Original Article

Effects of Virtual Reality Distraction and Nitrous Oxide Inhalation Sedation during Invasive Dental Procedures: A Comparative Evaluation Based on Dental Anxiety

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Abstract

Introduction: Effective paediatric dental care depends on strong communication and behaviour management. Dental anxiety, affecting 3%–43% of children, poses a major challenge. Modern techniques, both pharmacological and non-pharmacological, aim to ease anxiety. Virtual reality distraction, using immersive 3D environments, has emerged as a popular method to reduce fear and improve experiences. **Materials and Methods:** The study included 24 children, each attending three dental visits. During the first visit, oral examinations were conducted, behaviour guidance was provided and the dental setup was introduced. Eligible participants were randomly assigned to Group A (NOIS) or Group B (VR distraction), with 12 children in each group. Anxiety and behaviour were assessed during the second visit, where a Class I restoration was performed on a carious tooth (ICDAS score ≤2). At the third visit, the invasive procedure involving LA administration was carried out, and anxiety and behaviour were recorded. **Results:** Statistical analysis revealed that during the third visit, children in the VR group exhibited significantly higher pulse rates and Venham's Clinical Cooperation Scale (VCCS) scores compared to the NOIS group during LA administration. **Conclusion:** NOIS proved significantly more effective than VR distraction in reducing pain and anxiety and ensuring patient cooperation during LA administration.

Keywords: Anxiety reduction techniques, dental anxiety, invasive dental procedures, nitrous oxide inhalation sedation, pain management, sedation dentistry, virtual reality distraction

Introduction

Effective treatment of paediatric dental patients relies on strong communication between the dentist and child, paired with tailored behaviour management strategies.[1] Unpleasant dental experiences can negatively affect children, potentially impacting their future willingness to seek dental care.[2] One of the biggest challenges for paediatric dentists is managing anxious and uncooperative children.[3,4] Studies report that dental anxiety affects 3%–43% of children receiving dental treatment.[5] Dental anxiety is characterised as a heightened state of fear or apprehension about an impending dental procedure and is commonly observed during childhood and adolescence.[6]

Modern paediatric dentistry continually strives to create a comfortable, anxiety-free environment for young patients. This involves developing and applying various behaviour management techniques,[7-9] which can be broadly categorised into non-pharmacological and pharmacological approaches. These methods are designed to shape the child's behaviour according to the specific treatment needs, fostering a more positive experience.[10]

Among non-pharmacological techniques, virtual reality (VR) distraction has gained popularity. VR goggles are head-worn devices that immerse children in a 3D visual environment, offering an engaging 'being there' experience.[11] This immersive distraction effectively diverts the child's attention,

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reducing anxiety and pain perception and transforming a stressful dental visit into a more relaxing and enjoyable one.[12]

Nitrous Oxide Inhalation Sedation (NOIS) remains a widely used pharmacological method in paediatric dentistry.[13] It is safe, non-invasive and effective, offering advantages such as rapid onset, ease of administration, quick recovery without side effects, flexible dosage control and minimal systemic metabolism.[14] NOIS allows for precise control of sedation depth, making it an effective and reliable choice for managing anxious paediatric patients.[15] Its calming effects promote better compliance during dental procedures.[16]

This study is distinctive as it addresses a gap in the literature by comparing the effects of inhalation sedation and VR distraction on children's anxiety levels and behaviour during dental procedures. The findings aim to provide valuable insights into optimising behaviour management techniques in paediatric dentistry.

Aim

This study was conducted with the aim to compare the effects of inhalational sedation and VR distraction on the anxiety levels and behaviour of children during dental procedures.

Materials and Methods

This clinical study was conducted in the Department of Pediatric Dentistry of our hospital. This clinical study was conducted with the aim of comparing the effects of inhalational sedation and VR distraction on the anxiety levels and behaviour of children during dental procedures. Informed consent was obtained from the patients after presenting all the details related to the research work. The institution's (KUEC) ethical committee reviewed and approved this study with Reference No.: GDC/2021/237, Dated 10 June 2021. This study was planned and conducted under the Declaration of Helsinki (version 2008) and carried out from August 2021 to February 2023.

A total of 24 patients attending the outpatient department were selected and further enrolled in our study based on the eligibility criteria. Children with American Society of Anesthesiologists I or II and aged 3 years and older, with mild-to-moderate dental anxiety, who can tolerate a nasal mask and follow instructions were included in the study. Exclusions include respiratory issues, severe behaviour problems or allergies. Parental consent and effective communication are essential for its use.

In this study, each child attended three dental visits:

First visit

A comprehensive oral examination and medical and dental history were conducted. Parents/guardians were informed about the treatment plan, and consent was obtained. Children were familiarised with the environment, and basic behaviour guidance was provided. Subjects were then randomly assigned to one of two groups using the fishbowl method:

- Group A: Nitrous oxide/oxygen inhalation sedation
- Group B: VR distraction.

Second visit

To assess anxiety and behaviour, a Class I cavity restoration was performed on a carious tooth (ICDAS score 2) in all participants. Anxiety was measured using the Venham Clinical Anxiety Scale (VCAS), behaviour using the Venham Clinical Cooperation Scale (VCCS) and pulse rate with a pulse oximeter.

Third visit

During local anaesthetic administration, anxiety, behaviour (VCAS and VCCS) and pulse rate were recorded by an external observer while performing the treatment. A complete research workflow is provided in Figure 1.

Statistical analysis

Statistical analysis was done using Statistical Package of Social Science (SPSS Version 22.0; IBM SPSS Statistics, Illinois, Chicago Inc., USA.). Data comparison was made by applying specific statistical tests to find out the statistical significance of the comparisons; Kolmogorov–Smirnov and Shapiro–Wilk tests were performed to determine the normality of the data between the groups to anxiety and cooperation and Chi-square test for intergroup mean comparison. The significance level was fixed at $P < 0.05$.

Results

Statistical analysis in Table 1 and Figures 2 and 3 revealed significant differences in VCCS scores [Table 2] during the third visit. In Group A, 58.3% of children were 'relaxed', compared to only 8.3% in Group B ($P = 0.12$). While 33.3% of Group B patients were 'tense' and 58.3% were 'uneasy', Group A showed no 'tense' patients and 41.7% were 'uneasy'. However, no statistically significant differences were observed in VCAS scores [Table 3] between Group A and Group B during the second visit.

According to Table 4, pulse rate readings during local anaesthesia (LA) administration revealed that Group A had a lower pulse rate (90.67 ± 10.57) compared to Group B (103.50 ± 16.03), with a statistically significant difference ($P = 0.020$).

Discussion

Successful treatment of paediatric dental patients is essentially based on proper treatment planning and effectively using behaviour management techniques.[18] Gaining a child's trust is crucial for obtaining the patient's cooperation and, essentially, helps in the completion of treatment by the paediatric dentist.[19] However, when a child visits a dentist for the first time, in most cases, they primarily present with fear and anxiety in relation to the dental treatment to be carried out.[20] The most common cause of anxiety seen in children is the fear of needle injections used in local anaesthetic administration.[21] Ironically, that is the cornerstone in alleviation of anxiety and controlling pain during invasive dental procedures.

It is of primary importance that the paediatric dentist understands the patient's needs and implements the necessary management methods accordingly.[22] As we know, for years,

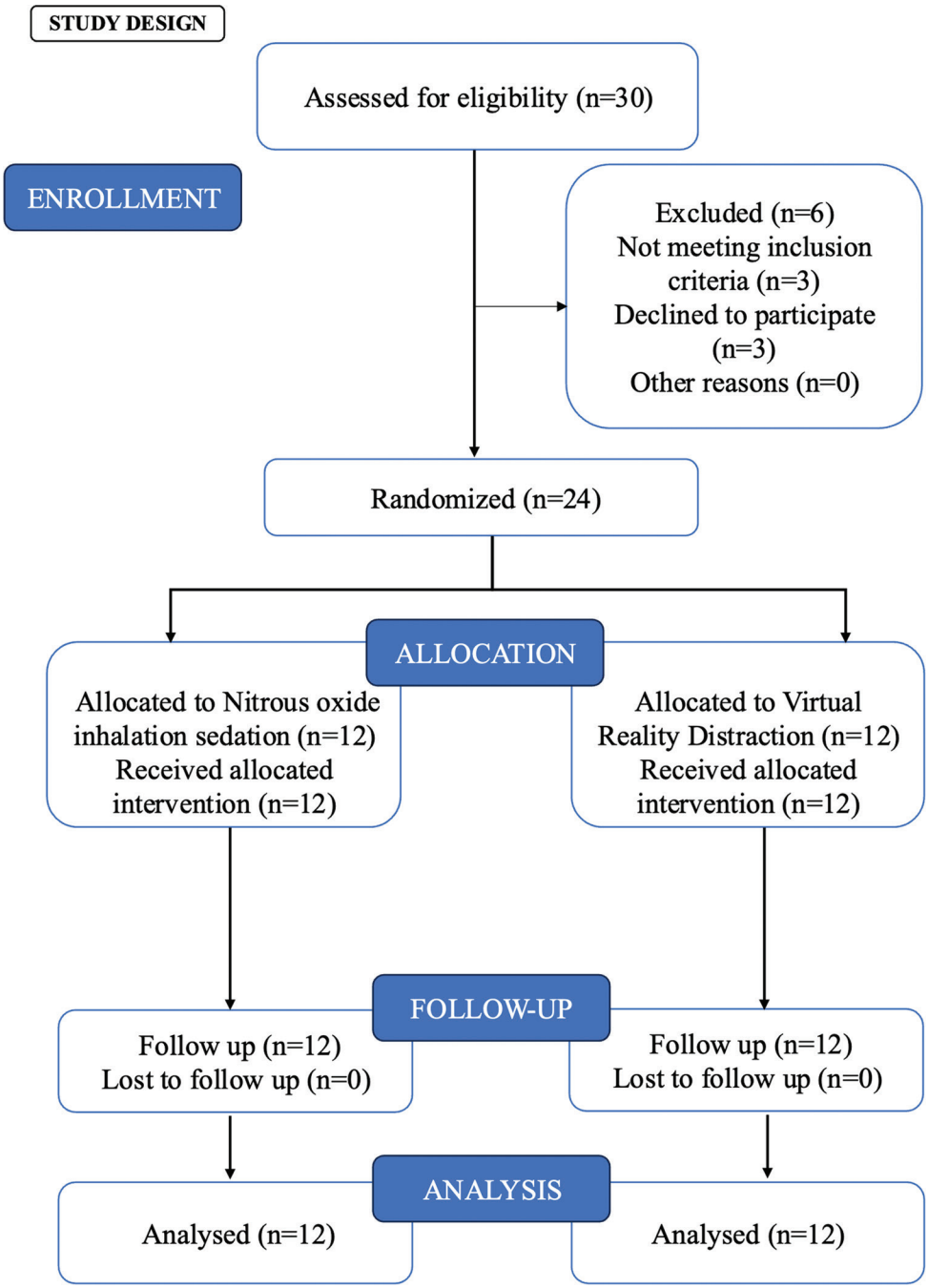

Figure 1: Study design.

paediatric dentists have utilised the conventional methods of behaviour management and have been successful in the behaviour shaping of children, essentially reducing their anxiety regarding dental treatment.[7]

Children of these generations have been exposed to newer technologies from a very young age and are quite savvy with the concept.[23] They are fascinated by the upcoming technology, thereby broadening their imagination and expectations. Hence, to keep up with that, paediatric dentists have employed the use of VR distraction as a relatively new, popular method of behaviour management.[24] The type of VR technology being used will determine whether it blocks out visual, auditory or both types of stimuli, effectively blocking out the outside world.[25] This psychological pain management technique is equally well accepted by both parents and children, which is one of its greatest advantages.[26]

Sometimes, parents are not always comfortable with the extreme measures and aversive conditioning used to control the child in a dental set-up, as it leads to unnecessary emotional trauma for the child.[27] In that case, pharmacological intervention is required and is commonly used by paediatric dentists worldwide.[28] Among the pharmacological techniques,

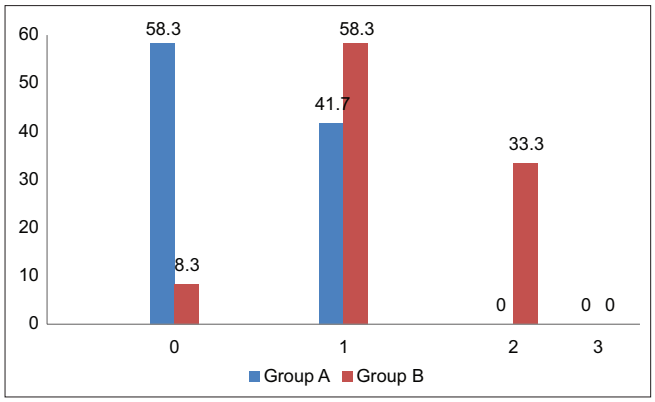

Figure 2: Comparative evaluation of Venham Clinical Cooperation Scale between Group A and Group B patients - Third visit.

Table 1: Comparative evaluation of Venham Clinical Cooperation Scale and Venham Clinical Anxiety Scale between Group A and Group B patients (third visit)

Third visit scores	VCCS		VCAS	
	Group A, *n* (%)	Group B, *n* (%)	Group A, *n* (%)	Group B, *n* (%)
0	7 (58.3)	1 (8.3)	2 (16.7)	7 (58.3)
1	5 (41.7)	7 (58.3)	8 (66.7)	5 (41.7)
2	0	4 (33.3)	2 (16.7)	0
3	0	0	0	0
Chi-square statistic	8.833		5.470	
P	0.012*		0.065 (NS)	

*Significant. NS: Non-significant, VCAS: Venham Clinical Anxiety Scale, VCCS: Venham's Clinical Cooperation Scale

Table 2: Venham Clinical Cooperation Scale description[17]

Score	Definition
1	Uneasy: Concerned, may protest briefly to show discomfort, hands remain down or partially raised. Tense facial expression. Capable of cooperating
2	Tense: Tone of voice, questions and answers reflect anxiety. During stressful procedures, verbal protest, crying and hands raised with tension, but not interfering very much. Protest more distracting and troublesome. Child still complies with request to cooperate
3	Reluctant: Prominent verbal protest, crying. Using hands to try to stop procedure. Treatment proceeds with difficulty
4	Interference: General crying, body movements sometimes needing physical restraint. Protest disrupts procedure
5	Out of contact: Hard loud swearing, screaming unable to listen, trying to escape. Physical restraint required

the most commonly used and widely accepted method is NOIS.[13] This sedation approach has proven to be tremendously beneficial in lowering the concerns, anxiety and apprehensions linked with dental appointments.[29]

Therefore, the aim of the present study was to compare and evaluate the effect of NOIS and VR distraction on the anxiety and behaviour of children during local anaesthetic administration.

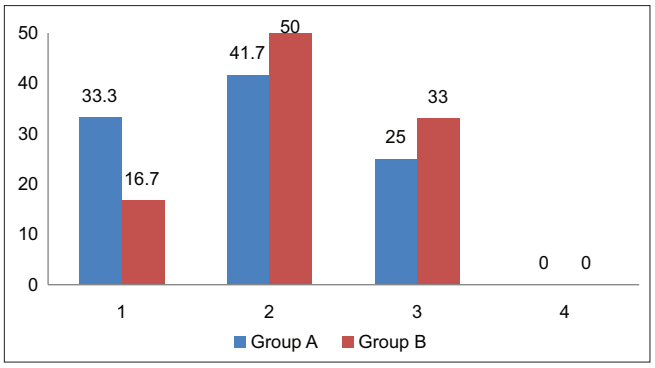

Figure 3: Comparative evaluation of Venham Clinical Anxiety Scale between Group A and Group B patients - Third visit.

The anxiety and behaviour of the child are multidimensional and subjective, varying according to pain perception and social and physiological parameters, including sensory, affective and cognitive components of the patient. Furthermore, subjective gauging may vary in children depending on the pain threshold level. Hence, the use of a single parameter to quantify anxiety and behaviour may not yield accurate results.[30] Therefore, a combination of pulse rate measurement, VCAS and VCCS was used for assessing anxiety and pain perception during LA administration.[17]

The pulse rate is controlled by the autonomic nervous system, which regulates certain physiologic activities in the body, such as heart rate, blood pressure and rate of respiration.[31] According to Ghibban *et al*.,[32] pulse rate is a true indicator of a child's anxiety and fear in a dental setting, and it especially increases during any clinical procedure. Sharma *et al*.[33] did a study on cardiovascular changes due to dental anxiety during local anaesthetic injections, and the results showed a significant increase in heart rate and blood pressure during the procedure. This parameter has been used in various studies and has produced successful results in detecting the degree of dental anxiety, especially in research on children's dental behaviour.

Venham *et al*.[34] developed two rating scales, the VCAS and the Venham Clinical Cooperation Scale, for assessing a paediatric dental patient's anxiety and behaviour, respectively, in response to stressful dental procedures. The authors obtained validated results for both scales and the rating scales were deemed reliable, valid and easily integrated in clinical or research activities. The rating procedure of the scales was reported to be very simple, quick and non-intrusive and raters could be easily trained in using the scales during dental procedures. Over the years, different studies have been using these scales as well-standardised anxiety and behaviour assessment tools and effectively enhanced the comparability of findings from diverse paediatric dental research studies.

According to the results of our study, during LA administration at the third visit, children of VR group, as per the gradings of VCCS, were 'uneasy' and, as per the gradings of VCAS, exhibited 'protest more prominent' against the invasive dental procedure. These anxiety gradings proved to be significant since there was a considerable reduction in the child's

Table 3: Venham Clinical Anxiety Scale description[17]

Score	Definition
1	Mild, soft verbal protest or (quiet) crying as a signal of discomfort, but does not obstruct progress. Appropriate behaviour for procedure, i.e., slight start at injection, 'ow' during drilling if hurting, etc.
2	Protest more prominent. Both crying and hand signals. May move head around making it hard to administer treatment. Protest more distracting and troublesome. However, child still complies with request to cooperate
3	Protest presents real problem to dentist. Complies with demands reluctantly, requiring extra effort by dentist. Body movement
4	Protest disrupts procedure, and requires that all of the dentist's attention be directed toward the child's behavior. Compliance eventually achieved after considerable effort by dentist, but without actual physical restraint. May require holding child's hands or other parts of the body to start treatment. More prominent body movement
5	General protest, no compliance or cooperation. Physical restraint is required

Table 4: Comparative evaluation of pulse rate during the third visit

Groups	Mean±SD	Mean difference	Paired *t*-statistic	*P*
Group A	90.6667±10.56868	12.83333	2.714	0.020*
Group B	103.5000±16.03122			

*Significant. SD: Standard deviation

cooperation and compliance with the treatment under NOIS, which produces the effect of mild anxiolysis and analgesia.

The bulky virtual headset proved to be a disadvantage as it was very uncomfortable for the child to keep wearing it for a longer period, which led them to become uncooperative and non-compliant with further treatment. From this, we can ascertain that VR distraction is not an effective procedure during local anaesthetic administration followed by a longer invasive dental procedure; cooperation of the child and efficacious results were not achieved from this behaviour management method.

In accordance with our study, Takkar *et al.*[35] evaluated the effectiveness of nitrous oxide/oxygen sedation and oxygen sedation on children during inferior alveolar nerve block administration. Their results showed that pain perception during LA administration was significantly reduced under N_2O-O_2 inhalation sedation.

Another study by Gupta *et al.*[36] evaluated the efficacy of NOIS with LA and LA alone in alleviating pain and anxiety in patients undergoing endodontic treatment in a vital tooth. The results showed that NOIS successfully alleviated the anxiety of patients along with a significant reduction in pain during the administration of LA, thus making it a safe, efficacious and convenient way to provide painless treatment to patients.

There was a statistically significant difference in pulse rate found between the NOIS group and VR distraction group, with a significant increase in pulse rate for patients in the VR group as compared to the NOIS group during the local anaesthetic administration, which proved that patients under nitrous oxide sedation showed less increase in pulse rate that led to lesser pain and anxiety among children. However, under VR distraction, there was a significant increase in pulse rate throughout the procedure of LA administration, which indicated that it was less effective in the management of the anxiety and pain of the patient.

Similar to our results, Takkar *et al.*[35] and Thomas *et al.*[37] observed a reduction in pulse rate when patients were administered LA under NOIS as compared to LA administration under oxygen sedation. Hence, it was concluded that NOIS was effective in reducing the pain perception and anxiety of the child and also improved their behaviour and cooperation during the treatment.

Like any other study, there were certain limitations faced by the researcher or clinician while conducting the study. Similarly, our study also had the following limitations:

1. The size of the VR headset was a disadvantage to the whole procedure. Although it was a source of entertainment as well as effectual masking of dental equipment, the young paediatric patients were unwilling to keep wearing the headset for a long period of time, which in turn adversely affected the anxiety levels of the child, and they seemed to become progressively uncooperative, especially during the invasive dental procedures
2. The audio presentation of the video in the VR headset hampered the communication and interaction between the patient and the dentist and may prevent the building of a proper rapport between the operator and the child. This could be avoided by adjusting the volume of the presentation in such a way that the patient is able to listen to the dentist's instructions.

Limitation

Keeping in mind all the limitations, this study is the first of its kind as it compares two drastically different methods of behaviour management strategies, NOIS vs VR. Despite the positive aspects, this study gives scope for future research for all the shortcomings we faced in the study. In future, we can expect smaller and lighter VR headsets from manufacturers that are easy to wear for a longer period of time. Furthermore, better development of technology and artificial intelligence is needed to make VR distraction an alternative to the conventional NOIS for being used even during invasive dental procedures and produce efficacious results in a reduction of anxiety levels in paediatric dental patients.

Conclusion

NOIS was significantly more effective than VR distraction in reducing pain and anxiety and achieving the cooperation of the patient during LA administration. This was owed to the fact that nitrous oxide induces anxiolysis and relative analgesia, which leads to a reduction in pain sensation during local anaesthetic administration. Children undergoing local anaesthetic

administration along with the VR distraction showed a significant increase in pulse rate (or anxiety) and pain sensation as compared to NOIS, indicating that it was less effective in reducing pain and anxiety during the local anaesthetic administration.

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Conflicts of interest

There are no conflicts of interest.

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