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REVIEW

Does virtual reality reduce anxiety and pain in patients undergoing third molar surgery? A systematic review and meta-analysis

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Abstract
This study aimed to systematically review the literature to evaluate the effectiveness of virtual reality in reducing anxiety and pain in patients undergoing third molar surgeries. Clinical trials evaluating patients who used virtual reality (VR) compared with no VR in the management of pain or anxiety after third molar extractions were included. A literature search was conducted in five electronic databases to identify relevant articles: Medline (PubMed interface), Web of Science, Virtual Health Library, Embase, and Scopus. There were no restrictions on the time or language of publication. The risk of bias was assessed using the Cochrane Risk of Bias Tool for Randomised Trials (RoB 2.0). A total of six studies were included in the qualitative analysis and three in the quantitative analysis. The results of the meta-analyses on anxiety revealed that patients in the intervention group before VR already showed less anxiety compared to those in the control group (-0.28 [-0.44 to -0.13, 95%CI] I^2=24.51%. In the post-intervention evaluation, the group that received VR remained with a lower level of anxiety and a slight reduction compared to the pre-intervention. (-0.34 [-0.49 to -0.19, 95%CI] I^2=36.61%. Virtual reality can be a clinical resource in dental care because it seems to cause a small reduction in anxiety, and with still uncertain results in the reduction of postoperative pain in extractions of third molars.

Keywords Virtual reality · Third molar · Exodontia · Anxiety

Introduction

One of the most frequent procedures in oral surgery is the extraction of third molars [1]. The extraction of third molars tends to generate high levels of anxiety in patients and thus increases pain perception [2]. Finding a suitable non-invasive strategy to reduce both anxiety and pain is justified and of utmost importance.[3] Alternatives have been investigated, such as psychological distraction interventions to manage anxiety and pain in the perioperative and postoperative periods, since they do not pose risks to patients [3]. Virtual Reality (VR) is one such psychological intervention.

Virtual reality (VR) is a technological system that allows the user to immerse themselves in a "virtual world" through visual, auditory, tactile, and olfactory sensations, providing an experience quite distinct from passively watching television or playing video games [4]. Originally created and used only for entertainment purposes, mainly in electronic games, its use was gradually extended to other areas, including the medical field [5, 6].

Previous studies have investigated the ability of VR to reduce anxiety and pain during third molar extraction procedures [2, 4]. However, results are mixed, as some studies have shown that VR intervention was able to reduce both dental anxiety and pain [4], while others found no statistically significant differences in pain assessment [2]. A recently published systematic review with network meta-analysis evaluated the comparative effectiveness of relaxing music, audiovisuals, and VR in reducing dental anxiety associated with tooth extraction. This study showed that relaxing music has the greatest potential to reduce anxiety,

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followed by VR [7]. However, this review included studies that evaluated third molar and primary teeth extraction [7].

Given the surgical complexities due to the particular differences between the deciduous and permanent dentition, in addition to recent investigations that considered only extraction in third molars [2, 4] and the inconclusiveness of the results, the development of this systematic review to evaluate the use of VR in dentistry, in third molar extraction procedures is justifiable. In addition, pain as well as anxiety are one of the greatest challenges in dental treatment [8], especially in invasive procedures such as tooth extraction. Thus, reviewing the available evidence on this topic is important to assist in the control of these outcomes in the extraction of third molars.

Therefore, this systematic review aimed to review the literature on the efficacy of virtual reality in reducing anxiety and pain after third molar surgery.

Methodology

Protocol and registry

The protocol of this study was previously registered in the International Prospective Register of Systematic Reviews and it can be accessed in website (https://www.crd.york.ac.uk/prospero). This systematic review was conducted based on the revised guidelines of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) [9] and Cochrane Handbook [10].

PICO question and eligibility criteria

The review was conducted to answer this PICOS question: "Does virtual reality reduce anxiety and pain in patients undergoing extraction of third molars?" P: Patients without a previous diagnosis of mental illness and/or uncontrolled chronic illness undergoing third molar extraction; I: use of any type of virtual reality; C: non-use of virtual reality; O: Postoperative anxiety and pain control; S: Clinical trials.

The following exclusion criteria were considered: (1) clinical trials from conference abstracts or published in conference proceedings with insufficient data; (2) patients using therapy to control anxiety and depression; (3) Patients who have undergone extraction of more teeth along with the third molar; (4) Use of VR associated with other pharmacological or non-pharmacological therapy. No restrictions have been applied as to the language or date of publication.

Search strategy and article selection

A comprehensive literature search was conducted in the following electronic databases to identify relevant articles as of September 19, 2023: Medline (PubMed interface) (www.pubmed.gov), Web of Science (www.webofknowledge.com), *Virtual Health Library* (http://bvsalud.org/), Embase (https://www.embase.com), and Scopus (https://www.scopus.com). Additionally, the clinicaltrials.gov site was explored to identify possible ongoing clinical trials. A manual search was also performed from the reference list of the included studies. The search also extended to grey literature, selecting the first 50 results from Google Scholar and Opengrey by DANS website (https://easy.dans.knaw.nl/ui/home). The terms MeSH, DECs, Emtree and relevant keywords related to "third molar surgery", "tooth extraction" and "virtual reality" were used with Boolean operators (OR, AND) to combine the terms in the elaboration of the search strategy that was adapted for each database, when necessary (Supplementary File 1).

All records identified by the database search strategy were imported to the Rayyan website (https://www.rayyan.ai/) and the identified duplicate records were removed. Titles and abstracts retrieved from electronic databases were evaluated separately by four authors to select potentially eligible studies. Subsequently, the full texts of the previously selected studies were acquired and submitted to a careful and independent evaluation by the same four authors, according to the previously established eligibility criteria. Any discrepancies among the reviewers were resolved through consensus.

Data extraction

The following epidemiological data were collected from the included studies: methodological characteristics: authors, year of publication, country, sample size, randomization, gender, age, classification of the extracted third molar; characteristics of the intervention: virtual reality methods, sample size by compared groups, outcomes, methodology for assessing the outcomes and timing of the intervention.

When any of this information was confusing or missing, the authors of the primary studies were contacted by email.

Risk of bias assessment

The methodological quality of the included studies was assessed using the Cochrane Risk of bias 2.0 (RoB 2) tool for risk of bias in randomised controlled trials [11]. This tool covers five fundamental domains: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of

the reported result. Four independent evaluators individually analysed the risk of outcome-related bias in each study. Ultimately, each study was classified as low, unclear, or high risk of bias. Any discrepancies among the reviewers were resolved through consensus.

Data analysis

A descriptive analysis of the findings of the included studies was performed on the use of virtual reality in patients undergoing third molar surgery. Meta-analyses were performed in the presence of the outcomes reported in at least two studies, using the Stata software, version 17.0 (Statistics and Data Science). The effect measure used was Cohen's d to calculate the standardized difference between means. The random-effect model was adopted because it considered substantial statistical heterogeneity ($I^2 > 50$). The analyses were divided according to the moment of the intervention analyzed - the preoperative and the postoperative periods. A subgroup analysis was performed according to the instrument used to assess the anxiety outcome and sensitivity analyses was not conduct. The results were presented with 95% confidence intervals in all cases.

Assessing the certainty of the evidence using GRADE

The certainty of the evidence was assessed for each outcome using the Grading of Recommendations: Assessment, Development and Evaluation (GRADE). Five analysis criteria were considered: risk of bias, inconsistency, indirect evidence, imprecision, and publication bias. In the end, the quality of the evidence was classified as high, moderate, low, or very low certainty of the evidence [12] (Supplementary File 2).

Results

Studies selection

The search of the databases resulted in 283 articles and 1 clinical trial record. After removing duplicates, 239 articles remained for selection by reading titles and abstracts. Of these, five were accessed to read the full texts. After evaluation, two studies were excluded because they did not meet the eligibility criteria. In the gray literature search, two studies were included, and one study was included after reading the list of references. A total of six articles were included in the systematic review [2, 4, 13–16]. The entire study selection process is detailed in Fig. 1.

Characteristics of the included studies

The included studies were published between 2020 and 2023 and were from four different countries. In total, 314 participants were included in the experimental group and 307 in the control group. Surgeries of impacted mandibular third molars have been reported in five studies [2, 4, 13, 15, 16]. Only one study did not specify the classification of the third molar [14] (Table 1).

All the contents of the virtual realities of the included studies were related to pleasant scenes of nature that were presented through the use of 3D (three-dimensional) glasses. One study presented three comparator groups in which VR through a video game was also used [16]. VR devices varied according to the brand and manufacturer of the equipment. No studies have used virtual reality (Non-VR) as a comparator group (Table 2).

Risk of bias assessment

Overall, for the "anxiety" outcome, two studies had a high risk of bias[4,14] and four had some concerns [2, 13, 15, 16]. The domains "randomization process" and "measurement of the outcome" were classified as having a high risk of bias and the "missing outcome data" domain presented a low risk of bias in almost all studies [2, 4, 13, 15, 16]. For the "pain" outcome, one study showed a high risk of bias [4] and four had some concerns [2, 13, 15, 16]. The domain "randomization process" was classified as a high risk of bias in at least one study [4] and the domain "missing outcome data" showed a low risk of bias in all studies (Figs. 2 and 3).

Assessment of anxiety and pain

Anxiety was assessed in all included studies [2, 4, 13–16]. The Spielberger State-Trait Anxiety Inventory (STAI) questionnaire was used to assess anxiety in three studies [2, 13, 14]. This tool consists of a self-report questionnaire with 40 items and can be subdivided into 2 subscales: the Spielberger State-Trait Anxiety Inventory subscale for state anxiety (STAI-S), composed of 20 items, assesses the transient emotional state at the moment, and the Spielberger State-Trait Anxiety Inventory subscale for trait anxiety (STAI-T) analyzes the relatively stable propensity to anxiety in general and is also composed of 20 items [4, 17]. Two studies presented the results for the STAI-S and STAI-T subscales [2, 13]. One study also used the Modified Dental Anxiety Scale (MDAS) questionnaire [13]. Another study used the Heart rate for the assessment of anxiety [4]. And two studies used The Analogue Visual Scale (VAS) [15, 16]. Most studies have concluded that distraction VR applied during third molar surgery under local anesthesia may help reduce

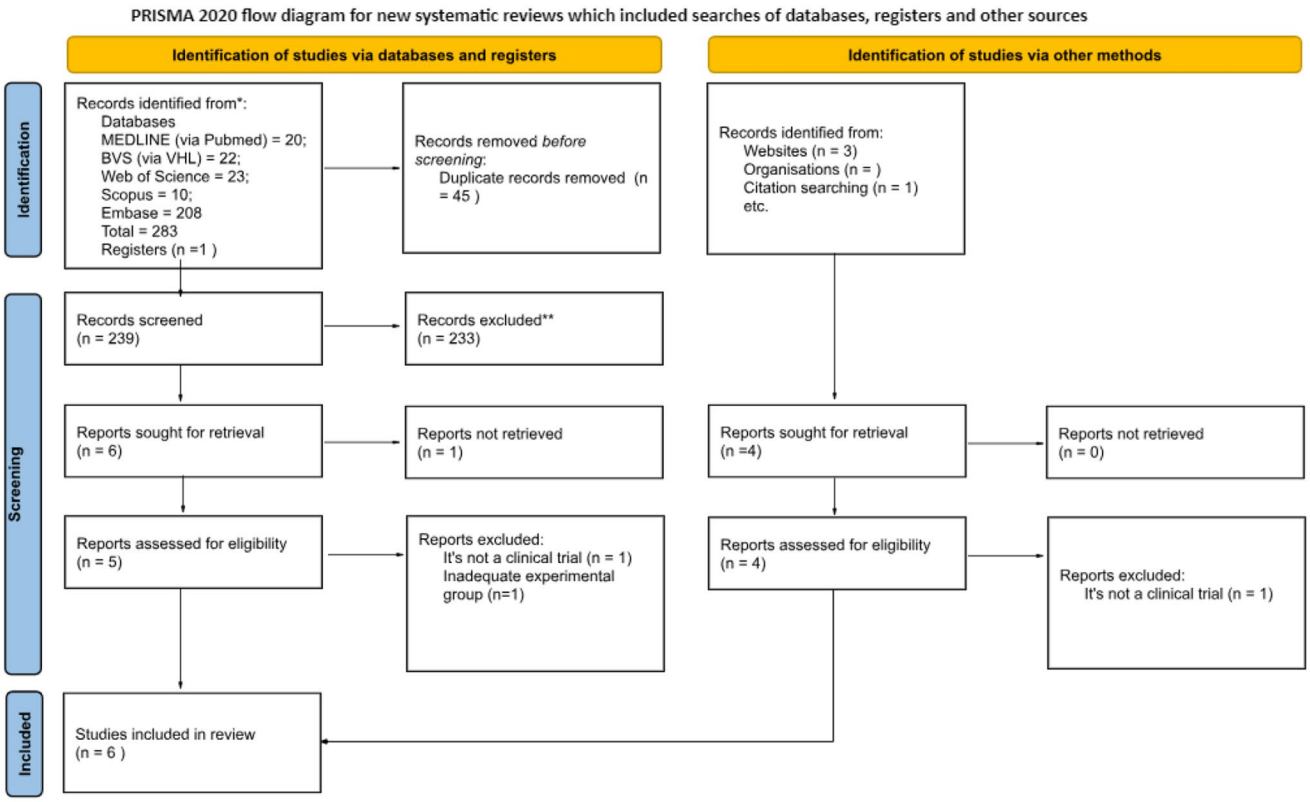

Fig. 1 Flowchart for study identification

Table 1 Methodological characteristics of the studies

Study year	Country	Sample (patients/ teeth)	Randomized (Y/*N*)	Sex (F/M)	Age (mea ± sd)	3 M classification
Luque-Ribas et al., 2020	Spain	30/30	Y	21 / 9	27.9 ± 1.4	Impacted mandibular 3 M
Mohammadpour et al., 2020	Iran	60/NR	Y	34 / 26	26.5 ± 4.9	NR
Yamashita et al., 2020	Japan	100/ NR	N	60 / 40	VR (27,6 ± 7,7) Control (35,0 ± 11,8)	Impacted 3 M (horizontally and 1–2 A or B by Pell and Gregory classification.
Mladenovic; Djordjevic, 2021	Serbia	74/148	N	28 / 46	34.9 ± 9.0	Impacted mandibular 3 M (1 or 2B by Pell and Gregory classification)
Yamashita et al., 2022	Japan	172/NR	Y	106 / 66	VR (27.6 ± 7.7) Control (34.9 ± 11.8) Game (29.4 ± 9.5)	Impacted mandibular 3 M (1–2 A or B by Pell and Gregory classification)
Sorribes De Ramón et al., 2023	Spain	275/275	Y	155 / 120	26.29 ± 9.28	Impacted mandibular 3 M (1–2 A or B by Pell and Gregory classification)

NR: No report; F: Female; M: Male; SD: Standard deviation; 3 M: third molar; VR: Virtual reality; RCT: Randomized clinical trials, NRCT: No Randomized clinical trials, Control: Non-VR

patients' anxiety [2, 4, 14–16]. In the study by Luque-Ribas et al. [13], patients' anxiety levels seem to remain unchanged after the intervention.

Pain outcome was assessed in five studies [2, 4, 13, 15, 16]. One study used the Wong-Baker Face Scale [4], two used VAS [2, 15], another study used the Painvision electric current assessment device [16] and the study by Luque-Ribas et al. [13] did not specify the pain assessment methodology. Three studies [4, 13, 16] concluded that distraction through VR in third molar surgery under local anesthesia can help reduce pain levels, while the results of the studies

Table 2 Intervention characteristics

Study year	Intervention (*n*)	Non-VR (*n*)	Outcomes	Assessment instrument	Timing of intervention
Luque-Ribas et al., 2020	Trans-operative eyeglasses (Cinemizer Eyeshield; Zeiss) (15)	15	Anxiety Intraopera-tive pain	STAI, STAI-S, STAI-T and MDAS NR	Pre and Pos intervention (after surgery)
Mohammad-pour et al., 2020	Preoperative VR device (gog-gles) and headset (Remax-RT-V03 audio-video glasses) (30)	30	Anxiety	STAI	Pre and Pos interven-tion (Before surgery)
Yamashita et al., 2020	Trans-operative VR (Oculus-Rift CV1, Oculus) (51)	49	Pain Fear and anxiety Satisfaction HRV	VAS VAS Questionary Acceleration plethysmograph	Before, during treatment and Pos intervention (After surgery)
Mladenovic; Djordjevic, 2021	Trans-operative VR goggles (Samsung Gear VR Oculus and Samsung Galaxy S10) (74)	74	Pain Anxiety	Face scale (Wong- Baker Face Scale) HRV	During treatment
Yamashita et al., 2022	Trans-operative landscape VR (Oculus Go32 FB, Oculus VR, Menlo Park, CA) (51) Vigeogame VR (73)	48	Fear and anxiety	VAS	Before, during treatment and Pos intervention (After surgery)
Sorribes De Ramón et al.,2023	Pre and Trans-operative VR (3D glasses Bnext) (93) Music therapy (91)	91	Pain assessed Anxiety	VAS STAI, STAI-S, STAI-T	Pre and Pos intervention (After surgery)

STAI: Spielberger State-Trait Anxiety Inventory; STAI-T: Spielberger State-Trait Anxiety Inventory subscale for trait anxiety; STAI-S: State-Trait Anxiety Inventory subscale for state anxiety; MDAS: Modified Dental Anxiety Scale; VAS: Visual analog scale; HRV: Heart rate variability; NR: Not reported

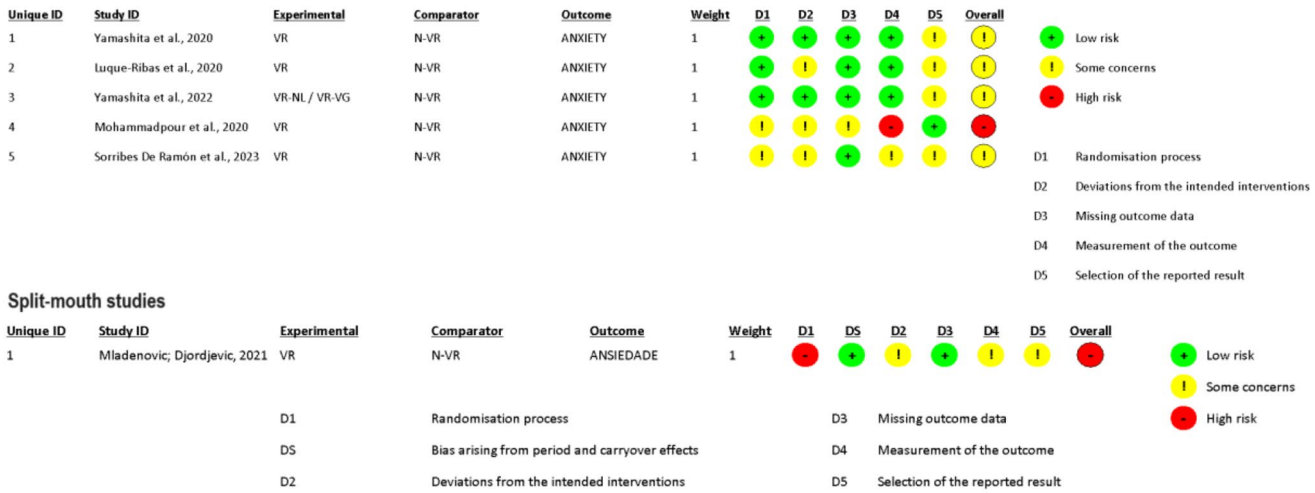

Fig. 2 Assessment of the risk of bias of the included studies for anxiety outcome

by Yamashita et al. [15] and Sorribes De Ramón et al. [2] did not show any clear effects in terms of pain relief.

Meta-analysis

Three studies [2, 13, 14] presented quantitative data for the assessment of anxiety. The Fig. 4 shows the level of pre-operative anxiety of the patients before receiving VR. In this analysis, the STAI instrument (-0.45 [-0.70 to -0.19, 95%CI] I^2=69.89%, very low certainty of the evidence) showed a significant difference in the baseline. Its subscales, STAI-S (-0.25 [-0.52 to 0.02, 95%CI] I^2=0%, low certainty of the evidence) and STAI-T (-0.13 [-0.40 to 0.14, 95%CI] I^2=0%, low certainty of the evidence), when evaluated, did not show this difference between the groups compared at baseline. The analysis that indicates the level of anxiety of the patients after the performance of VR shows that the intervention group remained lower compared to the control

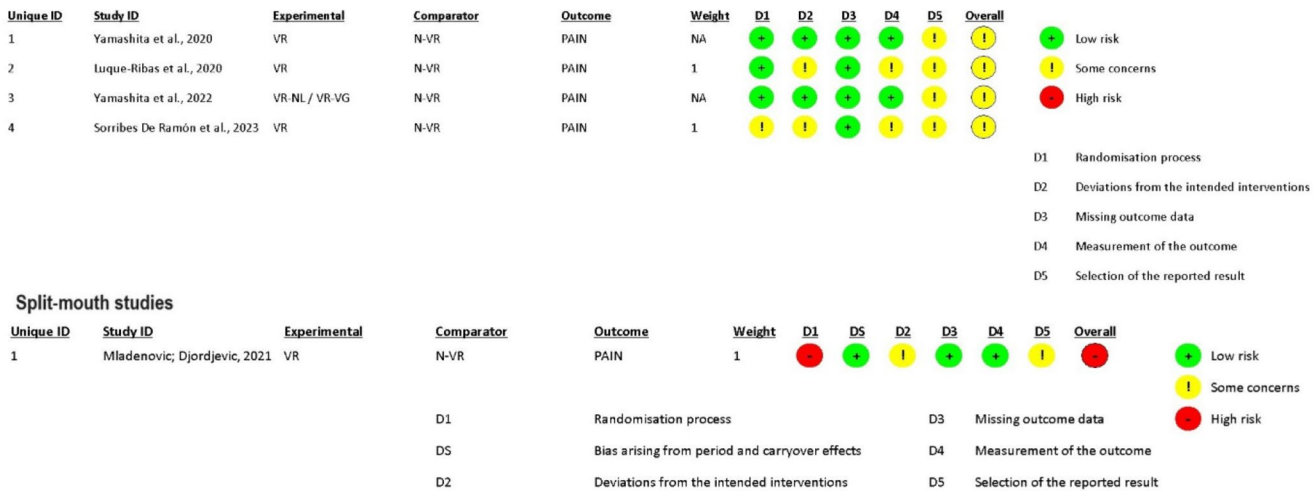

Fig. 3 Assessment of the risk of bias of the included studies for pain outcome

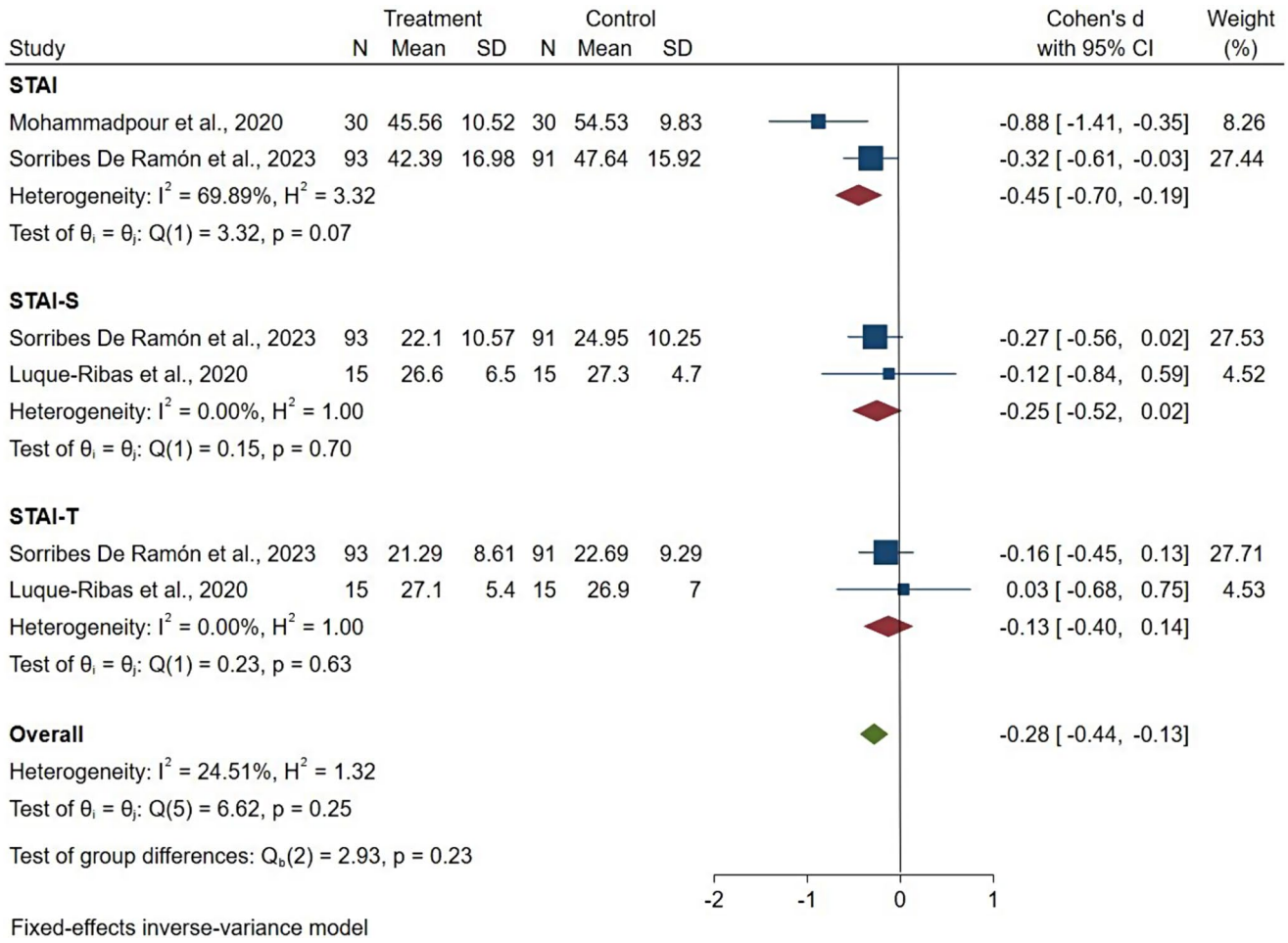

Fig. 4 Forest plot of the outcome of pre-intervention anxiety according to the STAI instrument

group, but without a significant change in the mean level of anxiety compared to the baseline. In this analysis, the STAI instrument (-0.31 [-0.56 to -0.06, 95%CI] I^2=81.19%, low certainty of the evidence) and respective subscales, STAI-S (-0.30 [-0.57 to -0.03, 95%CI] I^2=0%, low certainty of the evidence) and STAI-T (-0.42 [-0.69 to -0.15, 95%CI] I^2=11.25%, low certainty of the evidence) showed less anxiety in patients who received VR compared to the control group (Fig. 5).

Due to methodological incompatibility, variability of instruments, and lack of data, it was not possible to perform quantitative pain analysis. Five studies evaluated pain [2, 4, 13, 15, 16], and one study reported median instead of mean values [4]. Another presented anxiety data negatively [15], and two presented data in percentage [13, 16]. Only a single study could enter the meta-analysis as it reported sufficient data [2].These authors were contacted by e-mail to request raw data or mean and standard deviation values, but no responses were obtained.

Discussion

The present systematic review revealed that individuals undergoing third molar removal tend to benefit from the use of virtual reality in reducing anxiety levels, but postoperative pain remains uncertain. Third molar removal is one of the most performed oral surgeries worldwide by dentists and oral and maxillofacial surgeons [18]. This type of surgery is often associated with increased anxiety in the preoperative period, which can significantly affect pain perception during surgery, and is even considered a risk factor for postoperative complications [19]. Therefore, the study on anxiety control in third molar surgeries is of great relevance for dentists, who seek the best evidence on this topic.

The results of this review indicated that VR provided a slight reduction in the level of postoperative anxiety in the group that received it. It is important to note, however, that anxiety reduction did not occur significantly, since baseline data showed that patients in the intervention group already had a lower level of anxiety before the intervention was received. It is also noteworthy that the level of certainty of the evidence was classified as very low. VR can be used

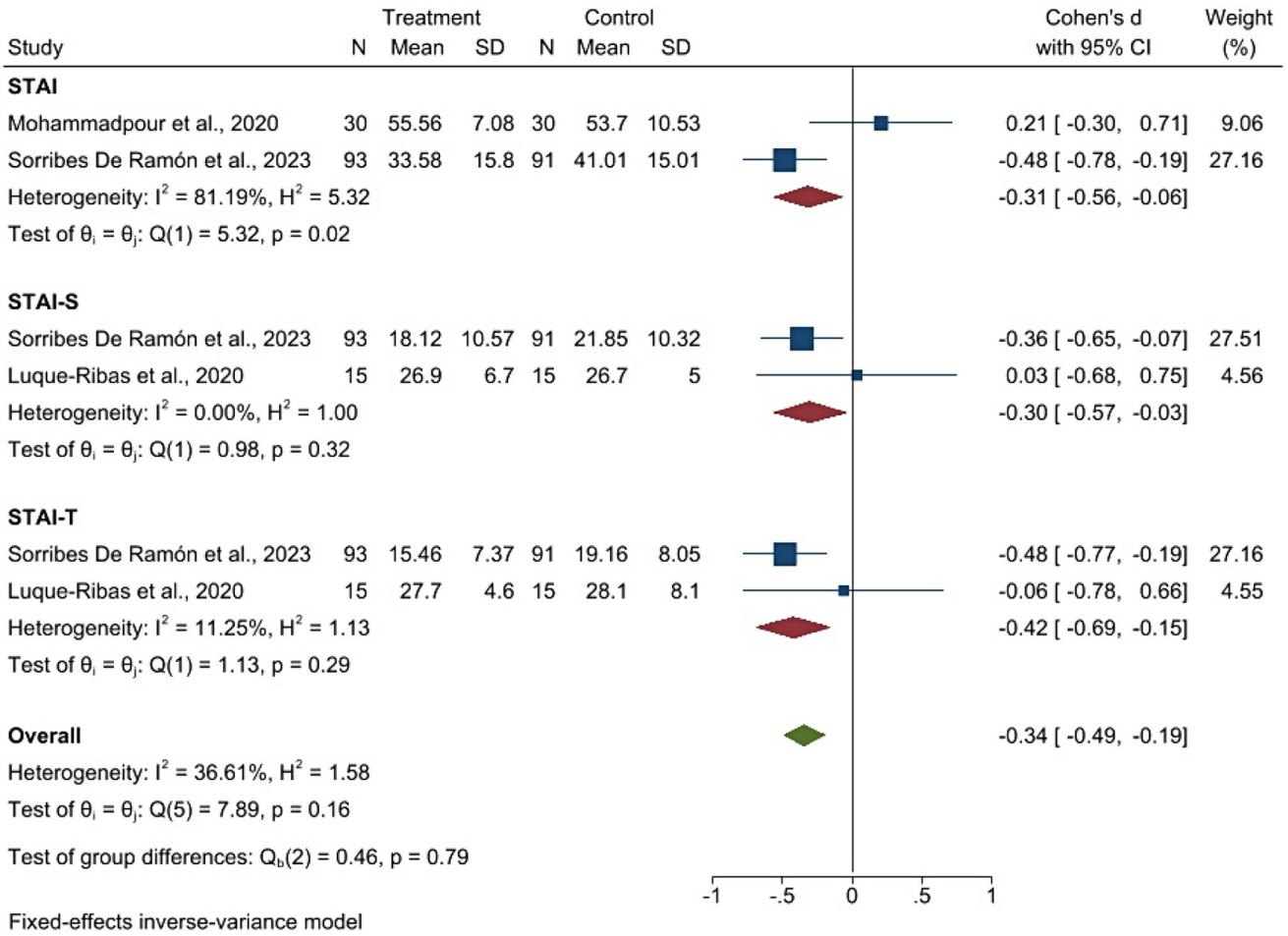

Fig. 5 Forest plot of the post-intervention anxiety outcome according to the STAI instrument

effectively to augment and enhance traditional treatment methods such as cognitive behavioral therapy and exposure therapy [20]. A systematic review pointed to a significant reduction in the perception of anxiety in children who used VR in dental procedures. 70% of the studies evaluated in this review suggest the benefits of VR technology in order to provide an immersive and interactive experience, making it effective [21]. In the context of surgical procedures, VR also provides an immersive distraction that can help alleviate the anxiety and fear associated with these procedures [22]. A recent systematic review with network meta-analysis investigated alternative methods such as music therapy, audiovisual aids, and virtual reality in reducing anxiety in tooth extraction procedures [7]. In this study, audiovisual resources do not seem to show an influence on anxiety reduction, as also demonstrated in another review in which they were compared to written informational prescriptions [23]. On the other hand, music therapy and VR evaluated in the network meta-analysis were associated with reduced anxiety, and music therapy was shown to be more effective than VR. It is believed that the use of devices involved in VR such as 3D glasses, headphones, and video games, among others, may contribute to a lower effectiveness in reducing anxiety.

Anxiety is one of the main challenges in dental care that dentists continually face [8, 24]. Different ways to assess this alteration have been reported in the literature as validated tools (visual analogue scale, heart rate, etc.). Among these, the STAI tool is useful in the evaluation of anxiety in patients undergoing third molar extraction [25] and was the main form of evaluation of the studies included in this review [2, 13, 14]. It is used to quantify subjective components related to anxiety and was developed by Spielberger et al. [17]. This tool has two subscales that demonstrate the state of anxiety at the moment and the anxiety trait of the patients. According to the results presented in this study, both in the assessment of the status (STAI-S) and the trait (STAI-T), the patients already had a level of mild anxiety. Anxiety is classified as mild when the score ranges from 20 to 31, moderate from 32 to 63, and severe from 64 to 80 [14]. After VR, the results showed that there was a slight reduction in the level of anxiety according to the evaluation of these subscales. These findings show that the state and the trait can be interconnected and that the preparation for the surgical procedure can generate anxiety, even if mild, as shown in the preoperative analysis of the STAI-S.

In addition to the STAI tool, other forms of anxiety level assessment such as the MDAS [13], which is composed of five multiple-choice items that report patients' subjective reactions to dental situations [26], the visual analogue scale (VAS) [15, 16] and heart rate [4] were used by the studies in this review. The heterogeneity in the presentation of the results of these studies made it impossible to include them in the quantitative analysis. The use of validated tools contributes to the reliability of the results and allows consistent recommendations [27]. While some anxiety assessment instruments, such as STAI and MDAS, demonstrate solid performance in terms of validity and reliability, it is important to note that the results are based on the patient's self-reports. Thus, such tools should not be used as the only method for diagnosing anxiety, but they can quantify symptoms associated with this alteration when interventions are or are not being used, which was the objective of this review.

Extractions of third molars, as they can cause an increase in the level of anxiety in patients, can consequently cause an increase in pain sensation with acute changes in the autonomic nervous system during the surgical procedure [28, 29]. Thus, the assessment of postoperative pain was also an outcome investigated in the present review. Although five studies evaluated pain [2, 4, 13, 15, 16] the methodologies used by them to assess this outcome were heterogeneous. Methodological incompatibility, variability of instruments, and lack of described data made it impossible to perform a quantitative analysis of postoperative pain through a meta-analysis. It should also be noted that pain can be a subjective experience with individual perceptions, and, therefore, its measurement is most often based on self-report tools that make comparisons difficult. Primary studies have shown in their results that VR can provide a lower level of postoperative pain in third molar extractions. These findings demonstrate the possible interrelationship of this outcome with the reduction of anxiety, as previously described.

The results of this systematic review suggest that the use of virtual reality may have a beneficial effect on reducing anxiety related to third molar surgeries and postoperative pain. However, the results found present very low certainty of evidence and should be considered with caution. This classification of the certainty of evidence is mainly due to the heterogeneity of the instruments used to assess the outcomes of pain and anxiety, as well as the variability of the evaluation periods without standardization, which made it difficult to evaluate and compare the findings between the studies included in this systematic review. Another limitation of this study is the low number of clinical trials available, making scientific evidence on the subject scarce. Therefore, new randomized cross-over clinical trials are needed to reduce the variability between the compared groups and confirm or disprove the results presented in the meta-analysis of this study.

Conclusion

Virtual reality seems to cause a small reduction in anxiety, with very low certainty of the evidence, and an uncertain effect on decreasing postoperative pain in third molar extractions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10006-024-01265-8.

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Data availability Data that support the findings of the metanalysis of this study have been deposited in the Figshare with the identifier https://doi.org/10.6084/m9.figshare.25431823.v1.

Declarations

Ethical approval Not Applicable.

Consent to participate Not Applicable.

Consent to publish Not Applicable.

Competing interests The authors declare no competing interests.

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