evidence-based suggestions for future adoption by assessing their clinical efficacy, theoretical foundations, and ethical implications. In the end, the combination of behavioral science and technological advancement has the potential to develop a pediatric dentistry model that is more sympathetic, interesting, and successful—one that balances clinical brilliance with each child's emotional health.

2. OBJECTIVES

2.1 Primary Objective

- To evaluate if the use of new technologies such as VR and AI provides significantly greater reduction in anxiety and improved behavioral outcomes in pediatric dental patients compared to traditional non-pharmacological techniques

2.2 Secondary Objectives

- To compare the advantages and limitations of new technologies versus traditional behavior management techniques such as tell-show-do and positive reinforcement
- To analyze the impact that virtual reality and artificial intelligence technologies have on pain perception, anxiety reduction, and treatment acceptance in pediatric dental patients undergoing clinical procedures.

3. MATERIAL AND METHODS

3.1. Focused Question

To approach our question, we followed the guidelines for creating a PICO question *"Does the use of new technologies such as VR and AI provide significantly greater reduction in anxiety and improved behavioral outcomes in pediatric dental patient compared to traditional non-pharmacological techniques?"*

3.2. Search Strategy

A number of electronic databases, including Medline, Dentistry & Oral Sciences Source, Scopus, and Cochrane, were searched. Only English-language studies with complete texts were included in the search. A manual examination of the reference lists of the included studies and earlier systematic reviews yielded additional pertinent papers. The following formula was used to do the search: [[[[Pediatric Dentistry] AND [Behavioral Management Techniques] OR [New Technologies]] OR [Virtual Reality]] AND [Anxiety Reduction]

3.3. Inclusion Criteria

- Studies focused on pediatric dental patients
- Studies from the past 5 years
- Studies that were available in English
- Randomized clinical trials, cross-section studies, Experimental studies
- Children and Parents

3.4. Exclusion Criteria

- Studies involving the non-dental healthcare setting
- Studies that did not focus on behavior management or anxiety reduction
- Case reports, editorials or opinion pieces with empirical data
- Studies with a lack of technological aspect relevant to behavioral management in children

4. RESULTS

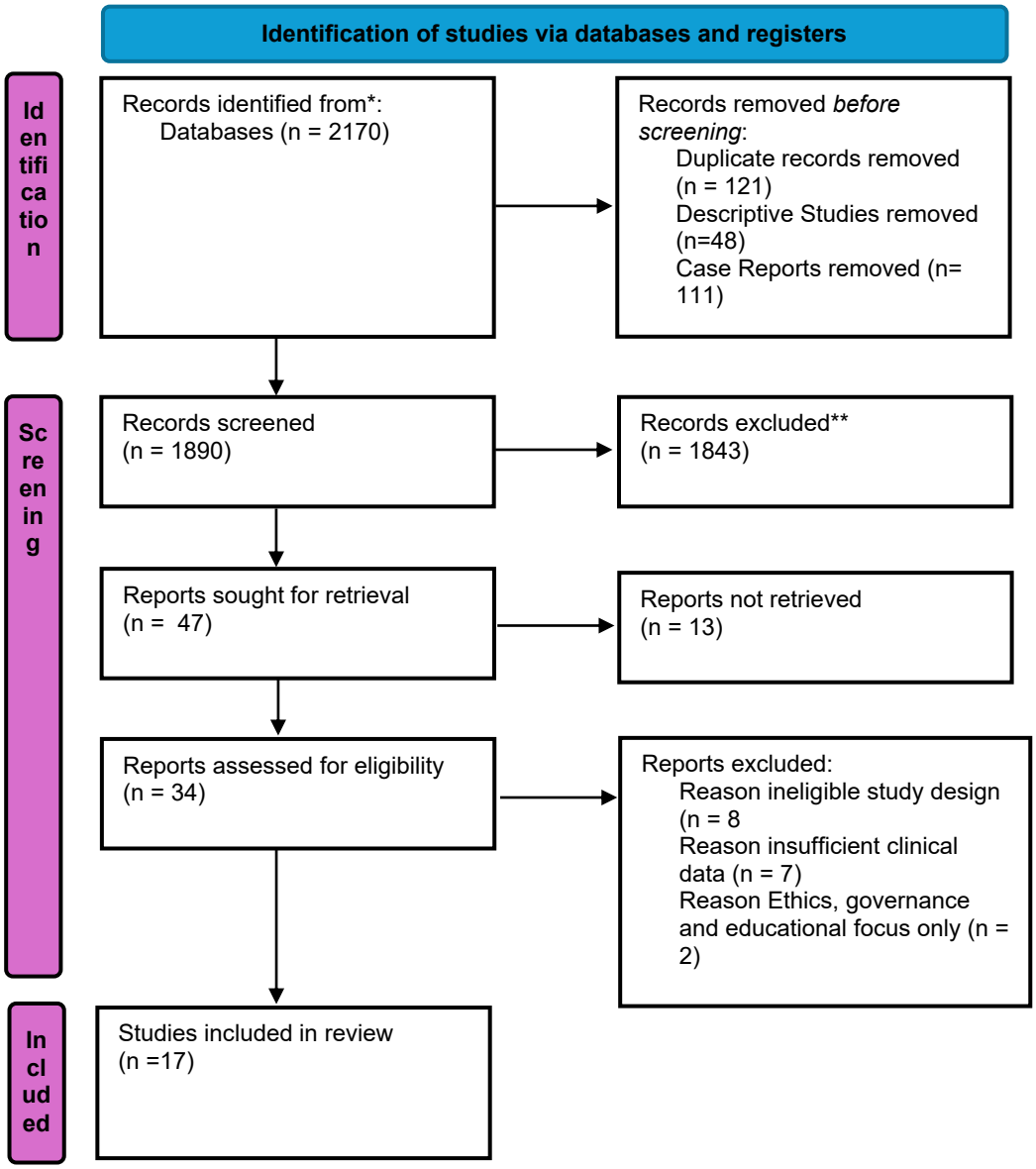


Figure. 1. Prisma search strategy flowchart

This review included 17 randomized controlled clinical trials (RCTs) that were used to evaluate different strategies for new technology-based behavior management techniques on pediatric dental patients. There were 10 studies that assessed using VR technology as the main

intervention, 4 studies used AR and mobile applications, and 3 studies focused on AI and robotic intervention.

The primary database search included 2170 records that were identified from databases such as Medline, Cochrane, Scopus and PubMed. Removal of articles included 121 due to being duplicates, 48 due to being descriptive studies and 111 due to being case reports. Afterwards 1843 records were excluded based on non-randomized design, focusing on adult population, non-clinical research and non-dental related applications.

47 reports were sought for retrieval and 13 could not be retrieved. 34 reports were assessed with full texts for eligibility. 8 were removed due to ineligible study design, 7 had insufficient clinical data to be evaluated and 2 had solely an educational/ethical focus. This screening resulted in a total of 17 RCT studies to be included in this review.

All studies measured characteristics such as anxiety levels, perception of pain, patient cooperation, and indicators such as heart rate and salivary cortisol/amylase. All follow ups were either immediate intraoperative assessment or short-term post-operative assessment.

Several studies also compare conventional behavioral management techniques (tell-show-do, audiovisual distraction) with newer immersive VR techniques. Augmented reality studies assessed patients' anxiety levels when administering local anesthesia. Smart phone applications were used to also help lower patient anxiety pre-treatment as well as during. AI animated instructional videos were combined with conventional communication techniques in some studies. One study specifically focused on using humanoid robots as a distraction technique. These RCTs provided new insights into how effective new digital technologies can be when they are integrated into pediatric dental procedures.

Table 1 Summary of the main characteristics of the 17 RCTs analyzed in this study

Authors (years)	Study design	No. patients & gender	Groups	Outcomes
Ran et al., 2021	RCT	120 Participants aged 4-8 years old	Treatment Group (T): VR distraction Control Group (C): Conventional behavioral management techniques	Statistically significant reduction in anxiety and pain in VR group ($P < 0.05$) compared to Control group
Bagher et al., 2023	RCT	36 Participants aged 6-14 years old	T: VR distraction C: Watching cartoon on screen	Statistically significant reduction in salivary cortisol levels in VR group ($p < 0.001$) compared to control group
Zaidman et al., 2023	RCT	29 participants which an average age of 8.29 years old	T: VR distraction C: Conventional behavioral management techniques	Statistically significant lower pain perception in VR distraction group ($P < 0.005$) compared to control group
Salama et al., 2024	RCT	40 participants aged 5-7 years old	T: VR glasses distraction C: Conventional behavioral management techniques	No statistically significant difference between groups.

Mayer et al., 2023	RCT	184 participants aged 10-19 years old	T: Smartphone application (FALE) questionnaire aimed at reducing dental anxiety before treatment C: Conventional questionnaire aimed at reducing dental anxiety before treatment	Statistically significant reduction in anxiety in the treatment group ($P < 0.001$) compared to control group
Albaal & Bshara, 2025	RCT	108 participants aged 7-9 years old	T1: AR headset used during injection T2: AR headset used only before dental injection T3: AR headset used before and during dental injection C: Cartoons being watched on mobile device during injection	Statistically significant reduction in discomfort and pain perception for all treatment groups compared to the control group ($P < 0.05$)
Kasimoglu, 2023	RCT	102 participants aged 4 to 10 years old	T: A Humanoid robot was used during treatment to guide patient behavior and reduce dental anxiety C: Conventional	Statistically significant reduction in pulse rates and post-treatment FIS scores in treatment group compared to control group ($P < 0.05$).

			behavioral management techniques were performed	
Bali et al., 2025	RCT	40 participants aged 6-13 years old who needed cavity pre were chosen	T: Piano music app using smartphone for active distraction during treatment C: Conventional behavioral management techniques	Statistically significant reduction in self-reported dental anxiety for treatment group ($P < 0.005$) compared to control group.
Guinot et al., 2021	Randomized Crossover Clinical Trial	84 participants aged 6-8 years old	T1: Active audiovisual distraction with PlayStation videogames using Rimax iVision glasses during dental treatment T2: Passive audiovisual distraction through watching cartoons using Rimax Vision glasses during dental treatment C: Conventional behavioral	Statistically significant reduction in self-reported pain between control ($P = 0.016$) and treatment ($P = 0.013$) groups with the lowest being PlayStation video game group. No significant differences found in other variables assessed with the use of active distraction ($P > 0.05$)

			management techniques	
Kasimoglu et al., 2025	RCT	90 participants aged 6-10 years old	T1: Active distraction using VR glasses during pulpotomy treatment T2: Passive distraction using screen mounted on dental unit to watch cartoons during pulpotomy treatment C: Conventional behavioral management techniques	Statistically significant reduction in pulse rates of children in T1 post-treatment compared to pre-treatment ($P < 0.05$). No statistically significant differences found between groups in terms of pain perception or fear before and after treatment ($P > 0.05$)
Felemban et al., 2021	RCT	50 participants aged 6-12 years old	T: Local anesthesia administered while patients watched cartoon videos on VR goggles C: Patients watched cartoon video on screen during administration of anesthesia	Younger patients and specifically females reported higher pain level scores ($P= 0.034$ and $P= 0.004$) during the anesthesia regardless of the type of distraction used.

Selvaraj et al., 2025	RCT	66 participants aged 9-12 years old	T1: Preoperative Immersive VR exposure group T2: Preoperative non-immersive VR exposure C: Conventional behavioral management techniques	Statistically significant reduction in dental anxiety was observed in T1 and T2 compared to control group (T1 vs control: P= 0.008, T2 vs control: P= 0.009)
Ustun et al., 2025	Randomized Crossover Clinical Trial	68 participants aged 4-9 years old	T1: Cartoon assisted distraction technique during dental treatment C: Conventional tell-show-do method during dental treatment	No statistically significant differences between treatment group and control group were found.
Mohammadi et al., 2025	RCT	36 participants aged 6-12 years old	T1: Patients undergoing local anesthetic using VR goggles C: Patients undergoing local anesthetic without VR goggles	Statistically significant reduction in anxiety and heart rate was found in the treatment group compared to the control group (P < 0.001).

Balik & Usluoglu, 2024	RCT	60 participants aged 7-9 years old	T1: VR goggle usage for pre-treatment procedure explanation C: No VR goggle usage for pre-treatment procedure explanation	Statistically significant reduction in anxiety was found in the treatment group compared to the control group ($P < 0.05$)
Gomez-Polo et al., 2021	RCT	80 participants aged 5-10 years old	T1: VR headset used during dental treatments C: Conventional behavioral management techniques	Statistically significant reduction in anxiety was found in the treatment group compared to the control group ($P < 0.05$). Child behavior was also statistically significantly improved with treatment group as well compared to control ($P < 0.05$)
Vitale et al., 2025	RCT	42 participants aged 5-10 years old	T1: Explanation of treatment using AI animated videos and tell-show-do technique C: Explanation of treatment using only tell-show-do method	Statistically significant reduction in anxiety found in the treatment group compared to the control group ($P < 0.001$). Treatment group showed significantly lower MDAS scores compared to control group. No statistically significant differences between groups were found on Behavior (FLACC scale) ($P > 0.05$)

5. DISCUSSION

The purpose of this documental research review was to determine whether new digital technologies that are emerging can have a significant positive effect on the behavioral management of pediatric dental patients. There seems to be a clear trend towards the use of immersive and interactive technologies such as virtual reality, robotics, smartphone applications and augmented reality.

5.1 Virtual reality as a Behaviour Management Tool

Virtual reality seems to be the most prominent choice for dentists when they are choosing new technologies to test behavioral management of pediatric patients. The majority of RCTs included in this review were evaluated using this new system of management. These studies concluded that using VR interventions has a significant reduction in the anxiety levels and overall cooperation of the pediatric patients when undergoing dental procedures (1,2,19, 20). The results tend to support the idea that immersive digital environments do have a significant effect on reducing stressful stimuli for the patient.

Virtual reality inherently demands the attention of the child and occupies their cognitive space and by doing so allows them to divert feelings of pain and anxiety that are usually present when undergoing dental treatments. Specifically, studies that focused on using VR technology when undergoing invasive treatments such as local anesthesia and pulpotomies, showed a significant reduction in anxiety and pain perception (19, 20). These results support the use of VR and highlight the benefits it has towards children, specifically when they are put in these situations where they are vulnerable to stress.

Compared to more traditional behavioral management method VR may have the ability to produce stronger behavioural effects due to its immersive nature. Creating this environment for child by obtaining their attention, VR helps maintain focus away from the dental procedure at hand and in turn improves the patient's overall behavior during treatment (3, 21)

5.2 Comparison of Virtual reality with other digital distraction techniques

When comparing VR with other digital interventions, VR seems to have a stronger overall effect in reducing anxiety. Studies that evaluated VR technology had improvements in patient cooperation and reductions in anxiety compared to standard behavioral management techniques (3,26)

In contrast technologies such as smartphone applications and audiovisual distractions tools showed less of an effect on lowering patient anxiety. For example, a smartphone-based application studies that was designed specifically to educate patients on their dental procedure pretreatment also showed positive improvements in managing anxiety, but the overall effect was less significant than compared to VR interventions (7).

Audiovisual distraction systems also showed promise in improving patient behavior outcomes in pediatric patients, but their effectiveness depended highly on the level of interaction. Passive audiovisual distraction such as watching videos on a screen during treatment only provided a small amount of reduction in anxiety, whereas active audiovisual distraction such as playing videogames appeared to have significant positive effect (18,22).

These findings show that the level of immersion and engagement that the patient is involved in plays a crucial role in how effective the digital distraction technique is for reducing anxiety. Technologies that actively involve the patient while being in an immersive environment show more promise and may be more successful in redirecting attention from the dental procedure at hand compared to more passive distraction methods.

5.3 Evidence from Guinot Randomized Clinical Trial

The study by Guinot et al. also supported the importance of active distraction strategies for pediatric patients to garner their full attention away from the treatment. The authors of this study compared both passive and active audiovisual distraction tools during pediatric dental treatments. The results portrayed that children undergoing active audiovisual distraction showed significant improvement in cooperation and a lower pain perception compared to those undergoing passive distraction methods.

These findings support the idea that distraction techniques that require active cognitive participation may be the more effective option for treating children during dental procedures. These findings fall in line with the broader trend across the included studies which is that digital technologies capable of actively grabbing a child's attention such as VR or interactive audiovisual systems can enhance the behavioral management outcomes in pediatric dentistry (1,2,4,22)

5.4 Emerging Technologies: Augmented Reality, Robotics, and Artificial Intelligence

Beside VR and audiovisual distraction, other studies in this review explored other technological approaches for behavior management in children. Albaal & Bshara. 2025 explored the use of augmented reality during anesthetic injection and reported significant reductions in both pain perception and anxiety levels among their pediatric patients. AR based research is now limited in pediatric dentistry but shows promise for future development.

Another technology that was researched involved the use of humanoid robots as companions to pediatric patients during dental treatments. Kasimoglu Y. 2013 used the presence of robotic assistants during pediatric dental treatments and found that their presence resulted in reductions in both anxiety and physiological stress (salivary amylase levels). This clinical trial showed how socially interactive technologies may have the ability to improve pediatric patient comfort and cooperation during dental procedures.

AI has seen major improvements in its abilities this decade and this has been applied to behavioral management techniques for pediatric patients as well. Vitale et al. 2025 demonstrated in their study how AI-based instructions videos combined with traditional behavioral management techniques can reduce dental anxiety in children prior to treatment. AI technology has the potential to enhance patients understanding of dental procedures and in turn may reduce their anxiety about the treatment.

5.5 Variability Between Studies

The consensus in many of the studies reported in this review were positively associated with using new technologies for behavioral management techniques in pediatric patients, yet variability in the results was also included across the RCTs. The differences in the study populations, treatment protocols, and interventions may explain part of these variations. For example, some studies evaluated immersive VR environments during active dental treatment where others only used VR as a pre-treatment method to educate patients beforehand (23,24).

Outcome measures used to evaluate dental anxiety and behavior also varied between the studies. Researchers used a range of validated scales, physiological indicators and observational methods. This difference scales can make it challenging to compare results of different studies and can skew the magnitude of the treatment effects.

5.6 Limitations of the Study

There are four distinct limitations that should be considered when evaluating the findings of this review. The first includes that although all studies were RCTs the sample size of each study was relatively small and can limit the generalizability of the results. Small study populations may increase variability in the reported outcomes and reduce statistical power.

Secondly, the studies in this review evaluated a wide range of technologies such as VR systems, AR tools, smartphone applications, robots, and audiovisual distraction methods. This diversity in intervention types and study designs makes the direct comparisons between these studies challenging and affects the ability for fair quantitative analysis.

Thirdly, the variability in outcome measures used to evaluate anxiety and behavior may affect the comparability of the results across the studies. Furthermore, most studies were assessed on short-term procedures and timelines. The long-term impact of using new digital technologies for behavioral management on children's attitudes toward dental care remains unknown.

Lastly, social and cultural differences between study populations may also influence the interpretation of the results. The randomized controlled trials included in this review were conducted in different countries and healthcare settings, where cultural attitudes toward dental treatment, levels of dental anxiety, and communication styles between clinicians and patients may vary. These differences may affect how children perceive dental procedures and respond to behavioral management strategies. Therefore, the effectiveness of digital technologies for anxiety reduction may not be identical across different cultural or social contexts, and caution should be taken when generalizing the findings to all pediatric populations.

5.7 Implications for Clinical Practice and Future Research

Despite the limitations stated for this review the findings do suggest that new technologies do have a high potential to improve behaviour management techniques in pediatric dentistry. Immersive and interactive technologies show the capability to reduce dental anxiety, improve patient cooperation, and facilitate the delivery of dental care in young patients

From a clinical perspective, using tools such as VR headsets, AR systems, smartphone applications and audiovisual distraction methods may help dentists create a more positive and

welcoming environment for children. Potentially replacing the need for more invasive behaviour management techniques of the past.

Further research in this area should focus on using larger population sizes with standardized outcome measure so the comparability of the results across studies can improve. Long term studies should also take place to evaluate the effect these new technologies have on the attitude of children towards dental care. Additionally future research needs to as well take into the account the cost-effectiveness and practical integration of these technologies into the routine dental practice.

In all, the continued research of new digital technologies in pediatric dentistry may contribute to the development of a more patient-centred approach to behavior management and in the end improve the overall dental experience for pediatric patients.

6. CONCLUSIONS

1) The use of new technologies such as VR and AI provides a greater reduction in dental anxiety and improved behavioural outcomes compared to traditional non-pharmacological techniques. The reviewed randomized controlled trials consistently demonstrated enhanced patient cooperation and reduced anxiety levels when digital interventions were used during pediatric dental procedures.

2) New technologies present several advantages over traditional behavior management techniques, although some limitations remain. Digital tools such as VR offer higher levels of engagement and distraction compared to methods such as tell-show-do and positive reinforcement; however, factors such as cost, accessibility and clinical integration must be considered

3) VR and AI technologies have a positive impact on pain perception, anxiety reduction, and treatment acceptance in pediatric dental patients. These effects were particularly evident during invasive clinical procedures, where immersive and interactive technologies contributed to improved patient experience and cooperation.

7. SUSTAINABILITY

This Final Degree Project contributes to sustainable development in pediatric dentistry by encouraging new approach's involving non-invasive techniques and new technology for the management of dental anxiety and fear in children. Artificial intelligence along with augmented reality, virtual reality and mobile health applications have shown be to a very effective approach for minimizing the needs of disposable dental materials and pharmacological drugs. Instead replacing it with a reusable digital approach that supports environmental sustainability and aligns with Sustainable Development Goal 12 (SDG).

Economic sustainability also is improved through these technologies because these new digital behavior management techniques decrease the number of cancelled appointments, provide better efficiency in workflow and reduce overall treatment time. Augmented reality and virtual reality headsets are new innovations that are cost-effective and scalable solutions that aim to lower the financial pressure on families as well as healthcare systems worldwide. This addresses the SDG 9 (Industry, Innovation, and Infrastructure) by promoting the use of new innovative digital technologies to help lower costs for the patients and at the same time helping transform the dental industry for the better.

Coming from a social viewpoint the effects that these digital technologies have for behavior management on children is very apparent. Children have less fear and anxiety when using these technologies during treatments, improving the overall experience and mental wellbeing. These implementations contribute to SDG 3 (Good Health and Well-Being) by allowing the pediatric dental treatment process to be more effective as well as supportive emotionally.

All in all, the research provides a strong bases for ethical and professional commitment to encouraging a sustainable patient focused development in pediatric dentistry. Digital solutions are economic, efficient, ethical and most of all improve the overall social well-being for children that have any kind of anxiety towards going to the dentist.

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9. ANNEXES