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The effect of virtual reality for anxiety and pain in dentistry: A systematic review and meta-analysis

Hossein Motahari Nezhad[1], Amir-Hossein Ashourioun[2], Aslan Sadeghdaghighi[3]

[1]Obuda University, Hungary; [2]Department of Oral & Maxillofacial Surgery, Semmelweis University, Hungary; [3]Department of Medicine, Semellweis University, Hungary

Objectives: This study aimed to assess the impact of virtual reality (VR) on reducing anxiety and pain in dental patients across all age groups and dental procedures. ***Methods***: Systematic review with comprehensive search of PubMed and Cochrane Library databases for randomized controlled trials (RCTs) comparing VR interventions with non-VR methods in dental settings up to April 2024. The selection followed the PRISMA-P guidelines. Inclusion criteria were based on the PICOS framework, focusing on studies involving dental patients of any age, utilizing VR during dental treatments, and reporting outcomes on anxiety and pain. Data extraction and quality appraisal were performed independently by two reviewers using the ROB-2 tool and GRADE methodology. Meta-analyses used a random-effects model. ***Results***: Twenty-seven studies met the inclusion criteria, encompassing several dental treatments. In meta-analysis VR reduced anxiety in children (SMD -1.44, 95% CI -2.24 to -0.63) but not adults (SMD -0.35, 95% CI -1.11 to 0.4). For pain reduction, VR was effective in both children (SMD -1.11, 95% CI -1.65 to -0.57) and adults (SMD -0.59, 95% CI -1.187 to -0.001). Heterogeneity was high across studies, and evidence quality ranged from low to moderate. ***Conclusions***: VR is a promising intervention for reducing anxiety and pain in children during dental procedures. Its effectiveness in adults is limited to pain reduction. High heterogeneity and risk of bias suggest that findings should be interpreted with caution. Further research is needed to standardize VR content and explore its varying impacts across different age groups and dental procedures.

Keywords*: meta-analysis, technology, virtual reality, dental anxiety, dental pain, digital health*

Introduction

One challenge that dental patients face before even visiting the clinic is the fear of pain and anxiety (McNeil *et al*., 2001). Fear-related behaviors in dentistry can affect the quality and the treatment process and may lead to patients discontinuing treatment (McNeil *et al*., 2001). Patients who experience considerable pain tend to delay their dental visit until it becomes essential, which can further increase their fear of treatment (Hoffman *et al*., 2001). Ultimately, these negative emotions can intensify the patient's pain and anxiety (Cimpean and David, 2019). The fear of dentistry is the fifth most common fear and is more prevalent among younger than older individuals (Sweta *et al*., 2019). In general, one-third of children aged 2 to 6 years experience dental anxiety (Sun *et al*., 2024).

Managing fear and anxiety can also create an unpleasant experience for dentists. If patients do not cooperate, it prolongs the treatment duration and increases the use of resources, leading to dissatisfaction for both the dentist and the patient (Brahm *et al*., 2012; Moore and Brødsgaard, 2001). The relationship between the dentist and the patient, influenced by the patient's fear and anxiety, can result in incorrect diagnoses (Eli, 1993). Furthermore, avoiding dental treatment due to stress leads to poor oral health, decay, and tooth loss (Van Wijk and Hoogstraten, 2003). Another consequence is sleep disturbance, which negatively impacts social interactions and workplace relationships and stems from reduced self-confidence (Cohen *et al*., 2000).

Managing and treating dental fear and anxiety involves a variety of approaches. Therapeutic and psychological methods include psychotherapy, pharmacotherapy, singly or in combination (Appukuttan, 2016). The design and architecture of the dental office also impact patients' anxiety (Bare and Dundes, 2004; Lehrner *et al*., 2000, 2005). Furthermore, establishing a close and trustworthy relationship between the dentist and the patient is crucial (Marci *et al*., 2007). Other techniques for managing dental anxiety include relaxation (Biggs *et al*., 2003), guided imagery (Hofmann *et al*., 2010), biofeedback (Weinstein and Milgrom, 2009), hypnotherapy (Montgomery *et al*., 2000), acupuncture (Müller *et al*., 2023), and techniques to increase patient control (American Academy of Pediatric Dentistry, 2015). While these methods are diverse, many drawbacks include physical risks and being time-consuming. On the other hand, the distraction technique is considered a safe and affordable option for healthcare professionals (Rath and Khandelwal, 2019).

The American Academy of Pediatric Dentistry (2015) has identified various techniques for managing and treating fear and anxiety in children including communication, the tell-show-do (TSD) method, voice control, parental presence, and distraction. Distraction diverts the patient's attention from unpleasant experiences. One distraction technique is virtual reality (VR); an active method requiring the patient's participation (Addab *et al*., 2022; Asokan *et al*., 2020). Although uniform definition of VR is lacking (Bhardwaj and Bhardwaj, 2016; Mandal, 2013;

Correspondence to: Dr. Hossein Motahari Nezhad Email: h.motahari.lib@gmail.com

Pernekulova *et al*., 2021), it is generally understood as a human-computer interaction that immerses users in a three-dimensional environment disconnected from the real world (Xinxing, 2012). Patients interact with a virtual environment via a headset or hand controller, prompting them to respond and thereby diverting their attention from the dental procedure (Smith *et al*., 2020). Unlike other digital distraction techniques, VR provides a convincing sense of presence in a virtual world, effectively isolating the patient from real-world stimuli (Aziz, 2018; Chopra *et al*., 2020). The VR in dentistry market was worth over USD 550 million in 2022. It is projected to reach USD 3,554.1 million by 2030, growing at a CAGR of over 18% (Cognitive Market Research, 2023).

Studies have investigated the impact of VR in dentistry. For instance, three meta-analyses have focused on this topic. Custódio et al. (2020) explored VR's effect on pain and anxiety levels in children during dental treatments. This research included nine randomized clinical trials (RCTs) up to September 2018, concluding that VR does not influence anxiety levels during procedures such as local anesthesia, the use of a rubber dam, caries removal, and restoration. Another 2020 meta-analysis reviewed the literature up to November 2019 and included eight studies. It found that virtual reality significantly reduced both pain and anxiety in children (Fernández, *et al*., 2020). Lastly, Xinyi Yan (2023) and colleagues examined VR's effectiveness in reducing anxiety in pediatric dentistry. Drawing on 12 RCTs up to September 2022, the study reported significant effects on pain, anxiety, and heart rate, although the evidence was considered poor quality due to publication bias.

This research is driven by two primary concerns. First, previous studies have reported inconsistent results, possibly due to the dynamic nature of research and the timing of publications. For example, two meta-analyses published in 2020 included 9 and 7 articles, respectively, while a 2023 meta-analysis included 12 RCTs. Second, although most studies have focused on the effects of virtual reality on children, this encompasses all age groups. By reviewing the literature up to April 2024, our aim is to assess the impact of virtual reality across all dental conditions and age groups.

Methods

This study was developed in accordance with the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols) declaration as a framework for detailing the items in systematic review and meta-analysis protocols (Moher *et al*., 2015). The protocol can be accessed at https://doi.org/10.21203/rs.3.pex-2592/v1 (Motahari-Nezhad and Sadeghdaghighi, 2024).

Eligible studies were identified from PubMed and the Cochrane Library, on 1 April 2024. Distinct search syntaxes were used in each database as follows: ("Virtual Reality"[Mesh] OR "Virtual reality"[Title/abstract]) AND (dentistry[Title/Abstract] OR teeth[Title/Abstract] OR tooth[Title/Abstract] OR dental[Title/Abstract])

The searches were not time-limited. Additionally, after executing the search syntax in PubMed, the article type was specifically limited to 'Randomized Controlled Trials'.

We used the following search syntax in Cochrane library: "virtual reality" in Title Abstract Keyword AND "dentistry" OR "teeth" OR "tooth" OR dental in Title Abstract Keyword.

We included English-language, full-text RCTs, assessing the efficacy of virtual reality interventions against non-virtual reality control groups. The inclusion criteria, derived from the PICOS framework (Amir-Behghadami and Janati, 2020) were:

Population: All dental patients, irrespective of race, gender, or age.
Intervention: VR to manage treatment in dental patients
Comparator: Any non-VR to manage treatment in dental patients
Outcome: Anxiety and pain.
Setting: Dental treatment settings including dental surgeries etc.
Study Design: Limited to RCTs.

Following the search across two digital libraries, all the retrieved studies were compiled into a Microsoft Excel spreadsheet. Duplicates were eliminated based on their Digital Object Identifier (DOI) numbers. After duplicates were cleared, selection proceeded in two phases.

Initially, the titles and abstracts of the articles were examined. Any studies failing to meet the inclusion criteria were dismissed. The remaining studies were subjected to a comprehensive full text review to determine if they met the inclusion criteria. Additionally, the reference lists from these studies were examined to uncover further eligible studies (Motahari-Nezhad, 2023). Two reviewers (HM-N and AS) independently assessed the studies at the abstract/title and full-text stages. The process was depicted using a PRISMA flow diagram. A detailed list of the studies that were excluded at the full-text review stage, along with the reasons for their exclusion, is also provided.

Two independent reviewers, HM-N and AS, extracted the data, gathering information about the studies that met the inclusion criteria, including the year of publication, the first author's name and country of origin, and details about the study population, such as clinical features, gender, and age. Other information regarding the intervention, follow-up durations, comparison groups, and outcomes related to dental health, including the magnitude of effect, the statistical measurement of the effect size, its confidence intervals of 95% or standard errors, and the total number of studies' participants with a breakdown by group were also extracted. When sources did not report the effect size, it was computed when feasible based on the data available in the reports. If an author had more than one affiliation, only the first one was considered.

Two independent reviewers employed the Risk of Bias 2 (ROB 2) tool (Sterne *et al*., 2019) to assess bias in the included studies across five key areas: randomization, deviations from intended interventions, missing outcome data, how outcomes were measured and the choice of results reported. Whenever differences arose, the reviewers discussed to resolve them and achieve consensus.

The final analyses were organized according to the outcomes, with studies reporting the same outcomes grouped together. We conducted a random effects meta-analysis for each category using the DerSimonian and Laird approach in R software. Only reports that described matching effect sizes were considered to consolidate the effect sizes for analysis. When studies reported diverse effect sizes, attempts were made to standardize these measures to ensure comparability. The standardized mean difference (SMD) was calculated for each study to ensure the comparability of effect sizes. Studies that did not report the necessary measures for calculating the SMD were excluded from the meta-analysis. The heterogeneity among the studies in each meta-analysis was evaluated using the I-squared statistic. If this statistic exceeded 50%, meta-regression using age as a variable was employed to explore potential sources of heterogeneity. Furthermore, a subgroup analysis investigated variations in the overall effect sizes across different levels of bias risk. Methods, including the Trim and Fill (Duval and Tweedie, 2000) and statistical tests, such as Egger's and Begg's (Song *et al*., 2013), were used to identify potential publication bias within the meta-analyses.

The GRADE method was utilized to assess the evidence quality for each outcome (Guyatt *et al*., 2008; Schünemann *et al*., 2013). The evaluation encompassed five key factors: risk of bias, publication bias, inconsistency, imprecision, and indirectness. The certainty of each outcome was classified as High, Moderate, Low, or Very Low, depending on the aggregate number of downgrades (Motahari-Nezhad *et al*., 2021).

Results

The initial search identified 263 sources. After removing 52 duplicates, 207 articles remained for title and abstract screening, of which 159 were deemed inappropriate and excluded. Consequently, 48 articles were full text reviewed, of which 23 did not meet the inclusion and exclusion criteria, leaving 25 articles as eligible. After reviewing the references of these studies, two additional articles were identified for inclusion. Therefore, 27 articles were finally included (Figure 1). The table of excluded studies is available at https://docs.google.com/document/d/1AIdMYy3NpdM-mvq0wlOregc_DSPyBugOi/edit?usp=drive_link&ouid=104452075362753409107&rtpof=true&sd=true.

Most reports were published in 2024 (22%) and 2021 (19%), followed by 2019, 2022, and 2023 (11% each). Indian researchers authored 30% of the included studies. Following that, authors from Iran and Turkey each published 15% each. Seven other studies were published across Spain (11%), China (7%), and Jordan (7%).

The 27 included articles were published in 24 different journals. Most (56%) reported parallel group RCTs, 22% were cross-over, and the remaining six used a within-subject, split-mouth design. Almost half (41%) were funded by academic centers, while 33% were conducted without any external financial support. Further characteristics of the included studies are available at https://docs.google.com/document/d/1iYNc4s2qOjH977kA8Xru-jN1DeIvqGqo/edit?usp=drive_link&ouid=104452075362753409107&rtpof=true&sd=true.

The effect of VR with children was the focus of 70% of the reports. The other 30% involved adults aged 18 years and older. There was a predominance of female participants. Five articles (19%) did not specify the participants' gender. Further information is available at https://docs.google.com/document/d/1jIZeVlrvzraD8Rxd4Dmp50UCMhxbqTue/edit?usp=drive_link&ouid=104452075362753409107&rtpof=true&sd=true.

The effects of VR were explored across a wide range of dental procedures, primarily during surgical and invasive procedures such as the extraction of primary teeth, pulp therapy, and tooth extractions, or formocresol pulpotomies on primary mandibular molars. Restorative and

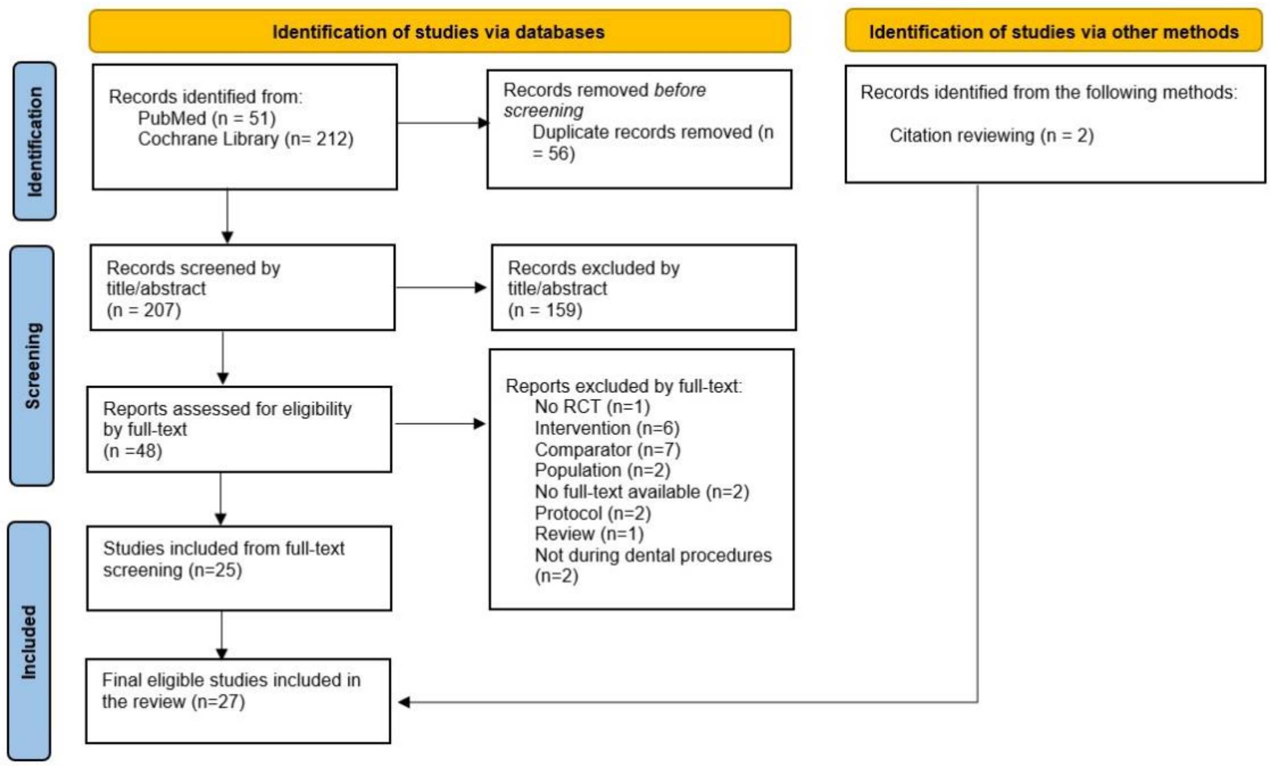

Figure 1. *PRISMA flow diagram of search and screening process (Page et al., 2021).*

conservative treatments were the focus of other studies, for instance, caries treatment and conservative dental treatments involving fillings. Furthermore, the dental procedures in some RCTs involved anesthesia and pain management, such as the administration of an inferior alveolar nerve block.

As most studies included children, most VR consisted of cartoons (56%) and nature and scenery (26%). Please refer https://docs.google.com/document/d/1pol-wmpdLEoe7KNo3_TSCgu-S3mSP8WC/edit?usp=drive_link&ouid=104452075362753409107&rtpof=true&sd=true to for more details of the types of dental treatments and procedures, VR devices, and content.

Anxiety and pain were the two most reported outcomes in the included RCTs, followed by heart rate and oxygen saturation. (Details of the outcomes in the included studies are available at: https://docs.google.com/document/d/10PiYCyBVyBegL1g-GaxGx2kvclu00X8e/edit?usp=drive_link&ouid=104452075362753409107&rtpof=true&sd=true).

A wide range of tools were used to measure outcomes. Anxiety assessments included the Children's Fear Survey Schedule-Dental Subscale (CFSS-DS), Frankl Behavior Rating Scale (FBRS), face version of the Modified Child Dental Anxiety Scale (MCDAS), Facial Image Scale (FIS), Venham's Picture Test (VPT), Venham's Clinical Anxiety Rating Scale (VCARS), and the Modified Venham's Anxiety Rating Scale (MVARS), among others. For pain assessment, various tools were also utilized, such as the Wong-Baker FACES Pain Rating Scale (WBFS), FLACC Scale, and Visual Analog Scale (VAS).

The included samples had varying levels of anxiety. Some studies included patients with different levels of anxiety (Alshatrat *et al*., 2022), others focused on patients with a predefined anxiety level. For example, participants were included by Ran et al. (2021) only if they scored above 19 on the Children's Fear Survey Schedule-Dental Subscale.

In the risk of bias assessment, there were concerns in 19 studies due to the concealment of the allocation sequence. All studies exhibited a high risk of bias from deviations from the intended interventions because the patients were aware of their interventions during the study. There was only one concern regarding participant dropout. All reports suggested that assessors were aware of the interventions received by the participants. Seventeen reports raised some concerns due to the unavailability of pre-registered protocols. Overall, all included studies had a high risk of bias (Figure 2).

The meta-analysis of 14 studies, encompassing a total of 957 patients, demonstrated an effect of VR in reducing anxiety levels in children (SMD -1.44, 95% CI -2.24 to -0.63, I^2=94%, low quality of evidence) (Figure 3). Two studies were not included in the meta-analysis due to insufficient data (Özükoç, 2020; Shams et al., 2024). The assessment revealed publication bias. Additionally, the meta-regression for age of participants was not conducted due absent age data in 5 articles (Aditya *et al*., 2021; Bahrololoomi *et al*., 2024; Greeshma *et al*., 2021; Pande *et al*., 2020; Shetty *et al*., 2019).

Five articles (total 485 participants) were included in the meta-analysis for the effect of VR on adult anxiety. No effect was apparent (SMD = -0.35, 95% CI: -1.11 to 0.4, I^2=83%, low level of certainty). With less than 10 studies in this meta-analysis, publication bias was not assessed. Meta-regression did not find a relationship between mean age and effect size (p = 0.264).

The meta-analysis of 11 studies (791 participants), revealed an effect of VR on pain reduction in children (SMD = -1.11, 95% CI: -1.65 to -0.57, I^2 = 91%)(Figure 4). The level of certainty was moderate. No publication bias was identified (p > 0.05). Meta-regression could not be conducted to determine the effect of age as data were lacking in two reports (Bahrololoomi *et al*., 2024; Shetty et al., 2019).

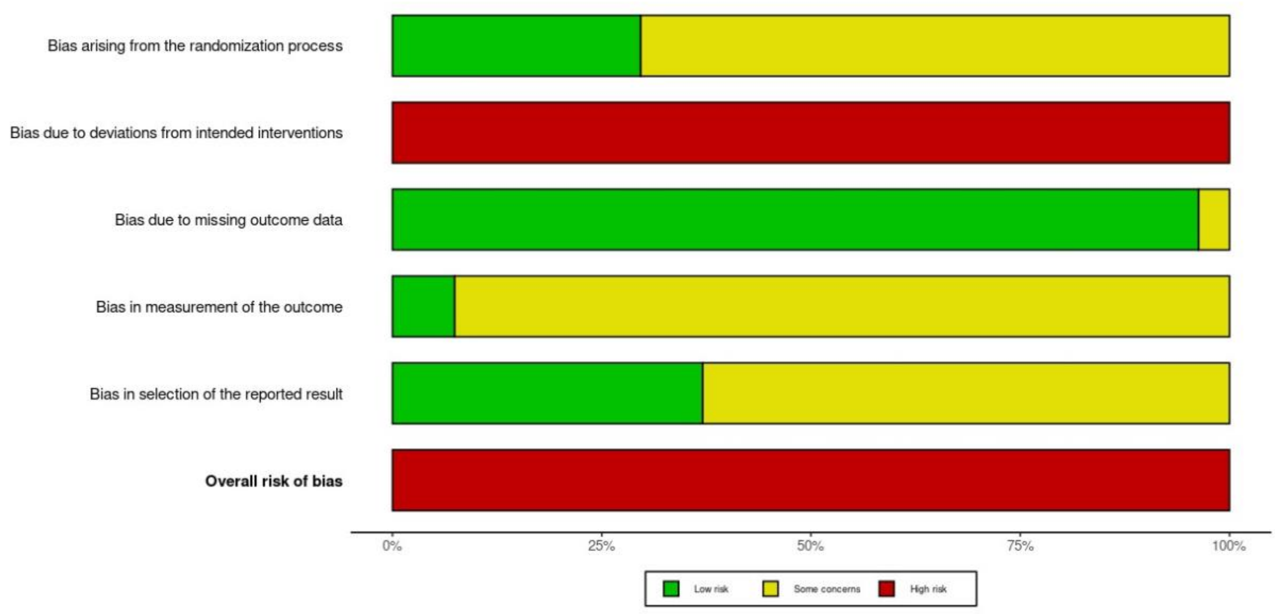

Figure 2. *Risk of Bias assessment using ROB2 tool.*

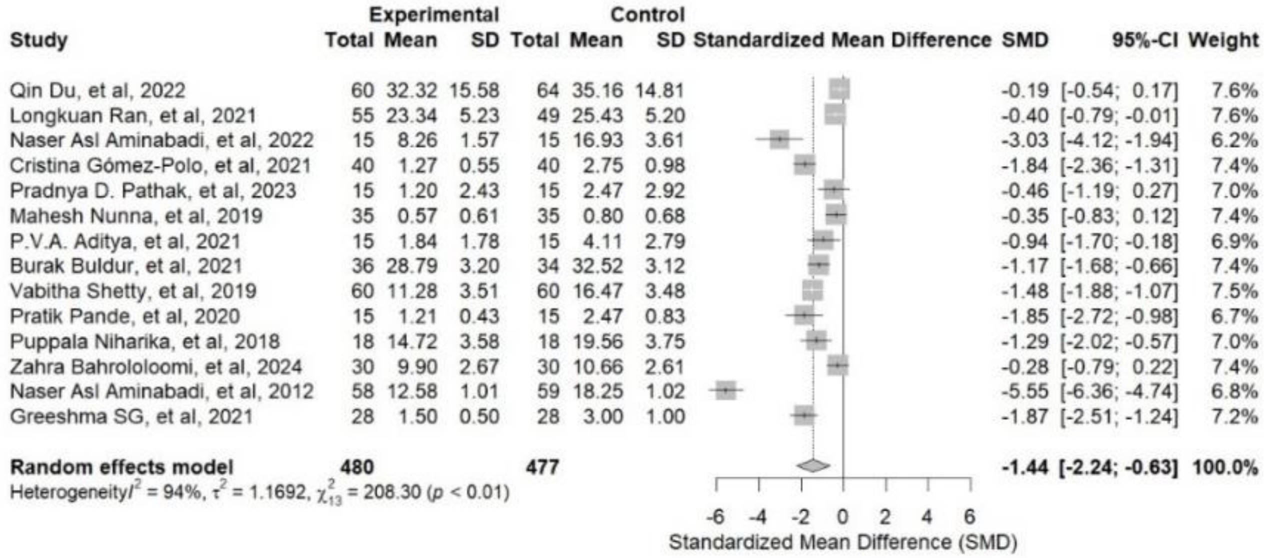

Figure 3. *The forest plot of the effect of VR on anxiety in children.*

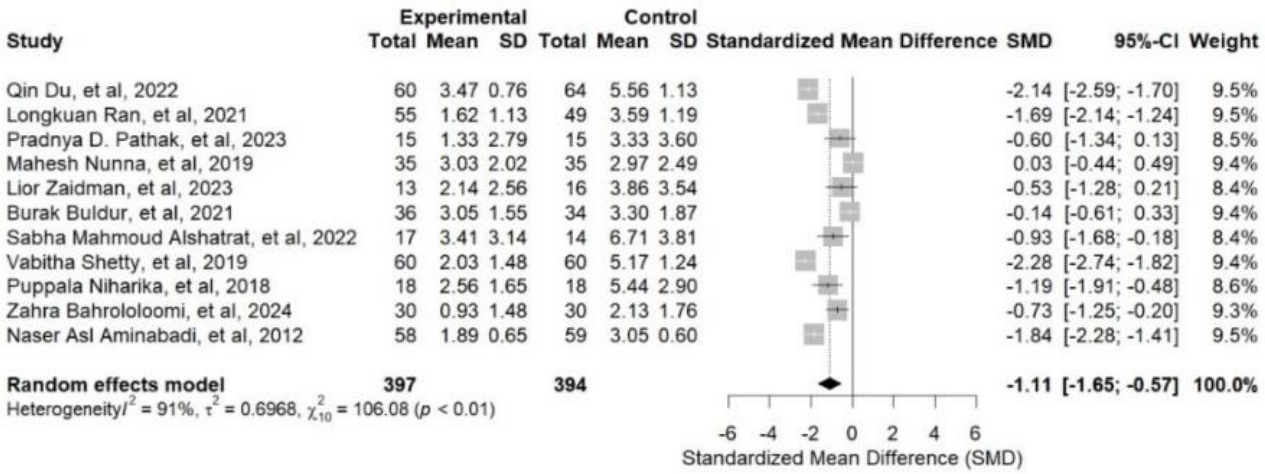

Figure 4. *The forest plot of the effect of VR on pain in children.*

Concerning the pain in adults, the data from 557 samples across 6 articles revealed a pooled SMD of -0.59 (95% CI: -1.187 to -0.001, $p < 0.05$, $I^2 = 83\%$, $p < 0.01$), indicating low evidence quality. We did not check for publication bias due to the limited number of included studies in the meta-analysis. Additionally, meta-regression showed that the mean age of participants was not significant ($p > 0.05$).

Discussion

This systematic review aimed to assess the effect of VR distraction technology on anxiety and pain levels in children and adults. To the best of our knowledge, it is the first to include all types of RCTs (parallel, crossover and split-mouth designs).

Virtual reality reduced anxiety in children during dental procedures. This finding is consistent with two other systematic reviews (Lopez-Valverde *et al*., 2020; Yan *et al*., 2023). VR appears to reduce anxiety by distracting from real-world stimuli with 3D images using visual and audio cues to immerse users in the virtual environment (Aziz, 2018; Margam, 2024).

In all the included studies, participants' anxiety was measured using questionnaires or visual assessments. One physiological indicator of anxiety is heart rate (Guinot Jimeno *et al*., 2011). While a meta-analysis revealed the effectiveness of VR in reducing heart rate in children (Guinot Jimeno *et al*., 2011), another failed to find this effect (Custódio *et al.*, 2020). Studies assessing the effect of VR on anxiety have used subjective and objective measures. Some have used physiological data, such as oxygen saturation. Two studies reported that VR did not affect the oxygen saturation levels of children in dentistry (Yan *et al*., 2023; Zhang *et al*., 2019) The variety of measures across the studies may have affected the results. Therefore, researchers in this field should use validated tools that align with their study objectives. Future studies should also determine whether the choice of measure impacts the results and which measures are more suitable for children.

Virtual reality did not appear to reduce anxiety in adults. This may be explained by several factors. First, adults may be less attracted to VR in dentistry and less distracted by it. Secondly, the content of the VR may not have been suitable for adults. Additionally, differences in the types of content, duration of exposure, and the specific contexts in which VR was used across studies may also effect the results. The difference in neuroplasticity between adults and children may also be responsible. Future research might explore how different mechanisms of VR interventions can influence anxiety across different age groups.

For pain, VR was effective in both children and adults, though the effect was larger in children. Again, this variation may be attributed to developmental differences, or the specific nature of the VR, which could influence how participants experience and process anxiety versus pain. Further research is needed to explore the mechanisms underlying these differences.

Distraction is effective in patients with mild to moderate levels of anxiety. The studies included in this review involved participants with different levels of anxiety. Future research could investigate whether participants' anxiety level influences the effectiveness of VR in reducing anxiety and pain.

Another method commonly employed to address anxiety is exposure therapy, which involves consistently and systematically facing a feared object or situation over time, while refraining from avoidance or escape behaviors (Mobach *et al.*, 2020). Unlike VR, which relies on advanced technology to create simulated or artificial environments, exposure therapy can be conducted in real-world situations or through imagined scenarios. VR provides highly controlled and customizable virtual settings, while graded exposure typically occurs in actual environments. Additionally, VR is more immersive, offering vivid, detailed sensory experiences, whereas graded exposure is less immersive and focuses on gradual progression through increasingly difficult real-life situations (Craske *et al*., 2014). Virtual reality exposure therapy has emerged recently and has been shown to be effective in reducing fear of dental procedures. For instance, trials comparing VR exposure therapy with informational pamphlets support the effectiveness of VR exposure therapy in reducing dentophobia compared to informational therapy (Gujjar *et al*., 2018; Majidi and Manshaee, 2021).

Some studies were not included in the meta-analysis due to reporting quality. RCTs are the most important studies for generating evidence for systematic reviews, health policy, and medical decision-making. However, the reporting quality of RCTs can hinder evidence-generation. This highlights the need for researchers to adhere to reporting standards such as CONSORT and TRACT (Cuschieri, 2019; Yin *et al*., 2021; Mol *et al*., 2023). Risk of bias arose in the included studies due to reporting quality. This led to concerns related to outcome measurement and the potential for bias in the selection of reported results. The primary reason for the high risk of bias was the deviations from intended interventions, which stemmed from the nature of the intervention itself, which made it difficult to mask participants. Researchers might reduce this risk of bias by using VR glasses without a video in the control group. This strategy would help ensure that assessors are also masked to the type of intervention. High risk of bias has also been reported in other digital health systematic reviews (Bevens *et al*., 2022; Siopis *et al*., 2023). Risk of bias an undermines the validity of meta-analyses, which should therefore be treated with caution.

In conclusion, VR reduced anxiety and pain during dental procedures in children. It did not reduce anxiety but did reduce pain in adults. Heterogeneity and risk of bias in the included studies reduces the validity of these results, which should be treated with caution.

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References

Addab, S., Hamdy, R., Thorstad, K., Le May, S. and Tsimicalis, A. (2022): Use of virtual reality in managing paediatric procedural pain and anxiety: An integrative literature review. *Journal of Clinical Nursing* **31**, 3032–3059.

Aditya, P.V.A., Prasad, M.G., Nagaradhakrishna, A., Raju, N.S. and Babu, D.N. (2021): Comparison of effectiveness of three distraction techniques to allay dental anxiety during inferior alveolar nerve block in children: A randomized controlled clinical trial. *Heliyon* **7**, e08092.

Akshay Bhardwaj and Minakshi Bhardwaj, A.G. (2016): Virtual reality: An overview. *International Journal of Scientific and Technical Advancements* **39**, 23–26.

Alshatrat, S.M., Sabarini, J.M., Hammouri, H.M., Al-Bakri, I.A. and Al-Omari, W.M. (2022): Effect of immersive virtual reality on pain in different dental procedures in children: A pilot study. *International Journal of Paediatric Dentistry* **32**, 264–272.

American Academy of Pediatric Dentistry. (2015): Guideline on Behavior Guidance for the Pediatric Dental Patient. *Pediatric Dentistry* **37**, 57–70.

Amir-Behghadami, M. and Janati, A. (2020): Population, Intervention, Comparison, Outcomes and Study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. *Emergency Medicine Journal* **37**, 387–387.

Appukuttan, D. (2016): Strategies to manage patients with dental anxiety and dental phobia: literature review. *Clinical, Cosmetic and Investigational Dentistry* **35**.

Asokan, S., Geetha Priya, P., Natchiyar, Sn. and Elamathe, M. (2020): Effectiveness of distraction techniques in the management of anxious children – A randomized controlled pilot trial. *Journal of Indian Society of Pedodontics and Preventive Dentistry* **38**, 407.

Aziz, H.A. (2018): Virtual Reality Programs Applications in Healthcare. *Journal of Health & Medical Informatics* 09(01):

Bahrololoomi, Z., Zein Al-Din, J., Maghsoudi, N. and Sajedi, S. (2024): Efficacy of Virtual Reality Distraction in Reduction of Pain and Anxiety of Pediatric Dental Patients in an Iranian Population: A Split-Mouth Randomized Crossover Clinical Trial. *International Journal of Dentistry* 1290410.

Bare, L.C. and Dundes, L. (2004): Strategies for combating dental anxiety. *Journal of Dental Education* **68**, 1172–1177.

Bevens, W., Weiland, T., Gray, K., Jelinek, G., Neate, S. and Simpson-Yap, S. (2022): Attrition Within Digital Health Interventions for People With Multiple Sclerosis: Systematic Review and Meta-analysis. *Journal of Medical Internet Research* **24**, e27735.

Biggs, Q.M., Kelly, K.S. and Toney, J.D. (2003): The effects of deep diaphragmatic breathing and focused attention on dental anxiety in a private practice setting. *Journal of Dental Hygiene* **77**, 105–113.

Brahm, C.-O., Lundgren, J., Carlsson, S.G., Nilsson, P., Corbeil, J. and Hägglin, C. (2012): Dentists' views on fearful patients. Problems and promises. *Swedish Dental Journal* **36**, 79–89.

Chopra, S., Bansal, P. and Bansal, P. (2020): Essix Appliance: An Innovation Modification for use as Temporary Bridge-A Case Report. *Journal of Advanced Medical and Dental Sciences Research* **8**, 184–186.

Cimpean, A. and David, D. (2019): The mechanisms of pain tolerance and pain-related anxiety in acute pain. *Health Psychology Open* **6**, 205510291986516.

Cognitive Market Research. (2023): *Augmented and Virtual Reality in Dentistry Market to Reach $3,554.5 Million by 2030: Cognitive Market Research*. https://www.prnewswire.com/news-releases/augmented-and-virtual-reality-in-dentistry-market-to-reach-3-554-5-million-by-2030-cognitive-market-research-301754218.html

Cohen, S.M., Fiske, J. and Newton, J.T. (2000): The impact of dental anxiety on daily living. *British Dental Journal* **189**, 385–390.

Craske, M.G., Treanor, M., Conway, C.C., Zbozinek, T. and Vervliet, B. (2014): Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy* **58**, 10–23.

Cuschieri, S. (2019): The CONSORT statement. *Saudi Journal of Anaesthesia* **13**, 27.

Custódio, N.B., Costa, F.D.S., Cademartori, M.G., da Costa, V.P.P. and Goettems, M.L. (2020): Effectiveness of Virtual Reality Glasses as a Distraction for Children During Dental Care. *Pediatric Dentistry* **42**, 93–102.

Duval, S. and Tweedie, R. (2000): Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. *Biometrics* **56**, 455–463.

Eli, I. (1993): Dental anxiety: a cause for possible misdiagnosis of tooth vitality. *International Endodontic Journal* **26**, 251–253.

Greeshma, S.G., George, S., Anandaraj, S., Sain, S., Jose, D., Sreenivas, A., Pillai, G. and Mol, N. (2021): Comparative Evaluation of the Efficacy of Virtual Reality Distraction, Audio Distraction and Tell-show-do Techniques in Reducing the Anxiety Level of Pediatric Dental Patients: An *In Vivo* Study. *International Journal of Clinical Pediatric Dentistry* **14**, S173–S178.

Guinot Jimeno, F., Yuste Bielsa, S., Cuadros Fernández, C., Lorente Rodríguez, A.I. and Mercadé Bellido, M. (2011): Objective and subjective measures for assessing anxiety in paediatric dental patients. *European Journal of Paediatric Dentistry* **12**, 239–244.

Gujjar, K.R., van Wijk, A., Sharma, R. and de Jongh, A. (2018): Virtual Reality Exposure Therapy for the Treatment of Dental Phobia: A Controlled Feasibility Study. *Behavioural and Cognitive Psychotherapy* **46**, 367–373.

Guyatt, G.H., Oxman, A.D., Kunz, R., Vist, G.E., Falck-Ytter, Y. and Schünemann, H. J. (2008): What is "quality of evidence" and why is it important to clinicians? *BMJ* **336**, 995–998.

Hoffman, H.G., Garcia-Palacios, A., Patterson, D.R., Jensen, M., Furness, T. and Ammons, W.F. (2001): The Effectiveness of Virtual Reality for Dental Pain Control: A Case Study. *Cyber Psychology & Behavior* **4**, 527–535.

Hofmann, S.G., Sawyer, A.T., Witt, A.A. and Oh, D. (2010): The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting and Clinical Psychology* **78**, 169–183.

Hossein Motahari-Nezhad, Aslan Sadeghdaghighi, A.-H.A. (2024): The effect of virtual reality in dentistry: A protocol for a systematic review and meta-analysis. *Protocol Exchange*. https://doi.org/10.21203/rs.3.pex-2592/v1

Lehrner, J., Eckersberger, C., Walla, P., Pötsch, G. and Deecke, L. (2000): Ambient odor of orange in a dental office reduces anxiety and improves mood in female patients. *Physiology & Behavior* **71**, 83–86.

Lehrner, J., Marwinski, G., Lehr, S., Johren, P. and Deecke, L. (2005): Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office. *Physiology & Behavior* **86**, 92–95.

López-Valverde, N., Fernández, J.M., López-Valverde, A., Juan, L.F.V., Ramírez, J.M., Fraile, J.F., Payo, J.H., Antona, L.A. B., de Sousa, B.M. and Bravo, M. (2020): Retraction: Use of virtual reality for the management of anxiety and pain in dental treatments: Systematic review and meta-analysis *Journal of Clinical Medicine* **9**, 1.

López-Valverde, N., Muriel-Fernández, J., López-Valverde, A., Valero-Juan, L.F., Ramírez, J.M., Flores-Fraile, J., Herrero-Payo, J., Blanco-Antona, L.A., Macedo-de-Sousa, B. and Bravo, M. (2020): Use of Virtual Reality for the Management of Anxiety and Pain in Dental Treatments: Systematic Review and Meta-Analysis. *Journal of Clinical Medicine* **9**, 3086.

Majidi, E. and Manshaee, G. (2021): Effects of Virtual Reality Exposure Therapy on Dentophobia in Clients of Dental Offices in Isfahan, Tehran, and Shahrekord (Iran): *Iranian Journal of Psychiatry and Behavioral Sciences* **15**.

Mandal, S. (2013): Brief Introduction of Virtual Reality & its Challenges. *International Journal of Scientific & Engineering Research* **4,** 304–309.

Marci, C.D., Ham, J., Moran, E. and Orr, S.P. (2007): Physiologic Correlates of Perceived Therapist Empathy and Social-Emotional Process During Psychotherapy. *Journal of Nervous & Mental Disease* **195**, 103–111.

Margam, R. (2024): Virtual Reality in Healthcare: Transforming Treatment. *International Journal of Artificial Intelligence & Machine Learning* **3**, 19–34.

McNeil, D.W., Au, A.R., Zvolensky, M.J., McKee, D.R., Klineberg, I.J. and Ho, C.C.K. (2001): Fear of pain in orofacial pain patients. *Pain* **89**, 245–252.

Mobach, L., Oar, E. and Hudson, J. (2020): *Exposure therapy for children with anxiety and OCD: Clinician's guide to integrated treatment (pp. 165–191):* Elsevier Science & Technology.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P. and Stewart, L.A. (2015): Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews* **4**, 1.

Mol, B.W., Lai, S., Rahim, A., Bordewijk, E.M., Wang, R., van Eekelen, R., Gurrin, L.C., Thornton, J.G., van Wely, M. and Li, W. (2023): Checklist to assess Trustworthiness in RAndomised Controlled Trials (TRACT checklist): concept proposal and pilot. *Research Integrity and Peer Review* **8**, 6.

Montgomery, G.H., Duhamel, K.N. and Redd, W.H. (2000): A meta-analysis of hypnotically induced analgesia: How effective is hypnosis? *International Journal of Clinical and Experimental Hypnosis* **48**, 138–153.

Moore, R. and Brødsgaard, I. (2001): Dentists' perceived stress and its relation to perceptions about anxious patients. *Community Dentistry and Oral Epidemiology* **29**, 73–80.

Motahari-Nezhad, H. (2023): An artificial neural network (ANN) model for publication bias: a machine learning-based study on PubMed meta-analyses. *Aslib Journal of Information Management*. https://doi.org/10.1108/AJIM-08-2022-0364

Motahari-Nezhad, H., Péntek, M., Gulácsi, L. and Zrubka, Z. (2021): Outcomes of Digital Biomarker–Based Interventions: Protocol for a Systematic Review of Systematic Reviews. *JMIR Research Protocols* **10**, e28204.

Müller, M., Schmucker, C., Naumann, J., Schlueter, N., Huber, R. and Lederer, A.-K. (2023): Acupuncture in management of acute dental pain – A systematic review and meta-analysis. *Japanese Dental Science Review* **59**, 114–128.

Nunna, M., Dasaraju, R.K., Kamatham, R., Mallineni, S.K. and Nuvvula, S. (2019): Comparative evaluation of virtual reality distraction and counter-stimulation on dental anxiety and pain perception in children. *Journal of Dental Anesthesia and Pain Medicine* **19**, 277.

Özükoç, C. (2020): Reducing Anxiety in Children with Molar Incisor Hypomineralization Using Virtual Reality - a Randomized Crossover Study. Comptes rendus de l'Acade'mie bulgare des Sciences. https://doi.org/10.7546/CRABS.2020.11.16

Page, M.J., Moher, D., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S. and McKenzie, J.E. (2021): PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 160.

Pande, P., Rana, V., Srivastava, N. and Kaushik, N. (2020): Effectiveness of different behavior guidance techniques in managing children with negative behavior in a dental setting: A randomized control study. *Journal of Indian Society of Pedodontics and Preventive Dentistry* **38**, 259.

Pernekulova, M.M., Sagikyzy, A., Ashirbekova, Z.B., Zhanabayeva, D.M. and Abdurazakova, G.A. (2021): Definition of Virtual Reality through Creative Act. *Academic Journal of Interdisciplinary Studies* **10**, 176.

Weinstein, P. and Milgrom, P. (2009): *Treating fearful dental patients : a patient management handbook* (3rd ed): Dental Behavioral Resources.

Ran, L., Zhao, N., Fan, L., Zhou, P., Zhang, C. and Yu, C. (2021): Application of virtual reality on non-drug behavioral management of short-term dental procedure in children. *Trials* **22**, 1–9.

Rath, S. and Khandelwal, M. (2019): Effectiveness of Distraction Techniques in Managing Pediatric Dental Patients. *International Journal of Clinical Pediatric Dentistry* **12**, 18–24.

Schünemann, H., Brożek, J., Guyatt, G. and Oxman, A. (2013): *Introduction to GRADE Handbook Handbook for grading the quality of evidence and the strength of recommendations using the GRADE approach*. https://gdt.gradepro.org/app/handbook/handbook.html#h.9rdbelsnu4iy

Shams, S.A., Reddy, A., Vaghela, L.L., Jain, M., Naik, H. and Krishnan, P. (2024): Comparison of Effectiveness of Audio and VR Distraction Techniques in Managing Pediatric Dental Patients. *Journal of Pharmacy and Bioallied Sciences* **16**, S504–S506.

Shetty, V., Suresh, L.R. and Hegde, A.M. (2019): Effect of virtual reality distraction on pain and anxiety during dental treatment in 5 to 8 year old children. *Journal of Clinical Pediatric Dentistry* **43**, 97–102.

Siopis, G., Moschonis, G., Eweka, E., Jung, J., Kwasnicka, D., Asare, B.Y.-A., Kodithuwakku, V., Willems, R., Verhaeghe, N., Annemans, L., Vedanthan, R., Oldenburg, B., Manios, Y., Oldenburg, B., Kwasnicka, D., Gong, E., Jung, J., Asare, B.Y.-A., Kodithuwakku, V. and Bruka, L. (2023): Effectiveness, reach, uptake, and feasibility of digital health interventions for adults with hypertension: a systematic review and meta-analysis of randomised controlled trials. *The Lancet Digital Health* **5**, e144–e159.

Smaïl-Faugeron, V., Fron-Chabouis, H., Courson, F. and Durieux, P. (2014): Comparison of intervention effects in split-mouth and parallel-arm randomized controlled trials: a meta-epidemiological study. *BMC Medical Research Methodology* **14**, 64.

Smith, V., Warty, R.R., Sursas, J.A., Payne, O., Nair, A., Krishnan, S., da Silva Costa, F., Wallace, E.M. and Vollenhoven, B. (2020): The Effectiveness of Virtual Reality in Managing Acute Pain and Anxiety for Medical Inpatients: Systematic Review. *Journal of Medical Internet Research* **22**, e17980.

Song, F., Hooper and Loke, Y. (2013): Publication bias: what is it? How do we measure it? How do we avoid it? *Open Access Journal of Clinical Trials* **71**, S34419

Sterne, J.A.C., Savović, J., Page, M.J., Elbers, R.G., Blencowe, N.S., Boutron, I., Cates, C.J., Cheng, H.-Y., Corbett, M.S., Eldridge, S.M., Emberson, J.R., Hernán, M.A., Hopewell, S., Hróbjartsson, A., Junqueira, D.R., Jüni, P., Kirkham, J.J., Lasserson, T., Li, T. and Higgins, J.P.T. (2019): RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* l4898.

Sun, I.G., Chu, C.H., Lo, E.C.M. and Duangthip, D. (2024): Global prevalence of early childhood dental fear and anxiety: A systematic review and meta-analysis. *Journal of Dentistry* **142**, 104841.

Sweta, V., Abhinav, R. and Ramesh, A. (2019): Role of virtual reality in pain perception of patients following the administration of local anesthesia. *Annals of Maxillofacial Surgery* **9**, 110.

Van Wijk, A.J. and Hoogstraten, J. (2003): The Fear of Dental Pain questionnaire: construction and validity. *European Journal of Oral Sciences* **111**, 12–18.

Xinxing, T. (Ed.): (2012): *Virtual Reality - Human Computer Interaction*. InTech. https://doi.org/10.5772/3333

Yan, X., Yan, Y., Cao, M., Xie, W., O'Connor, S., Lee, J.J. and Ho, M.H. (2023): Effectiveness of virtual reality distraction interventions to reduce dental anxiety in paediatric patients: A systematic review and meta-analysis. *Journal of Dentistry* **132**,104455

Yin, Y., Shi, F., Zhang, Y., Zhang, X., Ye, J. and Zhang, J. (2021): Evaluation of reporting quality of randomized controlled trials in patients with COVID-19 using the CONSORT statement. *PLOS ONE* **16**, e0257093.

Zhang, C., Qin, D., Shen, L., Ji, P. and Wang, J. (2019): Does audiovisual distraction reduce dental anxiety in children under local anesthesia? A systematic review and meta-analysis. *Oral Diseases* **25**, 416–424.