

QUALITY IMPLICATIONS OF VIRTUAL REALITY ASSISTED DISTRACTION PROTOCOLS IN PEDIATRIC DENTAL CARE: A SYSTEMATIC REVIEW

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Purpose: The increasing integration of immersive technologies into healthcare has stimulated interest in their potential to enhance pediatric patient experience, particularly in procedures associated with high levels of anxiety and stress. This study aims to systematically evaluate the application of Virtual Reality (VR) as a distraction modality in pediatric dentistry and to assess the extent to which quality-of-care indicators are incorporated into existing research.

Design/methodology/approach: A structured literature review was conducted using PubMed and Scopus databases in accordance with PRISMA guidelines. Predefined eligibility criteria were applied, and data were extracted using a standardized protocol. The analysis focused on the effectiveness of VR interventions and the presence of quality-of-care dimensions in the reviewed studies

Findings: The review identified a limited but growing body of evidence indicating that VR interventions effectively reduce perceived pain and anxiety during pediatric dental procedures. However, the findings reveal a significant gap in the literature, as most studies do not incorporate comprehensive quality-of-care indicators, such as process reliability, patient-centeredness, or outcome-based performance measures.

Research limitations/implications: The study is limited by the relatively small number of available studies and the heterogeneity of research designs. Future research should incorporate validated quality indicators and adopt more standardized methodologies to enable a more comprehensive evaluation of VR-supported care in pediatric dentistry.

Practical implications: The findings suggest that VR can be a valuable supportive tool for improving patient experience in pediatric dentistry. However, its implementation should be accompanied by systematic quality assessment frameworks to ensure its contribution to overall care quality.

Social implications: By reducing anxiety and improving the treatment experience for children, VR interventions may enhance patient well-being and increase acceptance of dental care. This has broader implications for public health, including improved oral health outcomes and reduced long-term treatment avoidance.

Originality/value: This study contributes to the literature by combining a systematic evaluation of VR effectiveness with a critical assessment of quality-of-care measurement in pediatric dentistry. It highlights an important gap between technological innovation and quality management in healthcare.

Keywords: virtual reality, pediatric distraction, quality indicators, dental care, patient experience.

Category of the paper: literature review.

1. Introduction

Dental anxiety in children is a persistent challenge that disrupts behavioral cooperation, prolongs clinical procedures, and contributes to patterns of avoidance that compromise both individual health outcomes and the operational efficiency of dental services (Marshman et al., 2016; Grisolia et al., 2021). Studies show that 36% of children globally experience dental anxiety and 20% dental fear and anxiety (Grisolia et al., 2021; Sun et al., 2024). Numerous children witness also dental phobia what causes the avoidance of visits and continuity of a treatment (Rosa et al., 2023). Virtual Reality (VR) has emerged as a promising behavioral guidance tool capable of modulating attention and mitigating anxiety through immersive distraction (Gerçeker et al., 2021; Yıldırım, Gerçeker 2023).

Previous research has substantially advanced the understanding of dental anxiety in pediatric populations and the potential role of VR as a non-pharmacological distraction tool in dental care. Epidemiological studies and meta-analyses have demonstrated that dental fear and anxiety are highly prevalent among children and adolescents and constitute a clinically significant barrier to effective and efficient dental treatment (Grisolia et al., 2021; Sun et al., 2024). Elevated anxiety levels are associated with poorer patient cooperation, prolonged procedures, and avoidance of dental visits, which negatively affect both treatment outcomes and the quality-of-care processes. At the same time, a growing body of empirical evidence indicates that VR-based distraction interventions can reduce perceived pain, anxiety, and physiological stress responses during pediatric dental procedures, with additional indications of improved cooperation and treatment experience (Cunningham et al., 2021; Yan et al., 2023; Zhao et al., 2023; Rosa et al., 2023; Goodship, Taylor, 2025). Clinical studies further suggest that the benefits of VR may be procedure-dependent, with more pronounced effects observed during longer and more demanding interventions that require sustained attention and cooperation from the child (Zaidman et al., 2023). Collectively, these findings position VR as a promising supportive tool for enhancing selected patient-centered aspects of care in pediatric dentistry. Despite these advances, the existing literature remains fragmented and heterogeneous with respect to both the VR technologies employed and the outcome measures used to evaluate their impact. Research to date has predominantly focused on short-

term effectiveness indicators, such as reductions in anxiety and pain, while broader quality-of-care dimensions, including process-related indicators, physiological stress markers, safety, acceptability of the intervention, and overall patient experience, have received comparatively limited attention (Cunningham et al., 2021; Yan et al., 2023; Zhao et al., 2023). The lack of a systematic synthesis integrating evidence on the technological characteristics of VR interventions and the quality metrics applied across studies limits comparability and hinders the development of coherent, evidence-based recommendations for clinical practice. This gap provides a clear rationale for conducting a systematic review that systematically organizes existing evidence on the use of VR in pediatric dental distraction protocols and critically examines how quality-of-care indicators are incorporated into current research.

At the same time, the perspective of the pediatric patient constitutes a central reference point for evaluating the quality of dental care. Dental fear and anxiety are highly prevalent among children and adolescents and have a substantial impact on patient cooperation, the course of clinical procedures, and long-term attitudes towards oral health care (Grisolia et al., 2021; Sun et al., 2024). In pediatric contexts, quality of care cannot be assessed solely in terms of the technical correctness of procedures but should also encompass the child's subjective experience, comfort, perceived safety, and ability to cope with the clinical environment. Technology-based distraction interventions, such as VR, directly target these experiential dimensions by modulating anxiety levels, pain perception, and emotional and physiological responses during treatment (Yan et al., 2023; Zhao et al., 2023). From a quality-of-care perspective, this implies that the evaluation of VR and other emerging technologies should be embedded within a patient-centered care framework, in which the experiences and needs of pediatric patients constitute a key criterion for assessing the value of clinical interventions (Cunningham et al., 2021).

Understanding the factors that contribute to dental anxiety and dental phobia is essential, as it influences further steps as avoidance of the dental visits, what shifts care from preventive to symptom driven. The delays of appointments caused by anxiety is the beginning of the cycle (Kapil et al., 2021) (Fig. 1, Fig. 2).

As healthcare systems increasingly prioritize patient centered care, non-pharmacological strategies that enhance comfort, reduce distress, and support predictable treatment flow have become integral to quality improvement efforts in pediatric areas. It is also essential to recognize that improving the process requires simultaneous consideration of three key factors: quality, response time, and cost (Cost & Effect: Using Integrated Cost Systems to Drive Profitability and Performance, 1998).



Figure 1. Factors of children's dental anxiety (Kapil et al., 2021).

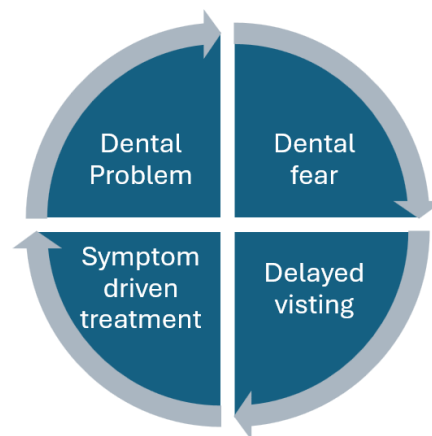


Figure 2. Vicious cycle of dental fear (Kapil et al., 2021).

Current evidence base is marked by heterogeneity in VR content, delivery methods, study designs, and outcome measures. There is limited number of clinical trials, and the existing literature remains fragmented and heterogeneous with respect to both the technological interventions employed and the ways in which their impact on quality of care is assessed. Prior empirical research has predominantly focused on narrowly defined, short-term effectiveness outcomes, such as reductions in anxiety and pain, while less attention has been devoted to a broader set of quality metrics, including process-related indicators, physiological stress markers, safety, acceptability of the intervention, and overall patient experience (Cunningham et al., 2021; Yan et al., 2023; Zhao et al., 2023). The lack of a systematic synthesis of evidence regarding which new technologies are being used in distraction protocols and which specific quality metrics are applied to evaluate their impact limits comparability across studies and hinders the development of coherent, evidence-based recommendations for clinical practice. Therefore, there is a clear rationale for conducting a systematic review that organizes the existing empirical evidence on the use of new technologies, such as VR, in pediatric distraction protocols and critically examines the quality metrics employed to assess their effects on quality of care.

2. Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. A PICO search was defined, and studies that fulfilled the following criteria were selected: population (P): young adults, youth, children (0-18), intervention (I): Use of Virtual Reality (VR) distraction in dentistry across different clinical use cases, comparison (C): standard care without VR or alternative distraction/behavior management techniques, outcomes (O): quality indicators.

Questions for the systematic review was: Does the use of virtual reality in dental anxiety in pediatric patients impact quality of the process? Which of the quality-of-care indicators are incorporated into existing research?

All English-language human studies reporting on children and adolescents under 18 undergoing dental treatment involving virtual reality. The exclusion criteria were studies exclusively adults, non-dental studies, non-English language papers, using VR as educational/training tool for medical staff. No exclusions were made from comparison groups. Search was performed without filtering limited time frame (1998-2026).

The search strategy was conducted on two databases by combining subject heading terms with keywords and text words. Search terms were “virtual reality”, “pediatric”, “quality”. The final search was carried out on 11th of January 2026.

All relevant studies fulfilling the inclusion criteria were included in this review (see figure 3). After removing duplication, a list of 383 abstract remained. The title and abstract screening were prepared to include only publications relevant to dentistry. Based on eligibility criteria 24 articles were assessed.

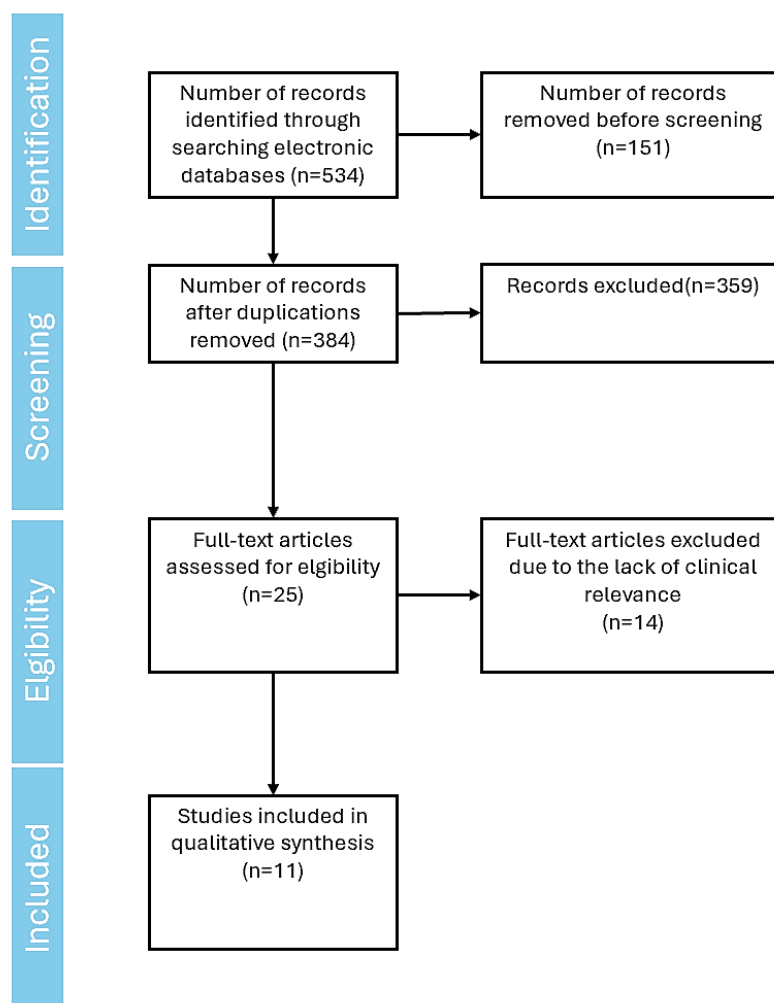


Figure 3. PRISMA diagram.

The applied PRISMA-based approach ensured a systematic, transparent, and reproducible study selection process. The final sample of studies ($n = 11$) constitutes a relevant and methodologically consistent basis for examining the impact of virtual reality interventions on pediatric dental anxiety and their integration with quality-of-care indicators.

3. Results

Dental anxiety among children and adolescents constitutes a significant public health problem that has a substantial impact on the quality of dental care, both in clinical and experiential terms. Global meta-analyses indicate that the prevalence of dental fear and anxiety in pediatric populations remains high, with a considerable proportion of children experiencing pronounced anxiety in relation to dental visits (Grisolia et al., 2021; Sun et al., 2024). Elevated levels of dental anxiety directly affect the course of treatment by reducing patient cooperation, increasing avoidance of dental appointments, and intensifying the subjective experience of pain.

In routine clinical practice, high anxiety is also associated with a greater need for pharmacological behavior management techniques, which increases the burden on healthcare systems and may expose patients to additional risks of adverse effects.

Consequently, the identification and implementation of effective non-pharmacological strategies for anxiety reduction represent an important pathway towards improving the overall quality of pediatric dental care. Within this context, virtual reality has emerged as a promising supportive intervention for managing anxiety and procedural stress. Systematic reviews and meta-analyses of clinical studies demonstrate that the use of VR as a sensory distraction technique leads to a significant reduction in situational anxiety among pediatric patients during dental procedures (Yan et al., 2023; Zhao et al., 2023). This effect is primarily attributed to the high level of immersion afforded by VR, which engages children's attentional resources and limits the cognitive processing of anxiety-provoking stimuli, such as the sounds of dental instruments or tactile sensations associated with treatment. Reductions in anxiety have direct implications for quality of care, as they increase patients' tolerance of clinical procedures, reduce avoidance behaviors, and limit oppositional reactions during treatment, thereby facilitating a more predictable and efficient clinical workflow (Goodship, Taylor, 2025). An important dimension of the impact of VR concerns pain perception and overall patient comfort. Empirical studies indicate that VR effectively reduces the subjective experience of pain in children undergoing dental treatment, a finding that can be explained by attentional theories suggesting that immersive virtual environments compete with nociceptive stimuli for limited cognitive resources, thereby attenuating the perception of aversive sensations (Zhao et al., 2023). The meta-analysis by (Yan et al., 2023) further suggests that VR-based interventions may be more effective in reducing anxiety and discomfort than traditional distraction techniques, such as watching videos on tablets or listening to music. Improvements in patient comfort are relevant not only from a subjective perspective but also in procedural terms, as children who experience less pain and anxiety are more likely to remain still during treatment. This facilitates more precise execution of clinical procedures, shortens treatment duration, and reduces the risk of complications arising from sudden patient movements (Goodship, Taylor, 2025).

Another mechanism through which VR may enhance the quality of pediatric dental care relates to improved patient cooperation and clinical efficiency. The level of cooperation displayed by children is a critical determinant of treatment success, and although conventional behavior guidance techniques, such as tell-show-do, modelling, and positive reinforcement, constitute the foundation of pediatric dental practice, their effectiveness may be limited in highly anxious patients (Kapil et al., 2021). In this regard, VR can function as a complementary tool that strengthens the impact of traditional behavioral approaches by providing children with an engaging and emotionally positive alternative focus of attention. Reviews of the literature indicate that VR is associated with increased engagement of pediatric patients in the treatment process and reduced oppositional behaviors, thereby creating more favorable conditions for the

delivery of care in accordance with clinical standards and potentially enhancing the technical quality of performed procedures (Cunningham et al., 2021; Rosa et al., 2023). Contemporary conceptualizations of healthcare quality emphasize the importance of patient experience as a central dimension of quality of care. Positive experiences during dental visits in childhood play a crucial role in shaping long-term attitudes towards oral health-related behaviors in later life.

Evidence suggests that VR may contribute to more positive perceptions of dental visits by reducing the salience of negative memories associated with pain and fear and by enhancing acceptance of dental procedures (Rosa et al., 2023; Yan et al., 2023). Over the longer term, such positive experiences may translate into greater regularity of follow-up visits, improved cooperation in subsequent stages of treatment, and higher adherence to preventive recommendations. In this sense, VR may influence quality of care directly by improving the immediate conditions under which procedures are performed, and indirectly, by fostering more favorable attitudes towards dental care.

Despite the documented benefits, the effectiveness of VR is not universal and appears to be contingent upon several factors, including the child's age, level of cognitive development, individual sensory sensitivity, the type of VR technology used, and the nature of the dental procedure. Systematic reviews consistently point to substantial heterogeneity in study findings and variability in methodological quality, which limits the strength of conclusions that can be drawn regarding best practices for clinical implementation (Cunningham et al., 2021; Zhao et al., 2023). Moreover, a large proportion of available studies focus on short-term reductions in anxiety and pain, thereby constraining inferences about the durability of VR effects and their long-term implications for the quality of pediatric dental care across the broader treatment trajectory (figure 3).

The collective findings demonstrate that VR-based interventions consistently reduced pain, anxiety, and related physiological stress responses in pediatric dental settings, with several studies also indicating improvements in behavioral cooperation (Cunningham et al., 2021; Yan et al., 2023; Zhao et al., 2023; Rosa et al., 2023; Kapil et al., 2021; Fahim et al., 2022; Goodship, Taylor, 2025). Although methodological quality varied, the overall pattern of results suggests that VR functions as a reliable nonpharmacological method capable of enhancing the patient's experience across multiple dental procedures (see table 1).

Table 1.*An explanatory note for the summary of the systematic review*

LP	Authors	Title	Tools	Age group	Pain and Anxiety	Key points in the context of quality of the process	Limitations
1	Rosa, A., Pujia, A.M., Docimo, R., Arcuri, C.	Managing Dental Phobia in Children with the Use of Virtual Reality: A Systematic Review of the Current Literature	VR	Children ≤ 18 years (pediatric focus); some adult data included but not primary	Anxiety measured via MDAS, VAS; pain measured via VAS, FLACC; VR generally reduced pain in children; anxiety reduction mixed and not always significant	Pain Management and understanding of the mechanisms in managing DP, Improvement of the dental experience, ethical considerations, technical constraints, individual variations, costs, enhance positive dental experiences, improve cooperation, and facilitate behavior change	Ethical considerations; technical constraints; cost; individual variation in VR response; VR not adequate for children with severe anxiety; heterogeneity of included studies; limited number of high-quality RCTs
2	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	VR eyeglasses, VR smartglasses, VR box, audiovisual glasses; bespoke smartphone app, tablet device (active distraction comparator)	4-15 years	VR reduced pain and anxiety in three perioperative studies; anxiety measured via pulse rate and MCDAS; pain measured via Wong-Baker FACES, FLACC, Faces Pain Scale-Revised. Smartphone apps reduced behavioural distress and procedural attempts in ASD population	The Ambiguity of the 'Behaviour' Parameter, oral health-related quality of life, behavioural management (Tell-Show-Do), home-based preparation, long-term management of a dentally phobic child, individual variations (ASD)	Limited number of studies; small sample sizes; heterogeneity of interventions and outcome measures; exclusively perioperative use (no preoperative VR trials); methodological weaknesses; lack of blinding; high risk of bias; no standardised VR protocols; no long-term follow-up; exclusion of non-English studies; absence of meta-analysis due to insufficient comparable data

Cont. table 1.

3	Fahim, S., Maqsood, A., Das, G., Ahmed, N.; Saquib, S., Lal, A., Khan, A.A.G., Alam, M.K.	Augmented Reality and Virtual Reality in Dentistry: Highlights from the Current Research	VR, Augmented Reality (AR) visual tools	Children (exact ages not specified)	VR reduced anxiety and pain; decreased heart rate and pain scores when children watched cartoons via VR goggles	Effective communication, pre-treatment preparation, Improvement of dental experience, behavioural management	forming technological standards with high- quality data and developing scientifically proven AR/VR gadgets for dental practice
4	Fan, L., Zeng, J., Ran, L., Zhang, C., Wang, J., Yu, C., Zhao, N.	Virtual reality in managing dental pain and anxiety: a comprehensive review	VR	Children aged 4-17 years (majority between 4-10 years).	VR significantly reduced pain in most pediatric studies, including during local anesthesia, endodontic treatment, and dental surgery.	behavioural management, adverse reactions, individual variations (mild intellectual disabilities)	VR technology may cause certain adverse reactions, and it is recommended to evaluate and personalize its application before the dental procedure screening.
5	Goodship, N., Taylor, G.	Can virtual reality reduce anxiety and pain in dental patients?	VR	Children and adults; majority of included studies ($\approx 70\%$) focused on paediatric patients.	VR significantly reduced anxiety in children; no significant effect on adult anxiety. VR significantly reduced pain in both children and adults.	standardization of VR content needed effectiveness across different pediatric age groups and dental procedures	Heterogeneity of VR interventions; inconsistent outcome measures; small sample sizes; limited standardization of VR content; some studies lacked blinding; cybersickness reported in a minority of patients; no long-term follow-up; variability in procedure types; no preoperative home-based VR studies in children.
6	Kapil, D., Saraf, B.G., Sheoran, N., Kalra, G., Elizabeth, S.	Contemporary Behavior Guidance Techniques to Outsmart Child's Anxious Mind	VR	4-8 years	VR reduced anxiety and pain; measured using Wong-Baker FACES, MCDAS, pulse rate, oxygen saturation, salivary cortisol	behavioural management (Tell- Show-Do or Tell- Play-Do), quality oral health care safely, quality dental treatment	None (no VR-specific barriers reported in the review)

Cont. table 1.

7	Yan, X., Yan, Y., Cao, M., Xie, W., O'Connor, S., Lee, J.J., Ho, M.H.	Effectiveness of virtual reality distraction interventions to reduce dental anxiety in paediatric patients: A systematic review and meta-analysis	VR glasses; VR head-mounted display; VR box (smartphone-based)	4-12 years	VR significantly reduced anxiety, pain and heart rate on caries treatment, dental fillings, pulp therapy and inferior alveolar nerve block, but no significant effect on teeth extraction; measuring using MCDAS-f, CFSS-DS, FIS, CPMAS and VPT	general oral health, effectiveness	High heterogeneity; methodological weaknesses; inadequate allocation concealment; absence of double blinding; limited database search; predominance of pediatric and female samples reducing generalizability; lack of standardized VR protocols; inconsistent outcome measures; insufficient control of confounders
8	Gandhi, M., Lakade, L., Kunte, S., Patel, A., Shah, P., Chaudhary, S.	Effect of Virtual Reality and Musical Earplug Temporal Tap Technique in Reduction of Gag Reflex in Pediatric Patients	VR, Musical Earplug Temporal Tap Technique (METTT); Standard leg-lift distraction (baseline)	6-12 years	Heart rate, oxygen saturation, and Faces version of MCDAS were measured; METTT reduced heart rate (anxiety indicator); VR showed no significant effect	Quality dental care, effectiveness	However, neither VR nor METTT helped mitigate the gag reflex. There is minimal literature evidence; therefore, more research is needed to manage or reduce the gag reflex during impression making and creating a comfortable experience for the patient
9	Parakh, H., Thosar, N.	Evaluation and comparison of the effectiveness of kaleidoscope and virtual reality goggles to reduce dental anxiety in young children undergoing administration of local anesthesia	Kaleidoscope, VR	5-8 years old	Study not yet started; no empirical results available.	Standardized procedures (local anesthesia for pulpectomy or extraction) exist, effectiveness, quality dental care, behavior management	Exclusion of children with past dental experience may limit generalizability; lottery randomization less robust than computerized methods; limited literature on kaleidoscope use; potential variability in behavioral responses; resource constraints (e.g., software for randomization).

Cont. table 1.

10	Stan, D., Voicu, D., Zainea, P., Toma, A., Ciubară, A.	Reframing Dental Anxiety: Cognitive Behavioral Therapy and Its Role in Phobia Treatment-A Narrative Review	VR	No specific age ranges provided	VR reported to reduce pain and anxiety in pediatric dentistry according to cited scoping reviews and RCTs; VR shown to reduce procedural anxiety and discomfort during invasive procedures.	Quality of life, Cost-effectiveness, long-term comparative trials, behavior management	Yet, regulatory, ethical, and privacy issues remain barriers to clinical deployment. Limited long-term data; lack of standardized VR protocols; insufficient high-quality pediatric trials; variability in study designs; accessibility issues; need for tailored approaches for children with developmental or psychiatric comorbidities.
11	Pradnya, D., Pathak Laxmi, S., Lakade Krishna, V., Patil Preetam, P., Shah Alok, R., Patel Rucha, N., Davalbhakta	Clinical evaluation of feasibility and effectiveness using a virtual reality device during local anesthesia and extractions in pediatric patients	VR	6-12 years	The use of virtual reality devices in children is not able to reduce pain following deciduous molar extraction, measuring using VPT, WBS, FLACC	Quality dental care, behavior management methods, effectiveness	For the age group of six to eight years old, the device was hefty and the headphones were not well fitted, which made it challenging to totally muffle outside noises. The larger size of the device led to difficulty in assessing the facial expression component of the FLACC score. The smaller sample size and the inability to blind could have led to certain biases.

Abbreviations: MDAS – Modified Dental Anxiety Scale; MCDAS – Modified Child Dental Anxiety Scale; FIS – Facial Image Scale, VAS – Visual Analogue Scale; VPT – Venham’s Picture Test; CFSS-DS – Children’s Fear Survey Schedule-Dental Subscale, FLACC – Face, Legs, Activity, Cry, Consolability Scale; ASD – Autism Spectrum Disorder; METTT – Multidimensional Evaluation Tool for Therapeutic Technologies, CPMAS – Children’s Perioperative Multidimensional Anxiety Scale, Wong-Bakers Faces pain rating scale (WBS).

Research on the use of virtual reality in pediatric dentistry most frequently relies on patient-oriented quality metrics, commonly referred to as patient-reported outcomes. These include, in particular, measures of dental anxiety, subjective pain perception, and satisfaction with the dental visit, often incorporating the perspectives of parents or caregivers. Dental anxiety is typically assessed using standardized psychometric instruments such as the Children's Fear Survey Schedule, Dental Subscale, the Modified Child Dental Anxiety Scale, and the Facial Image Scale. These tools are widely employed in clinical studies and systematic reviews, which allow for a certain degree of comparability across investigations. The meta-analysis of randomized controlled trials conducted by (Yan et al., 2023) identified dental anxiety as one of the primary quality-related outcomes used to evaluate the effectiveness of VR-based distraction interventions. Similarly, the review by (Rosa et al., 2023) highlighted CFSS-DS and MCDAS as the most commonly applied and well-established instruments for measuring dental anxiety in pediatric populations. In clinical trials such as the study by (Zaidman et al., 2023), the Facial Image Scale and behavioral observation measures were used to capture children's emotional responses during dental procedures. The widespread use of these instruments reflects the central role of subjective patient experience in contemporary conceptualizations of quality of care. Another key patient-oriented quality dimension concerns pain perception, which in pediatric dental research is most commonly measured using visual or pictorial rating scales, including the Wong-Baker FACES Pain Rating Scale and the Visual Analogue Scale. The meta-analysis by (Yan et al., 2023) demonstrated that pain intensity constitutes one of the core clinical quality outcomes in studies assessing VR interventions during dental treatment. Likewise (Zhao et al., 2023), identified pain reduction as a central quality indicator closely linked to patient comfort and overall procedural experience. In pediatric contexts, pain perception is particularly relevant, as heightened discomfort not only affects the child's immediate experience but also influences cooperation during treatment and shapes longer-term attitudes towards dental care, thereby serving as an important marker of care quality. In addition to anxiety and pain, patient and parent satisfaction is frequently included as a broader indicator of quality of care and user experience. Unlike anxiety and pain, satisfaction is rarely assessed using a single standardised instrument; instead, study-specific questionnaires are commonly employed to capture perceptions of the visit and acceptance of technology.

The systematic review by (Cunningham et al., 2021) noted that satisfaction with VR interventions and acceptance of the technology by children and caregivers are important components of perceived quality of care and are often reported as supplementary outcomes in studies examining technological distraction in pediatric dentistry. These measures provide insight into the feasibility and acceptability of VR in real-world clinical settings and inform assessments of its potential for routine implementation. Beyond subjective patient-reported outcomes, studies of VR in pediatric dentistry also incorporate physiological indicators that serve as objective proxies for procedural stress and quality of the treatment experience. Heart rate is the most commonly used physiological metric, interpreted as an indicator of

autonomic arousal and stress during dental procedures. Yan et al. (2023) included heart rate measures as objective quality-related outcomes in their synthesis of randomized controlled trials, reporting that VR-based interventions were associated with reductions in physiological arousal. Similarly (Zaidman et al., 2023), assessed heart rate before and during dental procedures to compare stress responses in VR-assisted and standard care conditions. Other autonomic measures, such as blood pressure, have been used less frequently and are mainly reported in individual trials included in meta-analyses (Yan et al., 2023). These physiological metrics complement self-reported measures by providing objective indicators of stress and emotional regulation during treatment, with lower physiological arousal interpreted as reflecting higher procedural quality. Process-related quality metrics constitute another important category of outcomes in research on VR-assisted distraction. These indicators focus on the course of treatment and patient behavior during dental procedures. Patient cooperation and behavioral responses are often assessed using observational instruments such as the Frankl Behavior Rating Scale, which categorizes children's behavior from highly negative to highly positive. In the crossover trial by (Zaidman et al., 2023), behavioral ratings were used to compare cooperation during procedures performed with and without VR. The review by (Cunningham et al., 2021), further indicated that patient cooperation is among the most frequently reported process quality indicators in studies evaluating distraction technologies. Additional process-related measures include procedure duration and the number of interruptions during treatment. Some of the randomized trials included in the meta-analysis by (Yan et al., 2023), reported shorter procedure times or fewer interruptions in VR conditions, although these variables were typically treated as secondary or exploratory indicators rather than primary outcomes.

Research on the use of VR in pediatric dentistry has developed along several complementary streams, which together make it possible to understand both the scale of dental anxiety among children and the potential of VR as a tool for improving the quality of care. The first stream comprises epidemiological studies and meta-analyses of the prevalence of dental anxiety in children and adolescents. Although these studies do not directly test VR interventions, they provide crucial justification for the search for effective non-pharmacological methods of anxiety management. Grisolia et al. (2021) conducted a global systematic review with meta-analyses of the prevalence of dental anxiety in pediatric populations, demonstrating that this problem is widespread and clinically significant.

These findings provide an important starting point for designing interventions aimed at improving the quality of care, as high levels of anxiety are associated with poorer patient cooperation, avoidance of dental visits, and the prolongation of clinical procedures. Similarly, (Sun et al., 2024), focusing on early childhood, estimated the global prevalence of dental fear and anxiety and identified key risk factors, such as lack of previous dental visit experience and the presence of dental caries. The authors emphasized that anxiety-reduction interventions should be implemented at an early stage of children's contact with the dental care system.

From a quality-of-care perspective, these studies establish the fundamental premise that effective pediatric dental care requires strategies to reduce anxiety, as elevated anxiety levels significantly impair the quality and efficiency of treatment processes.

The second stream of research consists of teams synthesizing empirical evidence on the effectiveness of VR as a distraction technique and its impact on clinical indicators and patient experience (Cunningham et al., 2021) conducted a systematic review of studies on the use of VR and mobile dental applications in pediatric dentistry, indicating that although the number of empirical studies was limited at the time, the available evidence suggested beneficial effects of these technologies on the reduction of pain and anxiety, as well as potential improvements in the treatment process. In subsequent years, (Yan et al., 2023) carried out a systematic review and meta-analysis of randomized clinical trials involving several hundred pediatric patients, demonstrating statistically significant effects of VR in reducing anxiety, pain, and physiological parameters such as heart rate during dental treatment. At the same time, the authors highlighted substantial heterogeneity of results and the risk of bias in some studies, which is important for assessing the overall quality of the evidence base. A comprehensive review of the effectiveness of VR in reducing pain and anxiety during oral procedures was also provided by who emphasized the need for standardization of VR protocols, including the selection of content, duration of exposure, and patient eligibility criteria. A critical summary of the evidence from an evidence-based dentistry perspective was presented by (Goodship, Taylor, 2025), who concluded that VR is a promising adjunctive intervention for reducing anxiety and pain in pediatric dental patients, but that its routine implementation requires further high-quality clinical trials and the development of standardized application guidelines. Similar conclusions were drawn by (Rosa et al., 2023), who, in their review of studies involving children with dental phobia, identified VR as an effective method of distraction and preparatory intervention, while also noting limitations related to the small number of available studies and their heterogeneous methodological quality. From a quality-of-care perspective, this stream of research suggests that VR improves key patient-centered quality indicators, such as anxiety, pain, and physiological stress responses, and may facilitate the clinical process, while simultaneously underscoring the need to strengthen the empirical evidence base.

The third stream comprises clinical studies directly testing VR-assisted distraction protocols in dental practice settings, which most explicitly link the use of the technology to quality understood in terms of patient comfort, cooperation during treatment, and the technical conditions of clinical procedures. (Zaidman et al., 2023) conducted a randomized crossover trial among children aged 4 to 12 years, comparing dental visits with and without VR goggles during local anesthesia administration and rubber dam placement. The results indicated that VR significantly reduced perceived pain during more time-consuming procedures that require sustained attention and cooperation from the child, such as rubber dam placement, whereas its effect on pain associated with local anesthetic injection was limited and inconclusive (Zaidman et al., 2023). These findings suggest that improvements in the quality of care attributable to

VR are selective and procedure-dependent, which has important implications for the design of quality-oriented protocols and the rational implementation of this technology in routine clinical practice.

The need for additional behavior management strategies, including pharmacological interventions or intensified behavioral techniques, has also been reported in reviews as an indirect indicator of treatment facilitation and process quality (Cunningham et al., 2021, Rosa et al., 2023). Clinical outcome metrics that directly reflect the technical quality of care are less frequently reported but remain important for a comprehensive assessment of VR interventions. These include indicators such as procedural success or treatment completeness, defined as the extent to which planned dental procedures can be completed as intended. Such outcomes are occasionally reported in clinical trials and systematic reviews, including the work by (Cunningham et al., 2021), typically as secondary indicators of intervention effectiveness. In a limited number of studies, the number of visits required to complete treatment has also been examined as a proxy for process efficiency, although this metric is not routinely included and remains underrepresented in literature. Finally, safety and acceptability metrics form an integral component of quality assessment in studies of VR-based interventions. Systematic reviews report that potential adverse effects associated with VR use, such as dizziness, nausea, or sensory discomfort, are monitored in some studies, although their incidence appears to be relatively low (Cunningham et al., 2021; Zhao et al., 2023). Acceptance of VR technology by children and their caregivers, often assessed through brief questionnaires or subjective ratings, is also treated as an important dimension of implementation quality, as it determines the feasibility of integrating VR into routine clinical practice (Cunningham et al., 2021; Rosa et al., 2023). Taking together, the pattern of quality metrics employed in the literature indicates a strong emphasis on subjective patient experience and stress-related indicators, whereas strict clinical and organizational outcomes remain comparatively underexplored. This imbalance highlights an important gap in the current evidence base and points to the need for more comprehensive, multidimensional frameworks for evaluating the quality of VR-assisted care in pediatric dentistry.

4. Discussion

The key findings extracted from the reviewed publications collectively demonstrate that virtual reality has measurable potential to enhance the quality of pediatric dental care processes, although the evidence base remains heterogeneous and methodologically constrained. Across most studies, VR contributed to reductions in pain and anxiety, particularly in younger children and during procedures such as local anesthesia, restorative treatment, and endodontic therapy. Several reviews reported consistent decreases in pain scores measured with different

scales: VAS, FLACC, or Wong–Baker scales, and reductions in physiological anxiety indicators such as heart rate and salivary cortisol (Rosa et al., 2023; Cunningham et al., 2021; Kapil et al., 2021; Yan et al., 2023; Gandhi et al., 2024; Pathak et al., 2023). These outcomes align with quality-oriented objectives by improving patient experience and reducing procedural distress what leads to smoother behavioral management during treatment.

From a process-quality perspective, the included studies highlight several mechanisms through which VR may strengthen clinical workflows. Improvements in cooperation, reductions in behavioral disruptions, and enhanced patient engagement were repeatedly emphasized as contributors to more predictable appointment flow and more efficient delivery of care. For instance, Rosa et al. (2023) and Cunningham et al. (2021) underscored VR's role in improving cooperation and facilitating behavior change, while other reviews linked VR to better communication, pre-treatment preparation, and safer delivery of care within behavior guidance frameworks such as Tell-Show-Do or Tell-Play-Do. These findings suggest that VR can function as a distraction tool but also as an enabler of broader organizational efforts to modernize behavioral guidance practices and reduce reliance on more resource intensive or invasive anxiety management strategies.

However, the evidence also reveals substantial limitations that constrain the translation of VR into standardized, high-quality clinical process. A recurring issue across studies is the absence of standardized VR protocols, including variability in device type, content, duration of exposure, and timing of use. Multiple reviews explicitly noted heterogeneity in interventions and outcome measures, lack of blinding, small sample sizes, and insufficient control of confounders, all of which limit the comparability of findings and impede the development of evidence-based implementation guidelines. Importantly, none of the included publications assessed quality indicators in a structured manner or incorporated perspectives from all key stakeholders: patients, parents, and dental practitioners.

The limitations identified also underscore operational challenges that must be addressed before VR can be integrated as a routine component of pediatric dental care. Technical constraints, device ergonomics, and potential adverse reactions (e.g., cybersickness) were noted in several studies. Pathak et al. (2023) reported that VR headsets were too heavy for younger children, interfering with both comfort and the ability to assess facial expressions for FLACC scoring. Other reviews highlighted ethical considerations, cost barriers, and the need for personalized screening to account for individual variations, including children with ASD or mild intellectual disabilities. These factors illustrate the importance of structured implementation strategies that incorporate risk assessment, staff training, and workflow redesign.

Taken together, the results indicate that VR represents a promising tool for healthcare organizations seeking to advance quality and efficiency in pediatric dental services. The observed benefits are reduced pain, lower anxiety, improved cooperation, and enhanced

patient experience. It aligns with core quality improvement priorities and support the potential for VR to strengthen patient-centered care processes. Currently the evidence base also reveals a clear need for standardized procedures, stakeholder-inclusive design, and rigorous evaluation of the frameworks. Future research should therefore focus on developing and validating implementation protocols that integrate VR into routine care without extending visit duration, while ensuring that quality, safety, and equity considerations are systematically addressed.

5. Conclusions

The literature review demonstrates that the majority of studies report a substantial positive effect of virtual reality interventions on reducing anxiety and stress in pediatric dentistry. However, in procedures such as tooth extraction and in cases involving the gag reflex, the use of VR does not appear to produce statistically significant improvements.

Most authors emphasize the relevance of high-quality dental care and its contribution to the patient's overall quality of life. Nevertheless, none of the reviewed studies employ formal quality indicators to assess how the care process changes with and without VR support. Although some researchers refer to treatment effectiveness, they do not operationalize it through standardized quality metrics. Virtual Reality primarily reduces pain and anxiety and supported by various measurement tools, including self-report scales, heart rate monitoring, and salivary cortisol levels. These outcomes align with quality-oriented goals by enhancing patient experience and lowering procedural stress. Current research, however, remains focused on improving comfort for anxious pediatric patients, and no study proposes VR as an integrated component of standard clinical protocols.

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