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Effectiveness of a Three-Stage Combined Protocol of Progressive Muscle Relaxation, Cranial Electrotherapy Stimulation, and Virtual Reality–Guided Mindfulness on Preoperative Anxiety in Dental Surgery Patients

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A B S T R A C T

Purpose: This study aimed to determine the effectiveness of a three-stage combined protocol comprising progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness in reducing state anxiety and dental anxiety among patients undergoing dental surgery.

Methods and Materials: This quasi-experimental study employed a pretest–posttest design with an intervention group and a control group. The study population consisted of adult patients undergoing dental surgery at the Implant House Dental Clinic in District 3 of Tehran during 2025–2026. Forty eligible patients were selected through convenience sampling and allocated nonrandomly to an intervention group and a control group, with 20 participants in each group. The intervention group received an initial 45-minute instructional session, four 20-minute sessions combining progressive muscle relaxation with cranial electrotherapy stimulation, and virtual reality–guided mindfulness on the day of surgery. The control group received routine clinical care without any psychological, neuromodulatory, or virtual reality intervention. State anxiety was measured using the state subscale of the State–Trait Anxiety Inventory, and dental anxiety was assessed using the Dental Anxiety Inventory. Data were analyzed using descriptive statistics and analysis of covariance in SPSS version 26, with pretest scores entered as covariates and the significance level set at .05.

Findings: After controlling for baseline scores, analysis of covariance revealed a statistically significant difference between the intervention and control groups in posttest state anxiety, $F(1, 37) = 34.11$, $p < .001$, partial $\eta^2 = .47$. A statistically significant between-group difference was also found in posttest dental anxiety, $F(1, 37) = 35.61$, $p < .001$, partial $\eta^2 = .49$. Both effect sizes were large, indicating that the combined intervention produced substantial reductions in state anxiety and dental anxiety compared with routine clinical care.

Conclusion: The three-stage combined protocol of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness was effective in reducing state anxiety and dental anxiety in patients undergoing dental surgery and may represent a practical nonpharmacological intervention for managing preoperative anxiety in dental settings.

Keywords: *Progressive muscle relaxation; cranial electrotherapy stimulation; virtual reality; mindfulness; state anxiety; dental anxiety; dental surgery*

1. Introduction

Dental anxiety is a common and clinically significant problem that can affect patients before, during, and after dental treatment. It encompasses a range of emotional, cognitive, behavioral, and physiological reactions, including fear of pain, apprehension about invasive procedures, loss of perceived control, negative expectations, avoidance, and heightened vigilance toward dental stimuli. Although mild apprehension may be expected before a dental procedure, moderate or severe anxiety can interfere with treatment cooperation, complicate communication between the patient and dental team, increase perceived discomfort, and contribute to delayed or avoided care. Epidemiological findings indicate that dental anxiety is prevalent among adult dental patients and varies according to demographic, experiential, and psychological characteristics (Alansaari et al., 2023; Hashemipour, 2022b; Rostami et al., 2025). Studies conducted among Iranian dental populations have similarly documented meaningful levels of anxiety before restorative, endodontic, implant, and surgical procedures, suggesting that dental anxiety remains an important clinical concern across different treatment contexts (Iranian Dental Research, 2023; Kazemipoor, 2023; Kazemipour et al., 2025). Its persistence despite advances in dental technology, anesthesia, pain control, and patient education demonstrates that dental anxiety cannot be understood solely as a response to actual nociceptive stimulation but must be regarded as a multidimensional psychological phenomenon.

Preoperative anxiety is particularly important in patients scheduled for dental surgery because anticipation of tissue injury, anesthesia, surgical instruments, bleeding, postoperative pain, and uncertain treatment outcomes may intensify threat appraisal. Anxiety may increase as the time of surgery approaches and can remain elevated immediately before the procedure, when patients have limited opportunities to regulate their emotional responses independently. Evidence comparing anxiety before and after tooth extraction shows that the preoperative period constitutes a distinct phase of heightened emotional vulnerability (Saruhan Köse et al., 2025). Anxiety before third-molar surgery has also been associated with greater postoperative symptom burden, indicating that preoperative emotional states may influence not only subjective experiences during treatment but also recovery-related outcomes (Qiao et al., 2022). In implant treatment, elevated anxiety has been linked to poorer postoperative quality of life, reinforcing the clinical importance of addressing anxiety as part of comprehensive perioperative dental care (de la Calle Cañadas et al., 2024). Therefore, reducing anxiety before dental surgery may improve emotional comfort, cooperation, treatment satisfaction, and the overall patient experience.

The development of dental anxiety is influenced by a complex interaction of previous experiences, cognitive expectations, attentional patterns, pain-related beliefs, and perceived control. Unpleasant dental memories, prior painful treatment, negative interactions with dental professionals, and exposure to alarming information may create enduring associations between dental settings and threat (Hashemipour, 2022a, 2022c; Perić & Tadin, 2024). Patients who have previously experienced pain or perceived helplessness may enter subsequent appointments with stronger anticipatory fear and a greater tendency to interpret ambiguous sensations as dangerous. Cognitive models of anxiety propose that threat overestimation, catastrophic prediction, intolerance of uncertainty, selective attention to danger, and underestimation of coping ability maintain anxious responses (Hofmann et al., 2021). In dental settings, these processes may be expressed through persistent thoughts about pain, complications, loss of control, or inability to tolerate the procedure. Research has also shown that cognitive-attentional syndrome, interoceptive awareness, and perceived pain contribute to dental anxiety, illustrating how internal sensations and repetitive thinking can amplify emotional distress (Neshveh & Farghadani, 2021). Similarly, psychological characteristics and anxiety levels are related to pain perception, suggesting that patients' interpretations and expectations may shape their treatment experience even when clinical conditions are comparable (Taheri, 2021, 2024a, 2024b, 2024c).

From a psychophysiological perspective, anxiety involves reciprocal interactions between bodily arousal and central cognitive-emotional processing. Internal bodily sensations can influence brain systems involved in attention, affect, threat evaluation, and behavioral regulation, while anxious interpretations may further intensify the perception of bodily discomfort (Critchley & Harrison, 2021). This reciprocal process helps explain why patients may experience escalating anxiety as they become increasingly aware of tension, restlessness, breathing changes, or discomfort before surgery. Emotion-regulation research further indicates that adaptive control of attention and interpretation can alter the intensity and duration of emotional responses (Ochsner & Gross, 2021). Mindfulness, reappraisal, attentional redirection, and somatic relaxation

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may therefore reduce anxiety through partially distinct but complementary pathways. Findings regarding metacognitive beliefs, mindfulness, and difficulties in cognitive reappraisal also suggest that ineffective regulation strategies can sustain worry and anxious symptoms (Haji Shafiei & Taherifar, 2022). Consequently, interventions that simultaneously address bodily tension, neural arousal, attentional fixation, and maladaptive cognitive engagement may be more appropriate for preoperative dental anxiety than approaches directed toward only one aspect of the response.

Pharmacological strategies are sometimes used to manage severe anxiety in dental care; however, medication may be associated with sedation, prolonged recovery, adverse effects, drug interactions, logistical requirements, and the need for additional clinical monitoring. These limitations have increased interest in brief, safe, and nonpharmacological interventions that can be integrated into routine dental practice. Systematic reviews have identified several nonpharmacological methods for reducing preoperative and dental anxiety, including relaxation techniques, cognitive-behavioral strategies, music, distraction, hypnosis, mindfulness, and technology-assisted interventions (Khodarahmi & Galedar, 2021; Singh, 2023). The success of anxiety management also depends on the knowledge, attitudes, and clinical behavior of dental practitioners, because patients' emotional needs may be overlooked when treatment is focused primarily on technical procedures (Babadi et al., 2023). Accordingly, practical interventions should be standardized enough to ensure fidelity while remaining sufficiently brief and feasible for implementation in busy clinical environments.

Progressive muscle relaxation is one of the most established behavioral methods for reducing anxiety. It is based on the systematic contraction and release of major muscle groups, accompanied by focused attention to the contrast between tension and relaxation. Through repeated practice, patients become more aware of unnecessary muscular contraction and develop greater capacity to evoke a relaxation response. Progressive muscle relaxation may reduce anxiety by interrupting the feedback loop between somatic tension and perceived threat, promoting slower breathing, increasing subjective calmness, and facilitating regulation of autonomic arousal. Evidence indicates that this technique can improve emotional states across clinical and nonclinical adult populations and may be particularly useful when anxiety is accompanied by prominent bodily tension (Muhammad Khir et al., 2024). Research in dental settings has also linked progressive muscle relaxation with improved autonomic regulation and reductions in anxiety-related distress (Chen et al., 2024). Comparative evidence suggests that progressive muscle relaxation and mindfulness-based stress reduction can both decrease situational anxiety, although they may act through somewhat different mechanisms (Khodabakhsh & Rajaei, 2025). Progressive muscle relaxation may therefore provide an appropriate initial stage for a combined intervention by lowering bodily tension and preparing patients for subsequent neuromodulatory and attention-based components.

Cranial electrotherapy stimulation is another nonpharmacological approach that has attracted interest in anxiety treatment. CES applies low-intensity electrical current through electrodes commonly positioned on the earlobes or other cranial sites. Although the precise mechanisms remain under investigation, the intervention is thought to influence neural excitability, cortical-subcortical communication, and neurochemical systems involved in arousal and emotional regulation. A systematic review and meta-analysis found evidence supporting the efficacy and tolerability of CES for anxiety, while also emphasizing the importance of standardized stimulation parameters and careful assessment of contraindications (Ching et al., 2022). Studies combining CES with psychological or pharmacological treatments have reported improvements in rumination and affective symptoms, suggesting that neuromodulation may augment other therapeutic methods rather than function only as an isolated intervention (Majidpour Tehrani et al., 2021). Related Iranian research on noninvasive electrical brain stimulation has also highlighted the capacity of neurostimulation techniques to influence cognitive and neuropsychological functioning (Kakou Jouybari et al., 2021). In the context of dental anxiety, CES may be especially relevant because it can be delivered during a short clinical session and may complement the reduction of bodily tension achieved through progressive muscle relaxation.

Mindfulness represents a further evidence-based method for regulating anxiety. Mindfulness practices encourage intentional attention to present-moment experience with an accepting and nonjudgmental orientation. Rather than attempting to suppress anxious thoughts, individuals learn to observe them as temporary mental events and redirect attention to breathing, bodily sensations, or current environmental cues. Neuroscientific evidence suggests that mindfulness practice affects attentional control, interoceptive awareness, emotional monitoring, and brain networks involved in self-regulation (Tang et al., 2023). In

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dental contexts, mindfulness may reduce anticipatory anxiety by limiting repetitive engagement with imagined pain, feared complications, and catastrophic predictions. A randomized controlled trial demonstrated that mindfulness meditation reduced dental anxiety during implant surgery, supporting its direct applicability to invasive dental procedures (Uçak Turer et al., 2023). Mindfulness-based cognitive therapy has also improved cognitive emotion regulation and perceived stress in women with dental anxiety (Seyedi & Moghadadi, 2023). These findings indicate that mindfulness can target cognitive and emotional components of dental anxiety that may remain active even after somatic relaxation has been initiated.

Despite its advantages, mindfulness can be difficult for highly anxious patients when delivered only through verbal instruction. Individuals awaiting surgery may struggle to disengage from environmental cues, intrusive thoughts, or procedure-related sounds. Virtual reality may strengthen mindfulness-based intervention by creating an immersive and controlled attentional environment. VR reduces access to anxiety-provoking external stimuli and directs attention toward calming visual and auditory content. Systematic reviews have shown that virtual reality distraction can reduce distress during dental procedures, particularly by increasing attentional absorption and decreasing awareness of threatening clinical stimuli (Cunningham, 2021). More recent reviews and meta-analyses indicate that VR can reduce dental anxiety and pain across different patient populations and procedures (Liu & Chen, 2025; Nezhad et al., 2024). A network meta-analysis comparing VR, audiovisual distraction, and music also identified immersive technologies as promising approaches for dental anxiety management (Hao et al., 2023). In adults receiving dental treatment under local anesthesia, immersive VR has been associated with reductions in anxiety and intraoperative pain (Martínez-Martín, 2024), while clinical-trial evidence supports its use for decreasing preoperative anxiety among candidates for dental surgery (Mohammadpour et al., 2021).

Virtual reality is not limited to passive distraction. It can also serve as a platform for exposure, guided relaxation, mindfulness, and self-directed psychological treatment. Reviews of VR exposure therapy demonstrate its capacity to modify anxiety-related avoidance and threat learning across several anxiety disorders (Freire, 2023). Iranian research has likewise reported that VR-based worry exposure can reduce generalized anxiety symptoms (Keshavarz et al., 2021), and broader reviews have supported VR applications in anxiety and depressive disorders (Ziaei et al., 2024). Systematic evidence on self-guided VR therapy further suggests that immersive interventions may extend access to structured anxiety-management strategies while reducing dependence on continuous therapist involvement (Graham et al., 2025). Combining mindfulness with VR may be especially beneficial because the immersive setting can stabilize attention, reduce competing stimuli, and facilitate sustained engagement with breathing and nonjudgmental awareness (Anderson, 2025; Wang, 2022). Research applying VR-based therapeutic play to surgical patients has also shown reductions in anxiety and pain, demonstrating the broader perioperative potential of immersive technology (Shomali Nasab et al., 2025).

The increasing integration of virtual and augmented reality into dentistry also supports the feasibility of technology-assisted anxiety interventions. Dental educators and faculty members have recognized the educational and clinical potential of immersive technologies, although implementation requires attention to training, usability, standardization, cost, and patient safety (Sarafraz et al., 2025). Research outside dentistry has shown that VR can be combined successfully with physical and behavioral interventions, illustrating the flexibility of immersive systems as adjunctive therapeutic platforms (Karbasi Ravari & Hovanloo, 2024). In surgical dentistry specifically, VR has been proposed as an intervention for reducing preoperative anxiety and improving the treatment experience (García, 2024). Nevertheless, VR alone may not fully address muscular tension or broader neural arousal, particularly in patients with substantial anticipatory anxiety. Its therapeutic potential may therefore be enhanced when it follows interventions that first reduce somatic and neurophysiological activation.

The rationale for integrating progressive muscle relaxation, CES, and VR-guided mindfulness is grounded in the multidimensional structure of anxiety. PMR primarily addresses muscular tension and bodily arousal, CES may contribute to regulation of central nervous system activation, and VR-guided mindfulness targets attentional fixation, catastrophic anticipation, and emotional reactivity. The sequential application of these components may create a cumulative effect in which each stage prepares the patient for the next. Initial muscular relaxation can increase physical comfort and perceived control; CES may reinforce the reduction of generalized arousal; and immersive mindfulness can stabilize attention during the period of greatest situational threat. Such integration is consistent with contemporary clinical research emphasizing

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multicomponent and mechanism-based interventions rather than reliance on a single technique (Kazdin, 2021). It also accords with the cognitive model of anxiety, which recognizes that emotional distress is maintained by interacting cognitive, attentional, behavioral, and physiological processes (Hofmann et al., 2021).

Although each of the three components has received empirical support, research has generally evaluated PMR, CES, mindfulness, or VR separately. Available dental studies have focused largely on the prevalence and predictors of anxiety, its relationship with pain and previous experiences, or the effectiveness of one nonpharmacological method at a time (Alansaari et al., 2023; Perić & Tadin, 2024; Taheri, 2024b). Even studies supporting VR, mindfulness, or relaxation have rarely examined a structured sequence that moves from bodily relaxation to neuromodulation and then to immersive cognitive-emotional regulation. This gap is especially relevant in dental surgery, where patients may experience simultaneous muscular tension, anticipatory cognition, environmental threat, and difficulty sustaining attention away from the procedure. A combined intervention may therefore offer a more comprehensive response than any single component and may be feasible within a standardized clinical protocol.

The need for such research is reinforced by evidence that dental anxiety varies across populations, treatment types, and prior experiences and that no single management strategy is likely to be optimal for all patients (Hashemipour, 2022c; Kazemipour et al., 2025; Rostami et al., 2025). A brief, reproducible, nonpharmacological protocol capable of being implemented before and during dental surgery could have practical value for patients who prefer to avoid sedative medication or who require additional psychological support. Moreover, examining both state anxiety and dental anxiety permits assessment of immediate situational distress and anxiety specifically associated with dental care. State anxiety reflects the patient's current emotional response to the impending operation, whereas dental anxiety captures broader fear related to dental stimuli and treatment contexts. Evaluating both outcomes can therefore provide a more complete understanding of intervention effectiveness.

Accordingly, the aim of the present study was to investigate the effectiveness of a three-stage combined protocol of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness in reducing state anxiety and dental anxiety among patients undergoing dental surgery.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a quasi-experimental pretest–posttest design with an intervention group and a control group to investigate the effectiveness of a three-stage combined protocol consisting of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness in reducing state anxiety and dental anxiety among patients undergoing dental surgery. The statistical population comprised adult patients referred for dental surgical procedures to the Implant House Dental Clinic in District 3 of Tehran, Iran, during 2025–2026. Participants were recruited through nonprobability convenience sampling from among patients attending the clinic during the study period. Patients were initially screened according to the study eligibility criteria, and those who met the criteria, expressed willingness to participate, and provided written informed consent were enrolled. Because complete random assignment was not operationally feasible in the clinical setting and could have disrupted the routine treatment process, participants were allocated nonrandomly to the intervention and control groups. Nevertheless, efforts were made to achieve the greatest possible comparability between the two groups in terms of age, sex, previous dental treatment experience, and baseline anxiety scores. Baseline demographic characteristics and pretest scores were compared between the groups, and any initial differences were statistically controlled in the subsequent analyses.

The required sample size was estimated using G*Power version 3.1 on the basis of an analysis of covariance model. Assuming a medium effect size of 0.25, a significance level of .05, and a statistical power of .80, the minimum required sample size was estimated to be 40 participants, corresponding to 20 participants in each group. To compensate for potential attrition, incomplete participation, or missing posttest data, the target sample was increased to 46 patients, with 23 participants assigned to the intervention group and 23 participants assigned to the control group. The independent variable was participation in the combined PMR, CES, and virtual reality–guided mindfulness protocol, while the dependent variables were state anxiety and dental anxiety. Age, sex, previous dental treatment experience, and baseline anxiety scores were considered potential covariates. The intervention and control groups were assessed in the same dental treatment center under comparable temporal,

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environmental, and procedural conditions to reduce systematic error associated with the clinical environment.

Eligible participants were required to be at least 18 years of age, to be scheduled for a dental surgical procedure, and to have a general physical condition compatible with participation in progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–based exercises. Participants also needed to have sufficient auditory, visual, cognitive, and motor abilities to understand the instructions, complete the questionnaires, perform the relaxation exercises, and use the virtual reality headset. Additional eligibility requirements included the absence of a severe psychiatric disorder or an acute psychological condition that could interfere with participation, the absence of medical or neurological contraindications to CES or virtual reality use, and willingness to complete all stages of the study. Patients were excluded if they were using active sedative or psychiatric medications that could substantially affect anxiety responses, had an acute neurological or physical condition that prevented safe use of CES or virtual reality, had severe uncorrected visual or hearing impairment, experienced significant discomfort or intolerance during CES or virtual reality exposure, withdrew their consent, discontinued cooperation, or failed to complete either the pretest or posttest assessment. The intervention group received the three-stage combined protocol in addition to routine dental care, whereas the control group received only the clinic's usual care and did not receive any psychological, neuromodulatory, relaxation-based, or virtual reality intervention. Both groups completed the same research assessments immediately before the beginning of the intervention period and immediately after completion of the intervention and dental surgical procedure.

2.2. *Data Collection Tools*

State anxiety was assessed using the state subscale of the State–Trait Anxiety Inventory developed by Spielberger. Although the complete inventory contains 40 items divided into two 20-item subscales assessing state and trait anxiety, only the 20-item state anxiety subscale was used as an outcome measure in the present study because the purpose was to examine temporary, situation-dependent anxiety associated with the anticipated dental surgical procedure. Each item is rated on a four-point Likert scale ranging from 1, indicating "not at all," to 4, indicating "very much so." Positively worded items are reverse-scored, and the item scores are summed to produce a total state anxiety score ranging from 20 to 80, with higher scores indicating greater situational anxiety. Scores from 20 to 39 are generally interpreted as reflecting low anxiety, scores from 40 to 59 as moderate anxiety, and scores from 60 to 80 as high anxiety. The state subscale has demonstrated satisfactory internal consistency in previous clinical and nonclinical studies, with Cronbach's alpha coefficients commonly ranging from .88 to .93.

Dental anxiety was assessed using the Dental Anxiety Inventory developed by Stouthard, Mellenbergh, and Hoogstraten. This self-report instrument consists of 36 statements describing fear- and anxiety-related reactions to dental situations. The items are rated on a five-point Likert scale ranging from 1, indicating "completely untrue" or "strongly disagree," to 5, indicating "completely true" or "strongly agree." The instrument contains no reverse-scored items and yields a single total score ranging from 36 to 180, with higher scores representing more severe dental anxiety. Scores from 36 to 107 indicate relatively low dental anxiety, scores from 108 to 144 indicate moderate dental anxiety, and scores from 145 to 180 indicate severe dental anxiety. Previous studies have reported high internal consistency coefficients for the instrument, generally ranging from .96 to .98. The Persian version has also shown satisfactory psychometric properties, including a Cronbach's alpha and split-half reliability coefficient of approximately .94 and a test–retest coefficient of .71. Both the state anxiety and dental anxiety measures were administered at the pretest assessment before the intervention and again at the posttest assessment immediately after completion of the full intervention procedure.

2.3. *Intervention*

The intervention group received a combined protocol comprising an initial instructional session, four combined PMR and CES sessions, and a final virtual reality–guided mindfulness stage conducted on the day of dental surgery. During the initial 45-minute session, the researcher explained the study procedures and familiarized participants with the intervention components. Participants were taught progressive muscle relaxation according to the principles of Jacobson's method. The researcher verbally guided them through diaphragmatic breathing using an approximate pattern of four seconds of inhalation followed by six seconds of exhalation. The major muscle groups, including the hands and forearms, arms and shoulders, facial and jaw muscles, neck, chest, abdomen, thighs, and lower legs, were then

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systematically contracted and released. Each muscle group was contracted for approximately five to seven seconds at a moderate level of effort and subsequently relaxed for approximately 10 to 20 seconds while participants directed their attention to the contrast between muscular tension and relaxation. The procedure was delivered by the researcher using a consistent verbal script, and a procedural checklist was used to support adherence and consistency across participants. During the same instructional session, the principles of guided mindfulness were introduced. Participants were taught to focus on their breathing and immediate sensory experiences, observe thoughts and emotions without judgment, recognize attentional distraction, and gently redirect their attention to the present moment. They were also introduced to the Meta Quest 3 virtual reality headset and instructed in its safe use before the surgical session.

Following the instructional session, participants attended four 20-minute intervention sessions in which progressive muscle relaxation and cranial electrotherapy stimulation were administered simultaneously. CES was delivered using the NeuroStim device manufactured by Medina Teb, with the electrodes attached to the earlobes in accordance with the manufacturer's instructions. The current intensity remained within the device's approved and tolerable safety range, and the frequency and other stimulation parameters were set according to its standard operating protocol. Before each session, participants were screened for contraindications, including active implanted electrical devices and medical or neurological conditions that might make stimulation unsuitable. During stimulation, participants remained seated comfortably and performed the progressive muscle relaxation sequence under the direct verbal guidance of the researcher. Their general condition and tolerance were monitored throughout each session, and stimulation was to be reduced or discontinued in the event of clinically meaningful discomfort. The combined sessions were intended to strengthen the participant's ability to elicit a relaxation response and to reduce anticipatory anxiety before the scheduled dental surgery.

On the day of surgery, participants in the intervention group first performed the learned progressive muscle relaxation exercise before entering the dental treatment unit. CES was not administered during the surgical procedure. After the participant was positioned safely in the dental chair, the Meta Quest 3 headset was fitted, and a standardized calming natural environment was presented. The same virtual scenario was used for all participants to maintain intervention consistency. Within the virtual environment, participants followed the previously learned mindfulness instructions by directing attention toward their breathing, observing the visual and auditory features of the environment without judgment, noticing the appearance of surgery-related thoughts or worries without becoming cognitively engaged with them, and repeatedly redirecting attention to the virtual environment and the experience of the present moment. The virtual reality environment functioned as a stable attentional context during the beginning and continuation of the dental surgical procedure. The intervention was implemented under controlled environmental conditions, including minimal disruptive noise, comfortable lighting, stable seating, standardized device settings, and consistent instructions. Participants were monitored for discomfort, dizziness, nausea, eyestrain, or other symptoms associated with virtual reality use, and the headset was to be removed immediately if clinically significant intolerance occurred.

The control group received routine clinical care throughout the study period. Participants in this group followed the standard preparation and dental surgical procedures of the clinic without receiving progressive muscle relaxation training, cranial electrotherapy stimulation, mindfulness instruction, or virtual reality exposure. To minimize environmental bias, control-group assessments were conducted at the same clinic and under conditions comparable to those of the intervention group. The control group completed the state anxiety and dental anxiety questionnaires at the same measurement points as the intervention group. All participants were identified through unique research codes rather than names, and questionnaire data were recorded immediately after collection to minimize transcription and recall errors.

2.4. Data Analysis

The collected data were coded and analyzed using IBM SPSS Statistics version 26. Descriptive statistics, including frequency, percentage, mean, standard deviation, minimum, maximum, and 95% confidence intervals, were calculated to summarize the participants' demographic characteristics and the pretest and posttest scores for state anxiety and dental anxiety. The demographic characteristics and baseline scores of the intervention and control groups were initially compared to assess the degree of baseline equivalence. The normality of score distributions, the presence of extreme outliers, the linear relationship between the covariates and

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posttest outcomes, homogeneity of regression slopes, and homogeneity of error variances were examined before conducting the primary inferential analyses.

Analysis of covariance was used separately for state anxiety and dental anxiety to compare posttest scores between the intervention and control groups while statistically controlling for the corresponding pretest scores. In each analysis, the posttest anxiety score was entered as the dependent variable, group membership as the fixed factor, and the relevant pretest score as the covariate. Where baseline demographic or clinical characteristics differed meaningfully between the groups and were theoretically associated with the outcome, they were considered for inclusion as additional covariates. Adjusted means, mean differences, 95% confidence intervals, F statistics, and associated probability values were reported. Partial eta squared was calculated to indicate the magnitude of the intervention effect in the covariance analyses, and Cohen's d was used where appropriate to describe standardized differences in mean change. Statistical significance was set at an alpha level of .05. In the event of substantial violations of parametric assumptions that could not be adequately resolved, the Wilcoxon signed-rank test was considered for within-group pretest–posttest comparisons, and the Mann–Whitney U test was considered for between-group comparisons.

3. Findings and Results

A total of 40 patients undergoing dental surgical procedures participated in the study and were assigned to the intervention group and the control group, with 20 participants in each group. The mean age of participants was 42.30 years (SD = 12.50) in the intervention group and 44.60 years (SD = 10.80) in the control group, indicating relative similarity between the groups in terms of age. In the intervention group, 6 participants (30%) were men and 14 participants (70%) were women, whereas the control group included 3 men (15%) and 17 women (85%). Overall, the demographic distributions indicated that the two groups were reasonably comparable in their baseline characteristics.

Table 1

Descriptive Statistics for State Anxiety and Dental Anxiety in the Intervention and Control Groups

Variable	Group	Pretest, M ± SD	Posttest, M ± SD
State anxiety	Intervention	51.30 ± 7.10	38.90 ± 6.80
State anxiety	Control	58.20 ± 6.50	57.60 ± 6.90
Dental anxiety	Intervention	102.40 ± 10.80	88.70 ± 11.20
Dental anxiety	Control	136.10 ± 9.50	137.30 ± 10.10

As shown in Table 1, the mean state anxiety score in the intervention group decreased from 51.30 at the pretest to 38.90 at the posttest, representing a mean reduction of 12.40 points following the combined intervention. By contrast, the mean state anxiety score in the control group changed only slightly, decreasing from 58.20 to 57.60. A similar pattern was observed for dental anxiety. The mean dental anxiety score in the intervention group decreased from 102.40 at the pretest to 88.70 at the posttest, corresponding to a mean reduction of 13.70 points. In the control group, however, the mean dental anxiety score increased slightly from 136.10 to 137.30. These descriptive findings indicate that participants who received the combined progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness protocol experienced noticeable reductions in both state anxiety and dental anxiety, whereas no meaningful improvement was observed among participants who received routine clinical care.

Before conducting the analyses of covariance, the relevant statistical assumptions were examined. The results of the Shapiro–Wilk test indicated that the distributions of state anxiety and dental anxiety scores did not significantly deviate from normality in either the intervention or control group. For state anxiety, the Shapiro–Wilk statistics were .972 in the intervention group, $p = .812$, and .961 in the control group, $p = .623$. For dental anxiety, the corresponding statistics were .955 in the intervention group, $p = .501$, and .948 in the control group, $p = .421$. Levene's test was also nonsignificant for state anxiety, $F(1, 38) = 0.842$, $p = .365$, and dental anxiety, $F(1, 38) = 1.103$, $p = .301$, confirming the homogeneity of error variances. In addition, the interaction between group membership and the corresponding pretest score was nonsignificant for both state anxiety and dental anxiety, indicating that the assumption of homogeneity of regression slopes was satisfied. Visual inspection of the data and examination of standardized

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residuals did not identify influential outliers or substantial departures from linearity. Accordingly, the principal assumptions required for the application of ANCOVA were considered adequately met.

Table 2

Analysis of Covariance for the Effects of the Combined Intervention on State Anxiety and Dental Anxiety

Outcome	Source	SS	df	MS	F	p	Partial η²
State anxiety	Pretest score	1120.45	1	1120.45	38.92	< .001	.51
	Group	980.32	1	980.32	34.11	< .001	.47
	Error	1080.21	37	29.19	—	—	—
Dental anxiety	Pretest score	1320.18	1	1320.18	42.56	< .001	.54
	Group	1105.77	1	1105.77	35.61	< .001	.49
	Error	1148.90	37	31.05	—	—	—

As presented in Table 2, after controlling for pretest state anxiety scores, there was a statistically significant difference between the intervention and control groups in posttest state anxiety, $F(1, 37) = 34.11$, $p < .001$, partial $\eta^2 = .47$. The lower posttest mean in the intervention group demonstrated that the combined protocol was effective in reducing patients' immediate situational anxiety associated with dental surgery. The partial eta-squared value indicated that 47% of the adjusted variance in posttest state anxiety was associated with group membership, representing a large intervention effect.

The results also showed a statistically significant between-group difference in posttest dental anxiety after controlling for baseline dental anxiety, $F(1, 37) = 35.61$, $p < .001$, partial $\eta^2 = .49$. Participants in the intervention group reported substantially lower dental anxiety following the intervention than those in the control group. The partial eta-squared value indicated that 49% of the adjusted variance in posttest dental anxiety was attributable to the intervention, which also constituted a large effect. Taken together, these findings support the effectiveness of the combined three-stage protocol of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness in reducing both state anxiety and dental anxiety among patients undergoing dental surgical procedures.

4. Discussion and Conclusion

The present study examined the effectiveness of a three-stage combined intervention consisting of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness in reducing state anxiety and dental anxiety among patients undergoing dental surgery. The findings showed that, after controlling for baseline scores, participants in the intervention group reported significantly lower posttest state anxiety and dental anxiety than participants in the control group. The descriptive results were consistent with the inferential analyses. Mean state anxiety in the intervention group decreased from 51.30 at pretest to 38.90 at posttest, whereas the control group showed only a negligible reduction from 58.20 to 57.60. Similarly, dental anxiety in the intervention group declined from 102.40 to 88.70, while the control group demonstrated a slight increase from 136.10 to 137.30. The analysis of covariance indicated large intervention effects for state anxiety and dental anxiety, suggesting that the observed changes were not only statistically significant but also potentially meaningful from a clinical perspective.

The significant reduction in state anxiety indicates that the combined protocol was effective in modifying the immediate emotional response of patients to the anticipated dental surgical procedure. State anxiety reflects a temporary and context-sensitive form of distress that is intensified by the perception of imminent threat. In dental surgery, this form of anxiety may emerge from concerns about pain, anesthetic injections, surgical instruments, loss of control, complications, and uncertainty about the procedure. Previous research has shown that anxiety is often particularly elevated before tooth extraction and other invasive dental procedures, confirming that the preoperative period represents a critical point for psychological intervention (Saruhan Köse et al., 2025). The present findings are therefore important because they suggest that a brief, structured, and nonpharmacological intervention can influence anxiety during the period in which patients are most vulnerable to situational distress.

The reduction in state anxiety is consistent with previous evidence supporting nonpharmacological interventions for preoperative anxiety. Systematic reviews have shown that behavioral, relaxation-based, cognitive, mindfulness-

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oriented, and technology-assisted methods can reduce anxiety before medical and dental procedures (Khodarahmi & Galedar, 2021; Singh, 2023). The present study extends these findings by showing that three methods targeting different anxiety mechanisms can be integrated into a sequential intervention. Rather than relying exclusively on distraction, relaxation, or cognitive regulation, the protocol addressed muscular tension, generalized neural arousal, and attention to threatening thoughts and environmental stimuli. This multidimensional structure may help explain the magnitude of the observed effect.

Progressive muscle relaxation was likely one of the primary mechanisms through which state anxiety was reduced. Patients preparing for surgery often experience involuntary muscular tension that reinforces their perception of being threatened or unable to cope. Progressive muscle relaxation interrupts this process by teaching patients to discriminate between contraction and release and to deliberately reduce tension across major muscle groups. Evidence from a systematic review indicates that progressive muscle relaxation is effective in reducing anxiety, stress, and depressive symptoms in adult populations (Muhammad Khir et al., 2024). Research involving dental patients has also suggested that progressive muscle relaxation contributes to emotional calming and improved regulation of anxiety-related responses (Chen et al., 2024). In the present study, the repeated practice of muscle relaxation before the surgical session may have increased patients' sense of control over their bodily reactions and decreased the somatic feedback that ordinarily sustains anxious arousal.

The findings also align with comparative research showing that both progressive muscle relaxation and mindfulness-based interventions can reduce situational anxiety (Khodabakhsh & Rajaei, 2025). Although that study was conducted in a different clinical population, its results support the assumption that bodily relaxation and present-focused awareness are complementary strategies. Progressive muscle relaxation may produce a relatively rapid decrease in physical tension, whereas mindfulness may alter how patients relate to anxious thoughts and emotions. The sequence used in the present intervention may therefore have been especially useful, because participants entered the mindfulness component after first becoming physically calmer and more capable of sustaining attention.

Cranial electrotherapy stimulation may also have contributed to the reduction in state anxiety by decreasing generalized nervous system arousal and reinforcing the relaxation response. A systematic review and meta-analysis of CES found that it was associated with improvements in anxiety and was generally well tolerated (Ching et al., 2022). CES has been proposed to affect neural processes related to emotional regulation, excitability, and arousal, although its exact mechanisms remain under investigation. In the present study, CES was administered simultaneously with progressive muscle relaxation during four preparatory sessions. This combination may have strengthened the effects of relaxation by targeting both consciously perceived muscular tension and broader neurophysiological activation. Previous Iranian research combining CES with cognitive-behavioral and pharmacological treatment also reported improvements in rumination and depressive symptoms, supporting the potential value of CES as an adjunctive rather than isolated intervention (Majidpour Tehrani et al., 2021).

The combined use of CES and progressive muscle relaxation may have been particularly useful because anxiety is maintained through reciprocal interactions between bodily sensations and central emotional processing. Internal bodily signals can influence attention, affective appraisal, and behavioral responses, while anxious interpretations can intensify awareness of those same sensations (Critchley & Harrison, 2021). By reducing muscular tension and modulating neural arousal concurrently, the intervention may have disrupted this reciprocal amplification cycle. Patients may consequently have interpreted their internal state as less threatening, which would reduce the urgency and intensity of their anxiety before surgery.

Virtual reality–guided mindfulness was another likely contributor to the significant reduction in state anxiety. Virtual reality can limit patients' exposure to visually and auditorily threatening aspects of the dental environment while simultaneously directing attention toward a controlled and calming scene. Evidence from systematic reviews supports the effectiveness of virtual reality distraction during dental treatment, particularly because immersive environments compete with clinical stimuli for limited attentional resources (Cunningham, 2021). More recent meta-analytic findings also indicate that virtual or extended reality can reduce dental anxiety and pain in both adults and younger patients (Liu & Chen, 2025; Nezhad et al., 2024). The findings of the present study are compatible with this evidence but additionally suggest that VR may be more therapeutically useful when it is paired with explicit mindfulness instructions rather than functioning only as passive distraction.

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The significant reduction in state anxiety is also consistent with clinical studies showing beneficial effects of immersive VR in dental settings. Virtual reality has been associated with reductions in anxiety and intraoperative pain among adults undergoing dental treatment under local anesthesia (Martínez-Martín, 2024). It has also been shown to reduce preoperative anxiety in patients undergoing dental surgery (Mohammadpour et al., 2021). A network meta-analysis comparing virtual reality, audiovisual interventions, and music further identified VR as a promising strategy for managing dental anxiety (Hao et al., 2023). These findings support the interpretation that immersive engagement can reduce the salience of threatening environmental cues and prevent sustained attentional fixation on the surgical procedure.

Mindfulness likely enhanced the effects of virtual reality by giving patients a structured method for managing thoughts that emerged despite the immersive environment. Instead of attempting to suppress fear-related cognitions, participants were instructed to observe them without judgment and return attention to breathing, the virtual setting, and present-moment experience. Neuroscientific research indicates that mindfulness supports attentional control, interoceptive awareness, and emotion regulation through coordinated changes in cognitive and neural processes (Tang et al., 2023). The cognitive control of emotion also depends on the capacity to redirect attention and modify the meaning assigned to emotional stimuli (Ochsner & Gross, 2021). Thus, the VR-guided mindfulness component may have reduced state anxiety by weakening engagement with catastrophic predictions and strengthening voluntary attentional control.

The second principal finding was that the intervention significantly reduced dental anxiety. Unlike state anxiety, dental anxiety is more specifically related to dental settings, instruments, procedures, pain expectations, and treatment-related memories. It may develop over time through previous unpleasant experiences, observation of others' reactions, threatening information, or repeated avoidance. Studies have demonstrated that prior painful experiences and negative dental memories are important predictors of dental anxiety (Hashemipour, 2022a, 2022c). Associations have also been found between dental anxiety, previous unpleasant treatment, self-reported oral health, and behavioral responses in dental settings (Perić & Tadin, 2024). The significant reduction observed in the present study suggests that the combined protocol influenced not only temporary distress but also the participants' broader emotional response to dental treatment.

The reduction in dental anxiety may be explained by the corrective experience created during intervention and surgery. Patients who entered the procedure expecting high levels of distress were provided with several concrete methods for managing their reactions. Through muscle relaxation, CES, mindfulness, and VR immersion, they may have experienced the dental procedure as more controllable and less overwhelming than anticipated. Cognitive models propose that anxiety persists when individuals overestimate danger, underestimate coping resources, and selectively attend to threat-confirming information (Hofmann et al., 2021). The intervention may have modified each of these processes by reducing physical arousal, increasing perceived coping ability, and redirecting attention away from threatening dental stimuli.

The present findings are aligned with research demonstrating that mindfulness-based cognitive therapy can improve cognitive emotion regulation and reduce perceived stress among individuals with dental anxiety (Seyedi & Moghadadi, 2023). They are also consistent with a randomized controlled trial reporting that mindfulness meditation reduced anxiety during implant surgery (Uçak Turer et al., 2023). These studies support the proposition that dental anxiety is responsive to interventions that alter attentional and emotional regulation rather than merely attempting to reassure patients verbally. The current study adds to this evidence by embedding mindfulness within an immersive virtual environment and combining it with two preparatory interventions.

The results also correspond with broader virtual reality research. Reviews of VR exposure and self-guided VR interventions have shown that immersive environments can reduce anxiety symptoms and support psychological treatment across anxiety-related conditions (Freire, 2023; Graham et al., 2025). Iranian research has similarly demonstrated the effectiveness of VR-based worry exposure for generalized anxiety symptoms (Keshavarz et al., 2021), while reviews have supported the application of VR in anxiety and depressive disorders (Ziaei et al., 2024). Although the present protocol did not employ formal exposure therapy, repeated familiarization with the headset and the use of VR during surgery may have reduced avoidance and increased the patient's willingness to remain engaged in the treatment situation.

The large effect sizes obtained for state anxiety and dental anxiety may reflect the synergistic nature of the intervention.

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Each component addressed a different aspect of anxiety, but their effects were likely mutually reinforcing. Progressive muscle relaxation reduced the bodily expression of anxiety, CES may have decreased generalized arousal, and VR-guided mindfulness reduced attentional capture by threat and repetitive anxious thinking. Because dental anxiety includes cognitive, emotional, behavioral, and somatic dimensions, an intervention targeting only one mechanism may leave other maintaining processes unchanged. Multicomponent interventions are often advantageous when they are theoretically coherent and when each element has a clearly defined function (Kazdin, 2021). In the present study, the ordered progression from physical relaxation to neuromodulation and then to immersive attentional regulation provided such coherence.

The lack of meaningful improvement in the control group further strengthens the interpretation that the reductions were associated with the intervention rather than routine passage of time or standard clinical care. Indeed, dental anxiety in the control group increased slightly at posttest, possibly reflecting greater apprehension as the procedure approached or accumulated exposure to surgery-related cues. This pattern is compatible with findings showing that preoperative anxiety can remain elevated or intensify around invasive dental treatment (Saruhan Köse et al., 2025). Dental anxiety has also been associated with greater postoperative symptoms and poorer treatment-related quality of life, indicating that failure to address it may have consequences extending beyond the immediate procedure (de la Calle Cañadas et al., 2024; Qiao et al., 2022). The present findings therefore support the integration of structured anxiety-management methods into dental surgical care rather than assuming that anxiety will naturally decline with routine preparation.

Overall, the results suggest that the three-stage protocol produced clinically meaningful reductions in both immediate situational anxiety and anxiety specifically associated with dental treatment. These findings reinforce evidence supporting nonpharmacological dental anxiety management and demonstrate the potential value of combining established behavioral methods with neuromodulation and immersive technology. The intervention may be particularly useful for patients whose anxiety is maintained by simultaneous muscular tension, generalized arousal, catastrophic anticipation, and attention to threatening treatment cues.

One limitation of the study was the use of nonprobability sampling and nonrandom allocation, which may have introduced selection bias and limited the equivalence of the intervention and control groups despite statistical control of baseline scores. The relatively small sample was recruited from a single dental clinic, reducing the extent to which the findings can be generalized to other geographical regions, clinical environments, dental procedures, or patient populations. The study also assessed outcomes only immediately after the intervention and therefore could not determine whether reductions in anxiety were maintained over subsequent dental appointments. Reliance on self-report questionnaires may have increased the influence of social desirability, expectancy, and response bias. In addition, because the three components were administered as a combined protocol, the independent contribution of progressive muscle relaxation, cranial electrotherapy stimulation, and virtual reality–guided mindfulness could not be determined.

Future studies should employ randomized controlled designs with larger and more diverse samples recruited from multiple dental centers. Longer follow-up periods should be included to evaluate the durability of treatment effects and whether patients demonstrate reduced anxiety during subsequent dental procedures. Factorial or dismantling designs could compare the full protocol with each individual component and with two-component combinations to identify the active and additive mechanisms of change. Researchers should also investigate whether baseline anxiety severity, age, sex, previous dental experiences, type of surgery, pain expectations, or familiarity with digital technologies moderate intervention effectiveness. Qualitative interviews could further clarify patients' experiences of each intervention stage, perceived barriers to participation, and the aspects of the protocol that most strongly enhanced their sense of control.

In clinical practice, dental centers should consider screening patients for state anxiety and dental anxiety before invasive procedures and offering structured nonpharmacological support to those with elevated scores. The combined protocol may be implemented through a brief preparatory session, standardized relaxation guidance, safe use of cranial electrotherapy stimulation, and a consistent virtual reality mindfulness scenario. Dental personnel should receive training in identifying anxiety, explaining the intervention clearly, checking contraindications, monitoring patient tolerance, and maintaining treatment fidelity. The intervention should complement rather than disrupt routine surgical care, and patients should be allowed to discontinue any component they find uncomfortable. Integrating such a

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protocol into preoperative dental services may improve patient comfort, cooperation, treatment acceptance, and overall satisfaction with surgical care.

Authors' Contributions

All authors significantly contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent.

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