RESEARCH PAPER

Comparative Effects of Video Distraction, Nitrous Oxide–Oxygen Inhalation Analgesia/Anxiolysis, and Their Combination on Pain, Anxiety, and Physiological Responses in Children Undergoing Dental Treatment: A Randomized Three-Period Crossover Trial

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Abstract

Background: Dental anxiety and procedural pain can interfere with cooperation and successful delivery of dental care in children. Non-pharmacological distraction and pharmacological anxiolysis/sedation are commonly used, but evidence directly comparing video distraction, inhalation analgesia/anxiolysis, and their combined use within the same children remains limited.

Aim: To compare the effects of video distraction, pharmacological inhalation analgesia/anxiolysis, and their combination on pain, dental anxiety, and physiological responses in children undergoing comparable dental procedures.

Methods: This randomized three-period crossover trial included 45 children aged 6–10 years classified as ASA I or II and reported to have moderate-to-high dental anxiety. Each participant received all three interventions—video distraction (VD), inhalation analgesia/anxiolysis/sedation (CS), and combined video distraction plus CS (VD+CS)—according to one of three randomized treatment sequences based on a Latin-square design. Pain was assessed using the Wong–Baker FACES Pain Rating Scale, anxiety using the Venham Clinical Anxiety Scale, and physiological responses using blood pressure, pulse rate, and oxygen saturation. The original manuscript reports pairwise F statistics and P values; the statistical model, degrees of freedom, estimated treatment effects, and confidence intervals are not yet sufficiently documented for final publication.

Results: The current dataset summary reports statistically significant pairwise differences for pain between VD and CS (F=4.60, P=0.038), VD and VD+CS (F=6.93, P=0.012), and CS and VD+CS (F=3.98, P=0.049). For anxiety, identical statistics are reported. For blood pressure, VD versus VD+CS was reported as significant (F=7.75, P=0.008), whereas VD versus CS (F=4.22, P=0.053) and CS versus VD+CS (F=0.83, P=0.36) were not significant. For pulse rate, the reported pairwise results were VD versus CS (F=4.20, P=0.005), VD versus VD+CS (F=6.11, P=0.007), and CS versus VD+CS (F=0.95, P=0.41). These inferential results require verification against the original participant-level dataset and the prespecified crossover analysis before submission.

Conclusion: The available results suggest that combining video distraction with pharmacological inhalation analgesia/anxiolysis may provide greater benefit for subjective pain and anxiety than either modality alone. However, definitive conclusions should be drawn only after reanalysis using a statistical model appropriate for the three-period crossover design and after complete descriptive and effect-size reporting.

Keywords: pediatric dentistry; dental anxiety; pain; audiovisual distraction; nitrous oxide; anxiolysis; behavior guidance; crossover trial.

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Introduction

Dental fear and anxiety are common in children and may contribute to avoidance, disruptive behavior, and difficulty completing dental treatment. Reviews have estimated that clinically relevant dental fear and behavior management problems affect a meaningful proportion of children and adolescents, with prevalence varying according to age, population, and measurement method.[1]

Basic behavior guidance approaches, including effective communication and tell–show–do, remain fundamental to pediatric dental care. For children with greater anxiety or for procedures likely to provoke pain or distress, non-pharmacological adjuncts such as audiovisual distraction and pharmacological analgesia/anxiolysis may be used as part of an individualized behavior guidance plan.[2,3] Audiovisual distraction can redirect attention away from dental stimuli and has demonstrated reductions in anxiety and distress in pediatric dental settings.[4,5]

Nitrous oxide–oxygen inhalation is widely used in pediatric dentistry to reduce anxiety and provide analgesia while maintaining communication and protective reflexes when used within the minimal-

sedation framework. The American Academy of Pediatric Dentistry (AAPD) describes nitrous oxide/oxygen concentrations of ≤50% with the balance as oxygen, without another sedating medication, as minimal sedation in an otherwise healthy ASA I or II patient.[6] The current AAPD/American Academy of Pediatrics guidance also emphasizes presedation assessment, appropriate monitoring, trained personnel, rescue capability, recovery, and documentation.[7]

Although video distraction and inhalation analgesia/anxiolysis have each been investigated, fewer studies have evaluated their combined use in a randomized within-participant design. A crossover design can reduce between-child variability because each participant receives each intervention. However, crossover trials require explicit reporting of treatment sequences, periods, inter-period intervals, potential period effects, and an analysis that accounts for repeated observations within participants.[8]

The present study therefore aimed to compare video distraction, inhalation analgesia/anxiolysis or sedation, and their combination in children undergoing comparable dental procedures. The primary outcomes were pain and dental anxiety, with blood pressure, pulse rate, and oxygen saturation evaluated as secondary physiological outcomes. We hypothesized that the combined intervention would provide greater reductions in pain and anxiety than either intervention alone.

Materials and Methods

Study design and reporting framework

This study was designed as a randomized, three-period crossover clinical trial conducted in the Department of Pediatric and Preventive Dentistry, Saveetha Dental College and Hospitals, Chennai, India. The report should be prepared in accordance with CONSORT 2025 and the existing CONSORT extension for randomized crossover trials.[8,9]

Ethical approval was obtained from the institutional review body under approval number SRB/SDC/PEDO-2301/24/368. The study was stated to have been conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians, and child assent was obtained when developmentally appropriate.

Participants

Forty-five children aged 6–10 years who required local-anesthetic dental treatment were recruited. Participants were classified as ASA I or II and were reported to have moderate-to-high dental anxiety. Eligibility required the child to be medically suitable for the intervention and to require multiple comparable dental procedures of short duration. Children with respiratory or cardiovascular disorders, known contraindications or allergies to the sedative agent, developmental or communication conditions that could interfere with outcome assessment, or sensory impairments that prevented reliable reporting were excluded.

Randomization and treatment sequences

Participants were allocated using a computer-generated randomization schedule to one of three treatment sequences based on a Latin-square arrangement. Each participant received all three interventions over three treatment visits. The original manuscript states that the visits were separated by approximately one week to reduce potential carryover and order effects.

Because treatment experience can itself influence subsequent anxiety and behavior, the manuscript should distinguish pharmacological carryover from period or learning effects. The analysis should therefore account for the within-participant structure and treatment period rather than treating observations as independent.^8

Interventions

Video distraction (VD)

Children received age-appropriate audiovisual content on an iPad during the dental procedure.

Inhalation analgesia/anxiolysis or sedation (CS)

The original manuscript describes nitrous oxide–oxygen inhalation at a concentration of up to 50%, with titration according to standard practice.

For pediatric nitrous oxide/oxygen use, the AAPD recommends documentation of patient assessment, indications and contraindications, administration, monitoring, adverse effects, recovery, and discharge.

Combined intervention (VD+CS)

The combined intervention consisted of the same audiovisual distraction protocol used in VD together with the same inhalation analgesia/anxiolysis or sedation protocol used in CS.

Outcome measures

Pain was assessed using the Wong–Baker FACES Pain Rating Scale (0–10). The scale is widely used for pediatric pain assessment and has established psychometric support, although systematic reviews note that faces scales differ in utility and that the Faces Pain Scale–Revised may be preferable for some research applications.

Dental anxiety was assessed using the Venham Clinical Anxiety Scale, a clinician-observed scale based on observable anxiety-related behavior. The current manuscript reports a 0–5 scoring range.

Physiological outcomes included systolic/diastolic blood pressure, pulse rate, and oxygen saturation. These measures were recorded at baseline, during treatment, and after treatment using a multiparameter monitor.

by the same pediatric dentist to minimize operator variability. Outcome assessment was performed by a trained observer who was described as blinded to intervention allocation. Physiological measurements were recorded by the monitoring device.

Statistical analysis

The original manuscript states that repeated-measures analysis of variance was used. However, because each child contributed measurements under all three interventions, the final analysis should explicitly account for within-participant correlation and the three-period

crossover structure. A mixed-effects model with treatment as a fixed effect and participant as a random effect, with period and sequence included where prespecified and appropriate, would provide a transparent framework for continuous outcomes. For ordinal outcomes such as the Venham Clinical Anxiety Scale, an ordinal mixed-effects model or another method appropriate to the scale distribution should be considered. Model assumptions, missing-data handling, multiplicity adjustment for pairwise comparisons, and effect estimates with 95% confidence intervals should be reported.

Results

Participant characteristics

Forty-five children were enrolled, with 15 assigned to each of the three treatment sequences according to the current manuscript. The source document does not provide complete demographic, sequence-specific, period-specific, or attrition data; these data are required for a Q1-level report.

Primary outcomes

The source manuscript reports pairwise inferential statistics for pain and anxiety. For pain, the reported comparisons were VD versus CS (F=4.60, P=0.038), VD versus VD+CS (F=6.93, P=0.012), and CS versus VD+CS (F=3.98, P=0.049). The reported pattern is consistent with lower pain scores under the combined intervention than under either single modality.

For anxiety, the source manuscript reports the same three F statistics and P values as for pain. Because exact mean scores, standard deviations, model degrees of freedom, and the statistical output are not provided, this apparent duplication must be checked against the original dataset and software output before publication.

Physiological outcomes

For blood pressure, the reported pairwise comparisons were VD versus CS (F=4.22, P=0.053), VD versus VD+CS (F=7.75, P=0.008), and CS versus VD+CS (F=0.83, P=0.36). Thus, only the VD versus VD+CS comparison was reported as statistically significant.

For pulse rate, the source manuscript reports VD versus CS (F=4.20, P=0.005), VD versus VD+CS (F=6.11, P=0.007), and CS versus VD+CS (F=0.95, P=0.41). These values require direct verification because the reported P values do not appear internally consistent with a conventional F test using the likely degrees of freedom.

Oxygen saturation was described in the abstract as remaining stable across conditions, but no descriptive or inferential values are provided in the source manuscript. This outcome should not be presented as evidence of equivalence or safety without complete data and an appropriate analysis.

Table 1. Reported pairwise statistics for pain outcome. Values require verification from the original statistical output.

Comparison	Reported F	Reported P
VD vs CS	4.60	0.038
VD vs VD+CS	6.93	0.012
CS vs VD+CS	3.98	0.049

Table 2. Reported pairwise statistics for anxiety outcome. The duplication of the pain statistics should be specifically verified.

Comparison	Reported F	Reported P
VD vs CS	4.60	0.038
VD vs VD+CS	6.93	0.012
CS vs VD+CS	3.98	0.049

Table 3. Reported pairwise statistics for blood pressure outcome.

Comparison	Reported F	Reported P
VD vs CS	4.22	0.053
VD vs VD+CS	7.75	0.008
CS vs VD+CS	0.83	0.36

Table 4. Reported pairwise statistics for pulse rate outcome. The reported P values require verification against the original model output.

Comparison	Reported F	Reported P
VD vs CS	4.20	0.005
VD vs VD+CS	6.11	0.007
CS vs VD+CS	0.95	0.41

Discussion

The present randomized three-period crossover trial evaluated the comparative effects of video distraction, nitrous oxide–oxygen inhalation analgesia/anxiolysis, and their combined use on pain, dental anxiety, and physiological responses in children undergoing dental treatment. The principal finding of the present study was that the combined intervention (VD+CS) demonstrated a greater reduction in the reported pain and anxiety outcomes than either video distraction or inhalation analgesia/anxiolysis alone. The reported pairwise comparisons for pain showed significant differences between VD and CS, VD and VD+CS, and CS and VD+CS, suggesting a graded pattern in which the combined approach produced the most favorable subjective response. A similar pattern was reported for anxiety. Although these findings require confirmation through reanalysis of the participant-level dataset using a statistical model appropriate for the crossover design, they provide clinically relevant preliminary evidence supporting a multimodal approach to behavior guidance in pediatric dentistry.

The observed benefit of video distraction is consistent with the established role of distraction as a non-pharmacological behavior-guidance strategy. Distraction is based on directing the child's attentional resources away from potentially threatening or painful dental stimuli toward an engaging alternative stimulus. Koller and Goldman described distraction as an important intervention for reducing procedural distress in children and emphasized that its effectiveness is influenced by the child's developmental stage, characteristics of the distracting stimulus, and the nature of the procedure.[6] In pediatric dentistry, Prabhakar et al. demonstrated that audiovisual distraction could be more effective than

audio distraction alone in reducing anxiety-related behavioral responses during dental treatment.[7]Similarly, previous clinical investigations using audiovisual and three-dimensional video-based distraction have demonstrated reductions in dental anxiety during local anesthetic administration and restorative procedures.^4,5 These findings provide a plausible behavioral basis for the reduction in anxiety observed with video distraction in the present study.

The present findings should also be interpreted in the context of contemporary pediatric behavior-guidance principles. The AAPD emphasizes that behavior guidance should be individualized according to the child's developmental level, temperament, anxiety, treatment requirements, medical status, and the nature of the dental procedure.[16] Thus, audiovisual distraction should not be regarded as a universal replacement for pharmacological behavior guidance. Rather, it represents a readily accessible non-pharmacological adjunct that can be incorporated into a broader child-centered treatment strategy. The relatively low burden and ease of implementation of audiovisual distraction are particularly relevant in routine pediatric dental practice, where minimizing procedural distress while preserving communication and cooperation is an important clinical objective.[8,9]

The greater reduction observed with the nitrous oxide–oxygen intervention can be considered in light of the pharmacological properties of nitrous oxide. Nitrous oxide has both analgesic and anxiolytic effects and has been used extensively in pediatric dentistry because of its relatively rapid onset and offset and its ability to reduce anxiety while facilitating treatment. Emmanouil and Quock reviewed several mechanisms involved in the actions of nitrous oxide, including effects on opioid, gamma-aminobutyric acid, glutamatergic, and other central nervous system pathways, which may contribute to its analgesic and anxiolytic properties.^14 These pharmacological effects provide a plausible explanation for why the inhalation intervention may have produced greater reductions in pain and anxiety than distraction alone.

The interpretation of the nitrous oxide findings, however, requires precise consideration of sedation terminology and protocol. According to current AAPD guidance, nitrous oxide–oxygen administration at concentrations of up to 50% nitrous oxide, with oxygen as the balance and without another sedating medication, is generally categorized within the minimal-sedation framework for otherwise healthy ASA I or II patients.^6 Consequently, the term used to describe the intervention should accurately reflect the actual concentration, administration protocol, and depth of sedation achieved in the present study. This distinction is important because sedation depth is a continuum, and the clinical safety requirements depend on the level of sedation intended and achieved. The present study therefore supports the use of nitrous oxide–oxygen as part of pediatric behavior guidance only when administered within an appropriately structured and monitored protocol.

The combination of video distraction with nitrous oxide–oxygen produced the most favorable reported subjective outcomes in the present study. One possible explanation is that the two interventions act through complementary pathways. Nitrous oxide may reduce the affective and sensory components of procedural distress through pharmacological modulation, whereas audiovisual distraction may simultaneously reduce the child's conscious attention to the dental environment. Rather than relying on a single mechanism of behavior modification, the combined intervention addresses both the child's physiological and psychological experience of treatment. The critical review by Koller and Goldman supports the broader concept that distraction can complement other pediatric procedural interventions rather than functioning only as an isolated technique.[13] In the context of pediatric dentistry, the findings of Prabhakar et al. and other audiovisual distraction studies similarly suggest that the attentional component of treatment experience can be modified through engaging audiovisual stimuli.[4,5,15]

An important observation in the present study was that the physiological outcomes did not demonstrate a uniform pattern identical to the subjective pain and anxiety outcomes. Blood pressure showed a significant difference between VD and VD+CS, whereas the comparisons involving CS alone did not reach statistical significance. Pulse rate showed significant differences between VD and CS and between VD and VD+CS, while the difference between CS and VD+CS was not statistically significant. These findings suggest that pharmacological anxiolysis may have a measurable influence on autonomic responses, whereas the addition of distraction may exert a stronger effect on the child's subjective perception of the dental experience than on cardiovascular parameters. Such a distinction is clinically relevant because physiological variables should not be interpreted as direct surrogate measures of pain or anxiety. Heart rate and blood pressure are influenced by multiple factors, including movement, anticipation, local anesthetic administration, procedural stimulation, and individual autonomic reactivity.

The use of established pediatric outcome measures is another important consideration in interpreting these findings. Pain was evaluated using the Wong–Baker FACES Pain Rating Scale, which has been widely used for assessing self-reported pain in children. Tomlinson et al., in a systematic review of faces pain scales, emphasized that the psychometric characteristics and clinical utility of different faces scales vary and that selection should consider the child's age and ability to understand the response format.[10] Garra et al. also demonstrated validity of the Wong–Baker FACES Pain Rating Scale in a pediatric clinical population.[11] Therefore, the use of the Wong–Baker scale in the present study is appropriate for obtaining a child-reported

estimate of pain, although the interpretation of pain scores should remain contextual and should not be equated directly with physiological stress.

Dental anxiety was assessed using the Venham Clinical Anxiety Scale, which evaluates observable behavioral manifestations of anxiety. This is particularly relevant in pediatric dentistry because anxiety may manifest through avoidance, crying, physical resistance, muscular tension, or other observable behaviors even when children have limited ability to verbalize their emotional state. Agarwal and Das demonstrated the utility of Venham-based assessment in pediatric dental anxiety research.[12] The combination of a child-reported pain measure with an observer-based anxiety measure therefore provides complementary perspectives on the treatment experience. Nevertheless, because observer-based behavioral measures may be influenced by interpretation, maintaining observer blinding and using standardized assessment procedures are important methodological considerations.[13]

The absence of a reported clinically important difference in oxygen saturation across interventions is also relevant when considering the safety profile of the inhalation protocol. However, oxygen saturation should be interpreted as a safety-monitoring variable rather than as an efficacy outcome. Current AAPD guidance emphasizes systematic presedation assessment, appropriate monitoring, personnel trained in pediatric sedation and rescue, recovery assessment, and documentation when pharmacological behavior guidance is used.[6,7] Therefore, the absence of oxygen desaturation in the present sample should not be generalized as evidence that nitrous oxide–oxygen is universally risk-free. Rather, it indicates that no clinically important oxygenation disturbance was identified under the conditions of the present study, subject to confirmation from the complete monitoring dataset.

The crossover design represents a particular strength of the present investigation. Because each participant received all three interventions, each child served as their own comparator, thereby reducing the influence of between-child variability in pain threshold, temperament, baseline anxiety, and behavioral response. This feature is particularly valuable in pediatric dental research, where substantial inter-individual differences in anxiety and cooperation can influence treatment outcomes. However, the same design also creates analytical challenges.[14] Crossover trials require consideration of treatment, period, sequence, and potential carryover effects, and observations obtained from the same child cannot be considered statistically independent.[8] Consequently, the reported findings should be interpreted only after verification using an analysis that appropriately models the repeated observations and accounts for the crossover structure. The final statistical analysis should therefore provide treatment effects with confidence intervals and clearly describe the handling of period and sequence effects.

The reporting of the present trial should also adhere to contemporary randomized-trial reporting standards. CONSORT 2025 emphasizes transparent reporting of randomization, participant flow, outcomes, statistical analysis, harms, and other methodological characteristics necessary for reproducibility and interpretation.[9]The crossover extension further emphasizes the importance of reporting sequence allocation, period-specific information, treatment effects, and appropriate statistical analyses for crossover trials.[8].These considerations are particularly important for the present study because the currently available results contain only pairwise inferential statistics without complete descriptive data, effect estimates, confidence intervals, or detailed model information. Therefore, the statistical findings should be regarded as provisional until the original participant-level data are reanalyzed and all reported values are verified.

The clinical implications of the findings are potentially important. Video distraction is relatively simple to implement and does not expose the child to pharmacological agents, making it an attractive first-line adjunct for children who can cooperate with treatment using non-pharmacological techniques. For children with greater anxiety or procedures associated with increased anticipated discomfort, nitrous oxide–oxygen may provide additional analgesic and anxiolytic support when clinically indicated and administered according to established pediatric sedation protocols.[6,7] The present findings suggest that the combination of these approaches may be particularly useful when the clinician seeks to address both pharmacological and attentional components of procedural distress.[15] Nevertheless, the study does not establish that combined therapy is necessary for every child, nor does it demonstrate superiority for all types of dental procedures or anxiety severity levels. Consistent with AAPD behavior-guidance principles, treatment selection should remain individualized.[16]

The present study should be interpreted in light of several limitations. First, the sample comprised 45 children from a single pediatric dental setting, which may limit generalizability to other populations and clinical environments. Second, the crossover design creates the possibility of period and learning effects because children may become progressively more familiar with the dental environment across visits. Although an approximately one-week interval was used between treatment periods, the adequacy of this interval for eliminating behavioral carryover requires explicit justification. Third, complete descriptive statistics and effect estimates are not currently available, limiting assessment of the magnitude and clinical relevance of the observed differences. Fourth, blinding is inherently challenging when audiovisual distraction and inhalation analgesia/anxiolysis are visibly different interventions. Although outcome assessment was reportedly performed by a blinded observer, the possibility of expectancy or observer bias cannot be completely excluded.

Another important limitation is the need for verification of the currently reported statistical values. The manuscript reports identical F statistics and P values for pain and anxiety, and some of the reported physiological statistics require confirmation against the original statistical output. These issues should be resolved from the participant-level dataset rather than by adjusting or replacing individual P values. A rigorous reanalysis using a crossover-appropriate statistical model, accompanied by treatment estimates, 95% confidence intervals, adjusted pairwise comparisons, and transparent reporting of missing data and sequence/period effects, would substantially strengthen the validity of the study.

Despite these limitations, the study addresses a clinically meaningful question and provides a useful framework for evaluating multimodal behavior guidance in pediatric dentistry. Its principal contribution is the within-participant comparison of three clinically relevant strategies: a non-pharmacological audiovisual technique, pharmacological inhalation analgesia/anxiolysis, and their combination. Previous evidence has established the value of audiovisual distraction,[13,15] and pharmacological guidance with nitrous oxide is well established within pediatric dental practice when appropriately indicated and monitored.[6,7]The present investigation extends this concept by evaluating whether combining these approaches may provide additional benefit within the same children.

Future studies should build on these findings using larger, adequately powered multicenter crossover or parallel-group randomized trials, with standardized dental procedures, prespecified primary outcomes, validated anxiety and pain measures, and complete reporting of treatment effects and confidence intervals. Further research should also examine whether the benefit of combined therapy varies according to baseline anxiety severity, age, procedure invasiveness, previous dental experience, and developmental characteristics. In addition, studies comparing conventional audiovisual distraction with newer immersive technologies may help determine whether the magnitude of distraction influences the incremental benefit obtained when pharmacological anxiolysis is used.

Overall, the findings of this study support the concept that pediatric dental behavior guidance may be optimized by integrating complementary pharmacological and non-pharmacological approaches rather than relying on a single modality. Video distraction can provide an accessible attentional intervention, while nitrous oxide–oxygen can provide pharmacological analgesic and anxiolytic support when clinically indicated. The combination may therefore offer a particularly useful strategy for selected anxious pediatric patients. However, the strength of this conclusion depends on confirmation of the current statistical findings through appropriate analysis of the crossover dataset. The final interpretation should consequently emphasize the potential clinical benefit of multimodal behavior guidance while avoiding claims of definitive superiority until the complete statistical analysis has been verified.

Clinical implications

If confirmed by the final crossover analysis, the findings would support a multimodal behavior-guidance strategy in which audiovisual distraction is used as an adjunct to pharmacological anxiolysis/sedation rather than viewed as an alternative in all clinical situations. The choice of intervention should remain individualized according to the child's anxiety, developmental level, treatment needs, medical history, parental preferences, and clinician expertise, consistent with contemporary AAPD behavior-guidance principles.[2]

Conclusion

The present randomised crossover study addresses an clinically relevant question in pediatric dentistry by comparing video distraction, pharmacological inhalation analgesia/anxiolysis or sedation, and their combination within the same children. The currently reported results suggest a potential advantage of the combined approach for pain and anxiety. However, the manuscript is not yet suitable for Q1 submission because the participant-level descriptive data, exact intervention details, trial registration information, crossover statistical model, effect estimates, confidence intervals, and internally verified P values are incomplete. Final conclusions should be based on a verified reanalysis of the original dataset and reported in accordance with CONSORT 2025 and crossover-trial reporting recommendations.

Declarations

Ethics approval

Institutional approval was reported under reference SRB/SDC/PEDO-2301/24/368. The final manuscript should identify the approving committee by its official name.

Consent for participation

Written informed consent was obtained from parents or legal guardians, and assent was obtained from children as appropriate.

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