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REVIEW

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Virtual and augmented reality for anxiety reduction in orthopedic patients and providers: a systematic review

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Abstract

Background Anxiety impacts patients and healthcare providers during orthopedic procedures, yet virtual reality (VR) and augmented reality (AR) effectiveness remains inconsistently reported, lacking systematic synthesis in this setting. This review addresses this gap.

Methods Per PRISMA guidelines (PROSPERO: CRD42024553394), we searched PubMed, Scopus, Web of Science, and Embase in March 2024 for studies on VR/AR/mixed reality (MR) interventions for anxiety in orthopedic procedures. Data were narratively synthesized; bias assessed via RoB-2 and ROBINS-I.

Results Twenty-four studies (16 RCTs, 8 cohort, $n=1714$) showed VR (22 studies) and AR (2 studies) significantly reduced anxiety across procedure phases, notably in pediatrics. Healthcare providers (HCPs) reported lower anxiety and higher confidence with VR. Satisfaction rose, anesthetic use dropped, though inconsistent tools and methods limited comparisons.

Conclusion VR/AR reduce pediatric anxiety in orthopedics, with less conclusive adult/HCP benefits. Clinicians could adopt preoperative VR. Research needs standardized tools and adult-focused RCTs.

Keywords Virtual reality, Augmented reality, Anxiety, Fear, Orthopedic surgery, Casting, Pin removing, Pediatric

Background

Anxiety, characterized by fear and apprehension, significantly impacts medical procedures for both patients and healthcare providers [1, 2]. In patients, it leads to dissatisfaction, traumatic memories, and avoidance of elective orthopedic surgeries while potentially elevating complication rates [2, 3]. For providers, particularly novices, anxiety impairs decision-making and management [3]. Miller et al. found 87% of UK surgeons experience performance anxiety, negatively affecting wellbeing and performance [4]. Traditionally, sedatives reduce anxiety but carry side effects and are less suitable for minor procedures like casting [5]. Patient education and communication offer non-pharmacological relief, yet their effectiveness is often limited by time constraints and individual variability [6].

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These limitations highlight the need for advanced solutions, leading to the emergence of virtual reality (VR) and augmented reality (AR). VR immerses users in 3D environments, while AR overlays digital content onto reality, categorized as projection-based (PB), video see-through (VST), or optical see-through (OST) systems [7]. For trainees, VR offers a risk-free skill and confidence building platform [7, 8]; for patients, it's a distraction, reducing anxiety across procedure phases [9, 10].

In orthopedic settings, VR and AR show promise, yet findings are inconsistent in anxiety reduction across preoperative, intraoperative, and pediatric vs. adult contexts. Unlike broader medical VR/AR reviews, no systematic review has targeted orthopedics, a gap this study fills by analyzing relevant studies' methods and outcomes. We aim to clarify knowledge, identify gaps, and guide future research and applications.

Material and method

This systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [11]. The study protocol was prospectively registered on PROSPERO with the registration code CRD42024553394.

Search strategy

A comprehensive search string was developed, using relevant keywords and their variations, combined with Boolean operators: ("orthopedic*" OR ("orthopaedic* " OR OR "spinal" OR "spine") AND ("augmented reality" OR "virtual reality" OR "virtual reality*" OR "mixed reality" OR "extended reality*") AND (Anxiet* OR Stress* OR psycho* OR "Mental disorder*" OR distrac* OR disrup*). We also augmented our PubMed search using relevant Mesh terms. The search was conducted in March 2024 across the electronic databases PubMed, Scopus, Web of Science, and Embase. Additionally, reference lists of the included studies were reviewed to identify any related studies. No restrictions were applied regarding language or publication year.

Selection criteria

Two authors independently conducted the selection process. Initially, titles and abstracts were screened to identify potentially relevant studies. Full-text reviews were then performed to confirm the studies based on the eligibility criteria. Studies were included if they utilized one or more of the AR, VR, and extended reality technologies in patients undergoing orthopedic procedures to assess anxiety levels. The exclusion criteria comprised review, book chapters, letters, case reports, case series, and studies not written in English. Disagreements between authors were resolved through consultation with a third author.

Data extraction and data synthesis

To ensure quality, three authors independently extracted the data of each study and then all the conflicts were resolved by discussion to form a final master sheet. A table was created in Google Sheets, which included the following information: first author, year of publication, study period, country of publication, number of patients, sex, mean age, target population, inclusion criteria, exclusion criteria, procedure, groups, visualization, anxiety assessment tool, anxiety assessment time, and overall results. A fourth author was consulted to resolve any conflicts.

Due to insufficient data, no meta-analysis was conducted. Instead, we presented our results narratively with robust tables for further details. Tables were designed to illustrate study characteristics, procedures, type of visualization, measurement tools, assessment time points, and outcomes.

Quality assessment

One author conducted the quality appraisal for RCTs using the RoB-2 tool, and the first author rechecked all ratings for accuracy [12]. The assessment focused on five key domains. Studies were categorized as "High risk," "Some concerns," or "Low risk" based on their performance in each domain. Overall judgment was "Low risk" if all domains were "Low risk," "Some concerns" if any domain had "Some concerns," and "High risk" if any domain had "High risk." Regarding the non-RCT studies, we applied the ROBINS-I tool for assessing the bias [13], which evaluates bias across seven domains. Each domain, as well as the overall bias, was rated as "Low risk of bias," "Moderate risk of bias," "Serious risk of bias," "Critical risk of bias," or "No information."

Results

Study selection

This review retrieved 342 studies from PubMed, Scopus, Web of Science, and Embase on using AR/VR to manage anxiety during orthopedic procedures. After the systematic search, we performed title and abstract screening, excluded duplicate articles, and ultimately identified 24 studies that met our inclusion criteria following a full-text review [8, 14–36]. Further information is provided in Fig. 1.

Study characteristics

This review includes 16 randomized controlled trials (RCTs) and 8 cohort studies. A total of 1,714 participants were included in our study, with 936 in the intervention

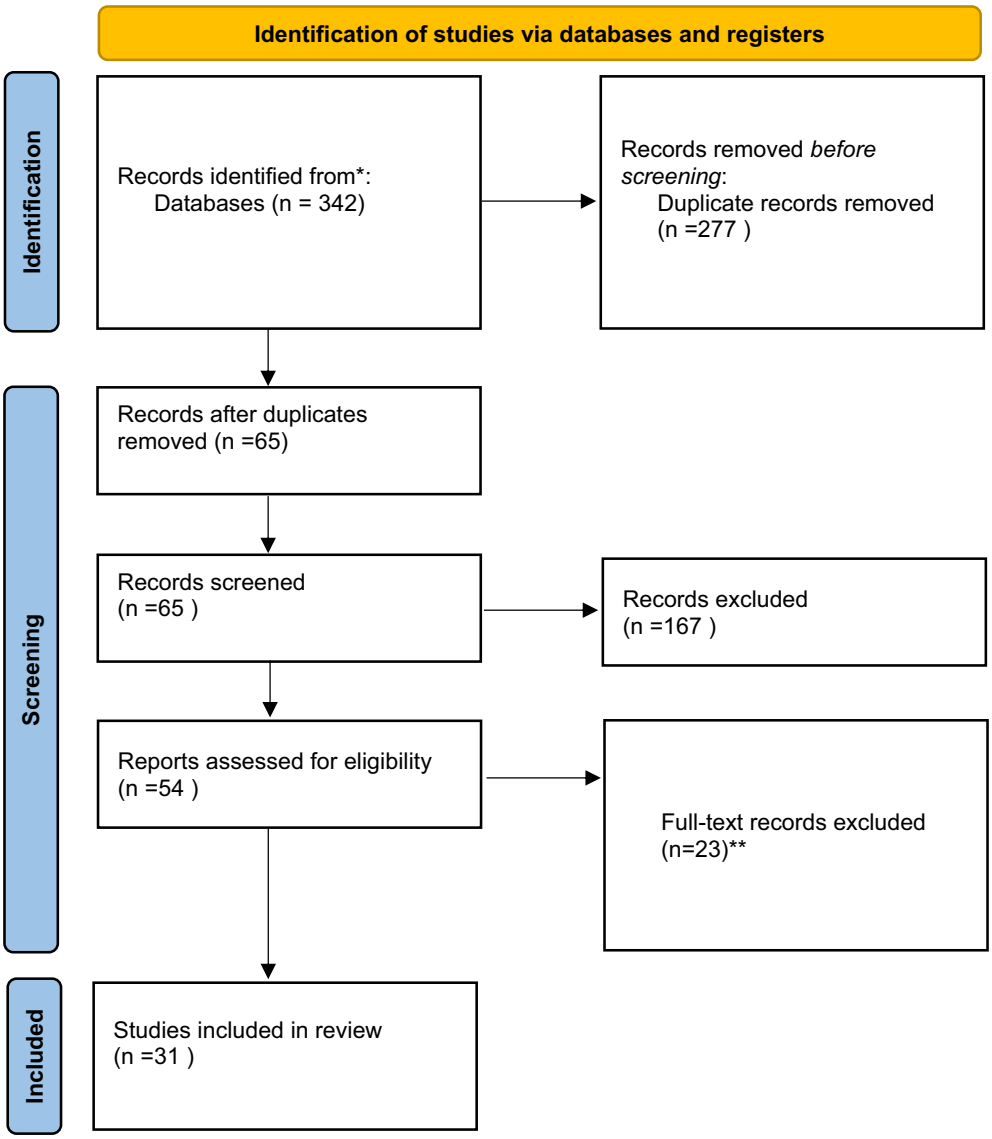

Fig. 1 PRISMA flow chart. *Pubmed:163, Scopus:182, Embase:140, web of science:134. ** Not about orthopedics procedures:19, not AR related:9, not related to anxiety:8

group and 726 in the control group, noting that one study did not specify the number of each group [22]. Patients were recruited across two age ranges: children and adults, ranging from 4 to 80 years old. The studies were published between 2016 and 2023 across various countries, the USA [17, 20, 23, 30], France [15, 25, 28, 31], and the UK [8, 19, 22, 27, 33] were among the most active countries in the field. Regarding the target population, 21 studies assessed patients' anxiety. In comparison, four studies [8, 14, 19, 22] investigated the impact of VR/AR on healthcare professionals (HCPs). Seven studies [14, 20, 24, 27, 29, 33, 36] concentrated on pediatric populations, primarily for cast and pin removal. Procedures involving elderly patients mainly included knee arthroplasty and upper limb surgeries. Most studies used head-mounted devices for visualization, which executed the intervention program through a smartphone or tablet (Table 1).This review includes 16 randomized controlled trials (RCTs) and 8 cohort studies. A total of 1,714 participants were included in our study, with 936 in the intervention group and 726 in the control group, noting that one study did not specify the number of each group [22]. Patients were recruited across two age ranges: children and adults, ranging from 4 to 80 years old. The studies were published between 2016 and 2023 across various countries, the USA [17, 20, 23, 30], France [15, 25, 28, 31],

Table 1 Characteristics and demographics of the studies

Author	Country	study type	Target population	Population			Procedure	Visualization		
				Intervention	Control	Total population		Type of intervention	Hardware	Software
[14]	Canada	Cohort	Children/ HCP	44 patients/ 11 HCPs (9 nurses, one doctor, one child life specialist)	No control	55	Intravenous insertions (n = 30), pin removals (n = 7), blood draws (n = 3), Botox injections (n = 2), dressing change (n = 1), and urodynamic test (n = 1)	VST	Oculus Rift (mobile cart + monitor + sensors, along with the VR headset and controller) Oculus Quest (only the VR headset and controller)	Dreamland game
[15]	France	Cohort	Adult	50	50	100	Ambulatory upper limb surgery under peripheral nerve block	VST	VR headset (Oculus Go 64 Giga Octet)	Guided Meditation VR
[37]	Lebanon	RCT	Adult	64	63	127	Craniotomy or spine surgery	VST	Headset (OCULUS Go 64 Giga Octet)	Na
[17]	USA	RCT	Adult	Group1:15	Group2: 15 Group3: 15	45	Chronic low back pain patients receiving spinal injections	VST	Audiovisual monitor-flat screen (AV) Virtual Reality headset (VR) Oculus GoÔ headset	Na
[18]	Belgium	RCT	Adult	30	30	60	Total knee arthroplasty (TKA)	VST	VR glasses and headphone (On comfort Sedakit X2)	HypnoVR Digital Sedation sessions
[19]	UK	cohort	Nurses	10	0	10	TKA	VST	TKA Simulator using headset and controllers (Attune ® Revision Total Knee System)	Na
[20]	USA	RCT	Children	cast:(VR game:37, VR video:36) pin:(VR game:36, VR video:44)	cast(tablet video:40), pin: (tablet video:41)	cast:113 pin:122	Cast removal pin removal	VST	head-anchored (Oculus, Meta Platforms Inc)	Nr
[21]	Israel	RCT	Adult	30	25	55	TKA	VST	HMD (Samsung Gear VR)	Nr
[22]	UK	RCT	Surgery residents	NM	NM	31	TFN-ADVANCED™ Proximal Femoral Nailing System	VST	DePuy Synthes Oculus Rift S	PIXELMOLKEREI

Table 1 (continued)

Author	Country	study type	Target population	Population			Procedure	Visualization		
				Intervention	Control	Total population		Type of intervention	Hardware	Software
[8]	UK	RCT	Physicians	7	7	14	Management of a multiply injured trauma patient	VST	Smart phone	VIRTI
[23]	USA	RCT	Adult	21	20	41	Upper extremity surgery	VST	Headset and headphones (Samsung)	Na
[24]	Canada	RCT	Children	45	45	90	Cast removal	VST	Headset and controller (Oculus Go)	Games
[25]	France	Cohort	Adult	53	46	99	Upper limb surgery	VST	VR headset (HYPNOVR)	Na
[26]	Poland	RCT	Adult	34	34	68	Hip arthroplasty-TKA	VST	VR HTC VIVE goggles and two controllers (VRTierOne device by Stolgraf)	Na
[27]	UK	Cohort	Children and parents	33	20	53	Elective pediatric orthopedic procedure	VST	VR headset (DR.VR Junior)	Na
[28]	France	Cohort	Adult	10	10	20	TKA	VST	VR headset (HyponVR ®)	Na
[29]	Germany	RCT	children	85	44	129	Cast and/or pin removals	VST	VR headset (not branded)	BaskHead Training
[30]	USA	RCT	Adult	46	49	95	Elective orthopedic surgery	OST	AR headset (not branded)	Na
[31]	France	RCT	Adult	30	30	60	Percutaneous hallux valgus surgery	VST	VR mask (Oculus Go)	Na
[32]	Turkey	RCT	Adult	31	1- PMR (31), 2-control (31)	93	TKA	VST	Headset (Google)	MedicRes E-Picos (Vienna, Austria
[33]	UK	Cohort	Children	32	0	32	Venipuncture (n = 21) or a cast procedure (n = 11)	VST	Headset (DR.VR Junior')	Nr
[34]	India	RCT	Adults	45	43	88	Arthroscopic knee surgery	VST	Headset (ROCUS, model PRO 1)	KM Player
[35]	Taiwan	Cohort	Adults	33	33	66	Elective orthopedic surgery	VST	Tablet, smartphone, etc. (not branded)	AR App
[36]	Republic of Korea	RCT	Adults and children	24	24	48	Arthroscopic knee surgery	VST	VR headset (HTC)	Nr

HCPs, Healthcare professionals; PMR, progressive muscle relaxation

and the UK [8, 19, 22, 27, 33] were among the most active countries in the field. Regarding the target population, 21 studies assessed patients' anxiety. In comparison, four studies [8, 14, 19, 22] investigated the impact of VR/AR on healthcare professionals (HCPs). Seven studies [14, 20, 24, 27, 29, 33, 36] concentrated on pediatric populations, primarily for cast and pin removal. Procedures involving elderly patients mainly included knee arthroplasty and upper limb surgeries. Most studies used head-mounted devices for visualization, which executed the intervention program through a smartphone or tablet (Table 1).

Assessment tools

The authors used various assessment tools, including the Numerical Rating Scale (NRS), Visual Analog Scale (VAS), Children's Emotional Manifestation Scale (CEMS), Social Interaction Anxiety Scale (SIAS), and Hospital Anxiety and Depression Scale (HADS), with the State Trait Anxiety Inventory (STAI) being the most frequent. The assessment time points were divided into pre-operation, during-operation, and post-operation, with most studies evaluating pre- and post-operation anxiety. More information is found in Table 2.

Anxiety in patients

For preoperative anxiety, three studies [21, 24, 29] observed less anxiety in participants who underwent VR exposure, which only one [36] reported to be significant. They utilized the APAIS assessment tool containing four subscales: anesthesia-related anxiety, information-related anxiety, surgery-related anxiety, and combined anxiety. The lower anxiety level was significant in the last two subscales [36].

Seven studies assessed intraoperative anxiety levels, all consistently reporting lower anxiety in the VR group. Among them, three studies (14, 24, 27) reached a significant level of difference compared to the control group. When separating the patients with preexisting anxiety, a significant level of difference was reached only during the hand surgery, not during injection [23]. Lopes et al. recorded the patients' anxiety during the operation with no significant difference. However, the level of anxiety was low [25].

Postoperatively, six studies [23, 24, 26, 31, 34, 37] found lower anxiety with VR, significantly vs. controls, while three [18, 21, 29] showed no difference, and two [28, 32] reported non-significantly higher VR anxiety. Variability in tools (e.g., STAI, APAIS, CEMS) across phases limits direct comparisons, reflecting field diversity (Table 2).

50% of our studies ($N=12$) evaluated the changes in anxiety levels from pre- to post-operative time points. In one study [28], the average postoperative anxiety level of controls was elevated in a higher value compared to those in VRs, and no statistical analysis was performed. In contrast, two investigations demonstrated that the reduction of anxiety levels from pre- to post-operative was significantly higher in the VR group compared to controls [26, 30]. As well, significant improvement of anxiety in VR group was seen in five, comparing post- with preoperative levels [15, 17, 21, 32, 33]. Although Fuchs et al. [21] and Lopes et al. [25] observed better modification of anxiety in patients who experienced VR intervention, the statistical significance was not achieved.

Efficacy for HCPs

Out of four studies, two of them [8, 19] identified a meaningful influence of VR exposure on anxiety (significant). Edward et al. [19], targeting nurses, showed less anxiety after VR intervention. The other study [8], which allocated on-call trauma physicians randomly into VR and non-VR groups, showed that the VR group presented with a lower level of anxiety in comparison to the non-VR group. Another study on surgical residents [22] demonstrated that the VR-training group had higher confidence and lower anxiety than those in the traditional training group (no statistical significance reported). Limited studies and small samples constrain generalizability.

Satisfaction

Eight studies [14, 15, 28, 29, 32, 34, 36, 37] assessed patient satisfaction with VR/AR. Most [29, 32, 36, 37] reported higher postoperative satisfaction vs. controls, notably in pediatrics, though Peuchot et al. [28] found no significant difference in adults. Preoperatively, two [36, 37] noted higher satisfaction, Bekelis et al. [37] linking it to VAS scores. Mixed results reflect subgroup variation, stronger in pediatrics, though data limits complete synthesis (Table 3).

Quality assessment

Based on the RoB-2 assessment, 11 out of the 18 studies exhibited"some concerns" [15, 16, 18, 20–24, 29, 30, 33], whereas 6 of them presented "High risk" [8, 17, 26, 27, 32, 34]. In the ROBINS-1 analysis, we observed that two non-RCTs had a "Moderate" overall risk of bias [28, 35], while two had a "Low" overall risk of bias [14, 25], and two presented a "Serious" risk of bias [19, 31]. Further details of our quality assessment can be found in Tables 4 and 5.

Discussion

In this review, we discussed the effectiveness of VR, AR, and MR tools in managing anxiety in patients undergoing orthopedic surgeries, cast removal, or pin removal. Moreover, we reviewed studies examining anxiety in healthcare providers with one of the VR technologies.

Our results cover all age categories, from children to adults. Overall, we observed positive impacts of the mentioned technologies on the patients, representing lower anxiety levels, higher satisfaction, lower stress, lower fear, reduced pain, and less anesthetic drug consumption.

Our findings suggest a reasonable control of preoperative anxiety, assessed by various tools (e.g., NRS, STAI, and HADS), aligning with studies such as Chan et al. [38] (gynecological surgery, reduced HADS scores) and Turrado et al. [39] (colorectal surgery, perioperative reduction), though adult variability differs from pediatric consistency in Simonetti et al.'s review [40]. Following the use of HMD for providing VR video, patients preoperatively experienced lower anxiety and stress compared to controls, of which all values were significant. Moreover, significantly higher postoperative satisfaction was observed in the intervention group [41]. Chan et al. reported a significant reduction in HADS anxiety scores, as well as significant improvement in EQ-5D-3L dimensions (usual activities, pain/discomfort, and anxiety/depression) following VR exposure in gynecological surgeries [38]. In a study on outpatient surgery settings, patients with high-stress levels (APAIS > 11) preoperatively experienced a VR program. Based on the post-intervention VAS score, the stress level was significantly diminished. Beyond the results of assessment tools, salivary cortisol level, as a biological marker of stress, met a significant reduction too [42]. Regarding the management of perioperative anxiety, our study shows a comparable decreased level of anxiety after VR intervention. Similarly, an RCT in the setting of colorectal cancer surgery has demonstrated that the perioperative anxiety was significantly reduced compared to the preoperative level in the VR group [39].

According to the literature, many studies seem to have evaluated the efficacy of these technologies in children, as they are more likely to be affected by the medical environment. Addab et al. reviewed the utilization of the clinical efficacy of VR in managing pediatric anxiety during post-burn physiotherapy, burn wound care, and needle-related procedures. They proved that VR could refine pain management by immersing children in a virtual environment, reducing anxiety and pain in the hospital [43]. Gerçeker et al. investigated pediatric hematology-oncology patients, assessing the level of anxiety and fear before and after inserting the port needle procedure. The results significantly indicated that VR is an effective method for reducing pain, fear, and anxiety associated with port needle insertion [44]. Simonetti et al. published a systematic review of the management of pediatric anxiety during the pre-operative period. The study findings support VR's effectiveness in reducing anxiety among pediatric patients undergoing elective surgery [40]. Overall, our findings support the literature on the positive impact of VR, AR, and MR in managing anxiety in stressful and tense medical procedures.

Our orthopedic focus sets us apart from prior systematic reviews. Eijlers et al. [10] found VR consistently reduced pediatric anxiety across procedures, aligning with our seven pediatric studies, though we note mixed adult outcomes. Simonetti et al. [40] confirmed VR's perioperative efficacy in children, but our review extends to adults and HCPs, albeit with fewer studies, reflecting a unique scope. Unlike these meta-analyses, our narrative synthesis accommodates orthopedic-specific variability, limiting statistical pooling.

In some of our included studies, VR intervention has been found to decrease the required dosage of anesthetic drugs. Cohen et al. [45] assessed the pain and anxiety levels of patients during epidural steroid injection in three groups: VR + local anesthetic, sedation + midazolam and fentanyl with local anesthesia, and local anesthetic alone. Although no significant differences were observed in anxiety, pain, or satisfaction, this approach offers notable advantages, including a lower incidence of side effects, faster recovery times, and improved patient communication. In another study, researchers assessed the effectiveness of immersive VR distraction technology in reducing pain and anxiety in female patients with breast cancer. They observed that a single session of immersive VR combined with morphine significantly reduced self-reported pain and anxiety scores in breast cancer patients compared to morphine alone. Furthermore, VR is a safer intervention than pharmacological treatments [46]. Overall, VR technologies could effectively act as an adjacent intervention in operations.

In the current study, we noticed that the efficacy of VR in pediatrics was more predominant than that of adults in terms of anxiety reduction. In support of our findings, a significantly lower level of preoperative anxiety was found in pediatrics undergoing surgery who used VR intervention, according to a meta-analysis. However, the intergroup difference in anxiety levels in adults did not reach a significant level [47]. Given the above, we speculated that VR-mediated distraction may occur intensely in children.

These technologies can enhance surgical training and preoperative planning, with practical integration into orthopedic practice. Preoperatively, VR could deliver patient anxiety-reduction modules (e.g., guided relaxation via HMD before surgery), while intraoperatively, AR overlays might project anatomical guides onto patients during procedures like knee arthroplasty, as suggested by our findings and training benefits. They improve skill

Table 2 Assessment tools and assessment times of anxiety/ fear

Author, Year	Assessment tool(s) / Scale(s)	Assessment time point(s)			
		pre-op	Intra-op	Post-op	Pre-to-post alteration
[44]	FACES Anxiety Scale (FAS) (0–4 scores)		*		
[15]	NRS (10-point graded scales)		*		*
[37]	APAIS			*	
[17]	questions recommended by the NIH task force on chronic LBP [11] and the MODI				*
[18]	STAI-6 – NRS; STAI-Y			*	
[19]	Likert scale rating (5 scores)		*		
[20]	patients aged 4 to 7 years used a VAS that included both Wong-Baker FACES and a numerical rating scale, while patients aged 8 to 14 years were presented with a numerical rating scale only. After the procedure, patients completed the pain and anxiety VAS again				*
[21]	STAI	*		*	*
[22]	STAI-6 score	*		*	
[8]	10-point Likert scale	*		*	
[23]	10-point Likert scale		*	*	
[24]	Intra-operative: CEMS- Pre- and Post- procedural: SAIS- PSWQ-C	*	*	*	
[25]	NRS (10 scores)		*		*
[26]	Anxiety and Depression Scale (HADS) (14 items)			*	*
[27]	10-point Likert scale- STAI-P				*
[28]	STAI Y-1			*	
[29]	Children's Anxiety Meter-State	*	*	*	
[30]	STAI				*
[31]	STAI			*	
[32]	STAI-S			*	*
[33]	Likert scale				*
[34]	STAI			*	*
[35]	a five-point agreement scale				*
[36]	APAIS—Likert scale	*			

The boxes with an asterisk are considered positive

APAIS, Amsterdam Preoperative Anxiety and Information; PSWQ-C, Penn State Worry Questionnaire for Children; SAIS, Short State Anxiety Inventory Scale; CEMS, Children's Emotional Manifestation Scale; STAI-P, State-Trait Anxiety Inventory parent version; NRS, numerical rating scal; MODI, Modified Oswestry Disability Index

acquisition, workflow, and confidence, reducing anxiety. In line with our findings, studies have shown that surgical trainee can benefit from VR to improve their skills, tissue handling, and lowering errors [48, 49]. Logishetty et al. found that VR can help obtain skills in total hip arthroplasty [50]. Furthermore, AR is promising and effective in the surgical education [51]. AR can potentially increase learning by providing a highly simulative, low-stress environment. Moreover, VR/AR provides surgical trainees with a safe environment to enhance their skills, reducing the risk of errors and ultimately improving patient safety [52].

Future research should refine the application of VR/AR in orthopedic settings by addressing specific gaps identified in this review. Given the variability in anxiety assessment tools, standardizing measures across studies could enhance comparability and enable meta-analyses, overcoming current restrictions. More extensive randomized controlled trials focusing on adult orthopedic patients are essential to balance the predominant pediatric focus and clarify mixed adult outcomes, while comparisons of passive versus interactive VR interventions could optimize efficacy for anxiety management and training. Longitudinal studies on VR's impact on HCP skill retention and anxiety reduction beyond small samples, alongside trials across diverse procedures like spinal surgery beyond cast removal and arthroplasty, would broaden applicability. Optimizing VR/AR dosing (duration and frequency) for patient subgroups and assessing cost-effectiveness against traditional methods would further support clinical adoption.

Like other studies, ours faced limitations, categorized as study design limitations: insufficient studies with similar interventions and outcome measures prevented

Table 3 Main outcomes of the studies

Author	Groups		Overall Results
	VR	Non-VR	
[44]	Group1: 6 patients using Oculus Rift Group2: 38 patients using Oculus Quest	N/R	-VR was efficient in procedural pain and anxiety - HCPs were found it effective in managing patient's anxiety, and were satisfied from the results -VR was easily integrated in clinical workflow
[15]	VR group: using VR headset + regional anesthesia	Regional anesthesia	-Significant reduction of anxiety only in VR group -Lower level of intraoperative anxiety in VR group -Increased postoperative satisfaction in VR group
[37]	Patients in the VR group watched a 5-min VR video through VR goggles	Patients in the standard preoperative experience were provided with routine audiovisual descriptions of the preoperative experience	-Significant lower level of postoperative anxiety in VR group -Significant correlation between lower anxiety and use of VR -Lower stress in VR group -Higher preparedness in VR group -Higher satisfaction in VR group
[20]	VR or AR	Group1: 15 patients using Audiovisual (AV) monitor-flat screen Group2: 15 patients no VR and AV	-Significant reduction in anxiety from baseline to preoperative in VR group -Lower preprocedural anxiety in intervention groups but no significant changes between groups
[18]	standard care: 2 mL hyperbaric bupivacaine 0.5% added with 0.2 mL of sufentanil 5 µg/mL + VR glasses and headphone	Standard care: 2 mL hyperbaric bupivacaine 0.5% added with 0.2 mL of sufentanil 5 µg/mL	-Similar postoperative anxiety and pain in both groups - Significant lower dose of midazolam in VR group
[19]	four-session immersive virtual reality curriculum with a minimum of 2 and a maximum of 10 days between sessions	N/A	- Anxiety was reduced significantly -Significant lower operative time with using VR -Lower assistive prompts and anxiety with using VR -Higher confidence (significant) and real-world skills with using VR (84% vs. 11%)
[20]	cast:1.VR gaming simulation2.VR goggles with noninteractive pin:VR gaming simulation2.VR goggles with noninteractive	Oculus, Meta Platforms Inc	-No differences in preprocedural to postprocedural VAS pain -No differences in preprocedural to postprocedural VAS anxiety
[21]	Continuous passive motion device (CPM) + VR headset	CPM	- Not significant lower preoperative and postoperative anxiety in VR group -Significant reduction in pain and anxiety in both groups (no difference between groups)
[22]	This group conducted a VR simulation of inserting the same TFN-ADVANCED™ Proximal Femoral Nailing System (TNFA system) which that comprised a halo headband with incorporated visual lenses and two handheld controllers	The traditional group training consisted of operative technique (Optech) notes for insertion of the TFNA	-Lower anxiety levels (33% vs. 55%) and higher confidence in VR group (84% vs. 61%)
[8]	access to a fully immersive interactive VR video via their smart phone using a unique app (VIRTI)	An hour-long simulation session on the management of a multiply injured trauma patient, in line with ATLS principles	-Lower level of anxiety of trauma calls in VR group (significant) - VR group was faster

Table 3 (continued)

Author	Groups		Overall Results
	VR	Non-VR	
[23]	They wore VR headset and headphones	not VR	-Significant lower anxiety and pain scores during injection, during the procedure, and at the end of the procedure in VR group -Patients with preexisting anxiety had only lower intrapro-cedural anxiety
[24]	SOC + VR headset and controller	Standard of care (SOC)	-Mean preoperative anxiety was lower in VR (no statistical report) -Significant lower intra- and post-procedural anxiety in VR group
[26]	Four-week conventional rehabilitation + 8 VR therapy ses-sions during their rehabilitation	Four-week conventional rehabilitation (standard care)	-Reduction in HADS score in VR group was significantly higher than control - Lower post-treatment anxiety in VR group (significant) -Reduction in pain score in both groups
[25]	VR headset + axillary block	No specific intervention	-No difference in intraoperative anxiety -VR group experienced higher reduction of anxiety (not statistically different from control)
[29]	Using VR headset	No specific intervention	-Significant lower anxiety and fear scores during the proce-dures in VR group -No differences between fear and anxiety scores before and after the procedures in both groups -Higher satisfaction scores in VR group
[27]	1) VR headset coupled with a control tablet pre-opera-tively 2) VR headset coupled with a control tablet in fracture clinic	Standard care facilitated by a play specialist, involving conventional distraction techniques such as games and toys	-Lower level of anxiety in parents and patients in VR inter-vention (significant) -Similar level of pain in both groups Improvements the hospital experience in both groups
[30]	They received both the standard surgical instruction packet and the AR experience	They received only the standard surgical instructions packet provided to all patients	-significant reduction of level of screening to preoperative anxiety in AR group compared to control -No significant difference in screening to postoperative anxiety (controls experienced higher reduction) -Reduction in anxiety score in postoperative survey in both groups -No difference between pain scores in both groups
[28]	Using the VR headset (+ sedative drugs if required)	Without the headset and with the standard protocol (+ sedative drugs if required)	-Higher postoperative anxiety level in VR group (not significant) -Lower sedation and intraoperative adverse event in group 1 -Higher in comfort score in VR group (significant) -No difference in patient satisfaction in both groups

Table 3 (continued)

Author	Groups		Overall Results
	VR	Non-VR	
[32]	spinal anesthesia + VR headset	Group1: standard care was applied to the control group Group2: The CD and a CD player were given to the patient (PMR group)	-Higher intragroup STAI-S scores in the PMR and VR groups (significant) -Higher satisfaction scores in the PMR and VR groups (significant)
[31]	They wore VR Hypnosis Mask during procedure	No specific intervention	-Lower postoperative and discharge anxiety scores in VR group (significant) -Significant Reduction in using analgesics like ketamine in VR group
[35]	An AR app was offered; included 10 kinds of respiration training, 34 kinds of resistance muscle training, and walking training	A pre-recorded video was provided to patients who chose conventional perioperative rehabilitation	-Higher level of anxiety reduction in VR group (not significant) -patients using the AR app had better subjective and objective outcomes
[33]	using headset	No specific intervention	-Significant reduction in anxiety -A total of 66% (21) showed a reduction in anxiety scores, 28% (9) had no change in score -No adverse events were recorded
[36]	Patients in the VR group watched a 3D model of their own MRI through a VR headset	Patients in the non-VR (NR) group received standard preoperative information about their MRI	-Lower preoperative anxiety level in VR group: in two subscales were significant: surgery-related and combined anxiety; in two was not significant: anesthesia- and information-related anxiety -Higher pre- and postoperative satisfaction in VR group (significant) -preoperative stress did not differ, but postoperative stress was significantly lower in VR group -No difference in preoperative preparedness
[34]	spinal anesthesia + Immersive experience was provided through a mobile phone-based HMD showing videos and headphone playing audios	Spinal anesthesia (0.02 mg·kg − 1 of intravenous midazolam)	-Lower postoperative anxiety level in VR group (Significant) -Higher satisfaction in VR group (significant) -No difference in anxiety scores from the preoperative to postoperative in both groups

Table 4 RoB-2 quality assessment results

RoB-2:	D1	D2	D3	D4	D5	Overall
[15]	Low	Some concerns	Low	Low	Low	Some concerns
[16]	Low	Some concerns	Low	Some concerns	Low	Some concerns
[20]	Low	High	Low	Some concerns	Low	High risk
[18]	Low	Some concerns	Some concerns	Some concerns	Some concerns	Some concerns
[20]	Low	Low	Low	Low	Some concerns	Some concerns
[21]	Low	Some concerns	Low	Low	Low	Some concerns
[22]	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
[8]	Some concerns	High	Low	Some concerns	Low	High risk
[23]	Low	Low	Some concerns	Some concerns	Some concerns	Some concerns
[24]	Low	Some concerns	Low	Low	Low	Some concerns
[26]	High	Some concerns	Low	Some concerns	Low	High risk
[27]	Low	High	Some concerns	Low	Low	High risk
[29]	Some concerns	Some concerns	Low	Low	Low	Some concerns
[30]	Low	Some concerns	Low	Low	Low	Some concerns
[32]	Some concerns	High	Low	Some concerns	Low	High risk
[33]	Low	Some concerns	Low	Low	Some concerns	Some concerns
[34]	Low	High	Some concerns	Low	Low	High risk
[36]	Low	High	Some concerns	Low	Low	High risk

Table 5 Main ROBINS-1 quality assessment results

Study	D1	D2	D3	D4	D5	D6	D7	Overall
[35]	Moderate	Low	Moderate	Low	Moderate	Moderate	Low	Moderate
[31]	Serious	Low	Low	Serious	Low	Moderate	Moderate	Serious
[28]	Low	Moderate	Low	Moderate	Moderate	Low	Low	Moderate
[25]	Low	Low	Low	Low	Low	Low	Low	Low
[19]	Serious	Low	Moderate	Low	Moderate	Moderate	Low	Serious
[44]	Low	Low	Low	Low	Low	Low	Low	Low

a logically sound meta-analysis. Measurement issues like variability in anxiety tools restricted comparability across studies. The greater focus on pediatrics (7 studies) vs. adults and notably small HCP sample sizes limit generalizability, particularly for provider outcomes.

Conclusion

VR/AR effectively reduces anxiety in pediatric orthopedic patients, though findings for adults and HCPs are less conclusive. Clinicians could use preoperative VR for anxiety relief and VR training modules for HCPs. Further research needs standardized tools and larger adult/HCP studies to address variability.

Supplementary Information

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Supplementary file 1.

Supplementary file 2.

Supplementary file 3.

Supplementary file 4.

Author contributions

N.N. Contributed to the conceptualization and design of the study, conducted data extraction and analysis, and contributed to manuscript writing and revision. Y. K. Contributed to data extraction, analysis, and interpretation, and drafted portions of the manuscript. A. S.: Assisted with systematic search, screening, and data synthesis, and contributed to manuscript preparation. M. B. Conducted quality assessment and critically reviewed the manuscript for intellectual content. E. S.: Provided methodological oversight, and contributed to manuscript primary draft. M. N. Contributed to the study design, supervised the overall process, and provided critical revisions to the manuscript. A. M. Conceptualized and designed the study, supervised all aspects of the project, and served as the corresponding author responsible for final approval of the manuscript.

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Declarations

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Consent for publication
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