Original Article

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Efficacy of kaleidoscope, virtual reality, and video games to alleviate dental anxiety during local anesthesia in children: a randomized clinical trial

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Background: Distraction is a technique used to divert a patient's attention from unpleasant procedures. This study aimed to evaluate the effectiveness of kaleidoscopy, virtual reality, and video games in reducing anxiety and pain during invasive dental procedures in children.

Methods: Sixty-six children aged 6 to 9 years were randomly assigned to three groups during local anesthesia administration: Group 1 (kaleidoscope), Group 2 (virtual reality), and Group 3 (mobile video games). The anxiety of the children was evaluated using physiological measures (heart rate) at three different time points: before, during, and after the procedure. The Raghavendra, Madhuri, and Sujata pictorial scale was used as a subjective measure before and after the procedure. Subjective measures of pain were assessed using the Wong–Baker Faces Pain Scale. The data were statistically analyzed using the Kruskal–Wallis and Wilcoxon signed-rank tests.

Results: In the intergroup comparison, there were no statistically significant differences in the physiological measures of anxiety scores between the three groups before, during, and after distraction. Raghavendra, Madhuri, and Sujata pictorial scale scores were assessed before and after distraction, but no statistically significant differences were observed. Among the three groups, the children in Group 2 showed a significant reduction in pain scores.

Conclusion: Compared with kaleidoscopes and video games, virtual reality is a promising distraction technique for reducing dental fear, anxiety, and pain during local anesthesia administration in children.

Keywords: Behavior Guidance; Children; Dental Anxiety; Dental Fear.

INTRODUCTION

Dental fear and anxiety are primary challenges in treating pediatric patients [1]. Although "dental fear" and "dental anxiety" are frequently used synonymously, they are related to distinct phases of an equivalent psychological condition [2]. Dental fear is generally attributed to a well-known stimulus, such as drills or injections, whereas dental anxiety is caused by an unknown stimulus [3]. The primary results of dental fear and anxiety are infrequent dental visits and intolerant behaviors among pediatric dentists [4]. The worldwide incidence of dental anxiety and fear is approximately 3–53% among children and adolescents [5]. The etiology of dental fear and anxiety is complex and multimodal; it is influenced by numerous factors, such as age, sex, past dental experience, parental fears, inadequate pain management, and local anesthesia administration [6]. Adequate pain management fosters a positive relationship between dentists and children and improves

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the interaction, general satisfaction, and compliance of children with dental treatment [7]. Local anesthesia is the most extensively used method for pain management in pediatric dentistry. Despite its beneficial effects, such as reducing pain and discomfort, it is associated with higher levels of dental fear and anxiety, which emphasizes the importance of behavior management techniques during dental treatment for children [8].

The AAPD recommends various nonpharmacological techniques to manage children's behavior during dental procedures. Distraction is a simple, economical, safe, and non-aversive approach [9,10]. In 1925, Robson was the first person to describe the distraction technique, which tends to distract a child from potentially unpleasant events and engage them in distractions [11]. Distraction can be passive, active, or a combination of the two. Active distraction involves engaging children in activities, such as virtual reality (VR), guided imagery, interactive toys, controlled breathing, and relaxation. Rather than requiring the child to actively engage in an activity, observation is at the core of passive distraction techniques. This includes activities, such as listening to music and watching television [12].

VR demonstrates a wide field of view with a 3D head-mounted display employed for human-computer interactions. VR immerses a child in the digital world, distracting them from the real environment and causing discomfort during dental procedures. Multiple senses, such as sight, kinesthetics, and sound, are used in VR distraction to detach a child’s social and emotional attention from the dental environment [13].

A kaleidoscope is colorful gaming material that involves patterns used to distract the child. The changing patterns in a kaleidoscope are created by reflections of light within the device [14]. Two 60-degree-incline mirrors are placed next to each other. Colored glass pieces, feathers, beads, and other items are placed between the mirrors inside a kaleidoscope. Deformed polygons and other shapes, which are typically not the same, may be observed when viewed from one end of this binocular [15]. Video games are a type of active distraction that brings about a substantial improvement in child behavior and self-reported pain throughout dental procedures [16]. Therefore, the present study aimed to assess the efficacy of kaleidoscopy, VR, and video games in reducing dental anxiety during local anesthesia administration in children.

METHODS

1. Study design

This study was a three-arm, interventional, parallel-group, randomized study to compare the efficacy of kaleidoscopy, VR, and video games in alleviating dental anxiety during local anesthesia in children. Patients who met all inclusion criteria were randomly allocated to one of the three intervention groups in a 1:1:1 ratio following the guidelines drawn from the Consolidated Standards of Reporting Trials 2010 statement. The Institutional Ethics Committee granted clearance for the trial [IEC/NDCH/2023/Mar/P-59]. This study is documented in the Clinical Trial Registry of India [REF/2024/04/081959]. This study was conducted between October and November 2023 in the Department of Pediatric and Preventive Dentistry. The study approach was thoroughly explained to the parents or guardians before obtaining their consent.

1) Inclusion criteria

1. Children who had not experienced local anesthetic procedures before.
2. Children between the ages of six and nine.
3. Children in need of invasive dental procedures.
4. Children with positive (+) or negative (-) behavior as grounded in Wright's modification of the Frankl behavior rating scale [17].
5. Children who agreed to participate and also obtained written consent from their parents/guardians.

2) Exclusion criteria

1. Children suffering from any type of mental or

Fig. 1. Distraction using kaleidoscope

Fig. 2. Distraction using virtual reality box

systemic illness.

2. Children who exhibited positive (++) or negative (--) behavior on Wright's modification of the Frankl behavior rating scale.
3. Children who exhibited uncooperative behavior during treatment procedures.
4. Children with dental emergencies, such as trauma.

3) Sample size

The method used to determine the sample size was power analysis at a confidence level and 80% power, with an estimated effect size of 0.5, using G*Power 3.0.1 software from Franz Fail Universität, Kiel, Germany. The final sample size was 66 patients (22 patients per group).

4) Randomization technique

Following the selection of eligible children, random allocation into three groups (Group I: kaleidoscope, Group II: VR box, and Group III: video games) was conducted using a computer-generated list. The computer generated a new random sequence for each child allocated to the trial arm. For example, sequences a, b, and c were shuffled each time a child was assigned to a trial arm to maintain an allocation ratio of one to one. To avoid inter-operator variability, the children included in the study were treated by a single trained and calibrated pediatric dentist. An experienced pediatric dentist unrelated to the study performed the allocation procedures.

5) Allocation concealment

A pediatric dentist who did not participate in the trial used the lottery approach to assign treatment sequence alternatives based on the intervention type (i.e., kaleidoscope, VR box, and video games) to all recruited participants. The allocation results were recorded, sealed in envelopes, and released to the operator before treatment.

6) Sample grouping

Children were assigned randomly into three groups with 22 members each.

Group I: Kaleidoscope, Group II: VR Box, and Group III: Video games


Fig. 3. Distraction using video games

7) Blinding

The operating dentist did not conceal the type of intervention; however, the data analyst conducting the analysis was blinded to the intervention types.

Written informed consent was obtained from the parents before the study, after outlining the goals, design, and potential benefits of the clinical trial. To prevent bias, each child was treated and evaluated by the same dentist in all groups in the same setting.

Group I: Kaleidoscope (Fig. 1)

In this group, the child is instructed to look through the kaleidoscope with one eye while rotating one of the cylinders, which causes the designs to change based on how the beads move. Every time around, children are attracted to different designs before the start of the procedure and during the administration of local anesthesia.

Group II: VR Box (Fig. 2)

In this group, the children were given a short time to become accustomed to the glasses. These 3D VR glasses help in completely obstructing the child's field of vision and have built-in headphones that emit sound effects to assist in distracting the child and preventing them from hearing voices. The children were asked to select their favorite phone video during the administration of local anesthesia.

Group III: Video games (Fig. 3)

First, we collected data on the most popular games played by children in our local region, which we installed on mobile devices through an iOS store. The games used in this study were friendly and did not display violent, painful, or distressing content. Before starting treatment, the children were asked to select their favorite video game, which helped keep them engaged and reduce their boredom. The majority of girls preferred the Barbie™ Magical Fashion game, whereas boys preferred the Temple Run game. We asked the children to dedicate their treatment time to playing their favorite video games.

8) Clinical procedure

Before the infiltration of local anesthesia, each child in Groups 1, 2, and 3 was acclimated to the distraction aid. One pediatric dentist performed the infiltration procedure and implemented all the distraction techniques. The method for administration was to gradually inject 1.8 ml of lidocaine with adrenaline at a rate of 1 ml/minute using a 2 ml disposable Luer-Lock syringe with a 23-gauge × 1-inch needle (HMD UNOLOK Syringe). The Luer-lock syringe was selected because of its ability to twist the needle hub over the barrel tip and lock it in position, thus creating a safe connection and preventing the needle from being inadvertently removed.

2. Behavior evaluation method

1) Heart rate

Heart rates were recorded for the groups at three time points: before, during, and after the intervention. A pediatric dentist who did not participate in the study recorded the scores using a pulse oximeter (ChoiceMed MD300C15D Pulse Oximeter, India).

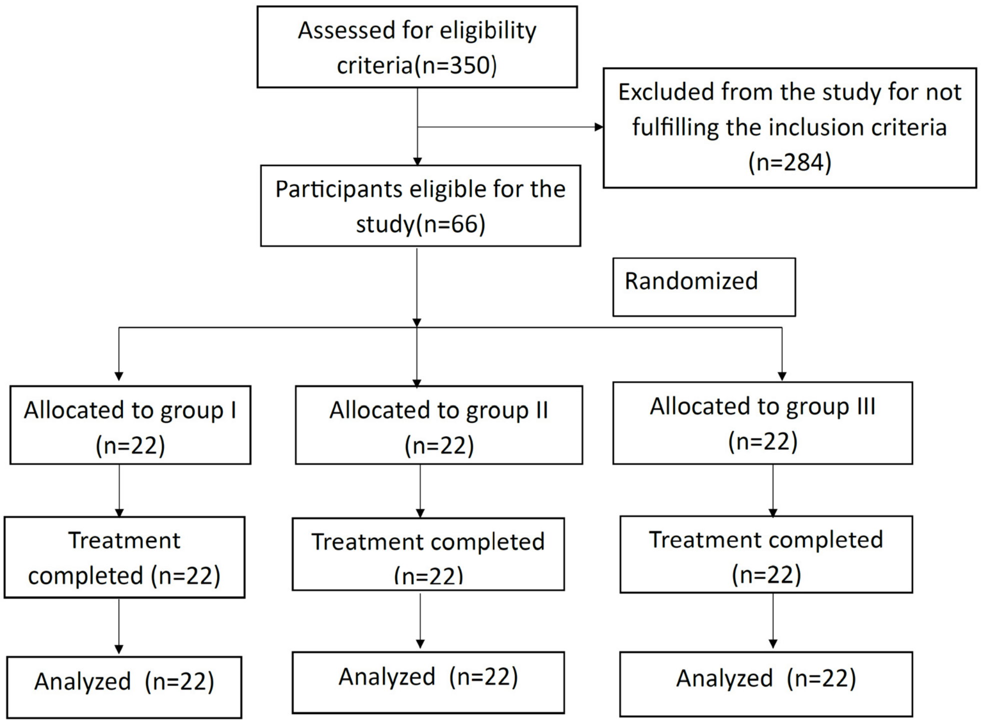

Fig. 4. Consolidated Standards of Reporting Trials flow diagram

2) Raghavendra, Madhuri, and Sujata Pictorial Scale (RMS-PS)

Behavioral guidance was evaluated subjectively using the RMS pictorial scale. There are five faces in each row on this scale, ranging from extremely happy to extremely unhappy. Two distinct sets of images were used for boys and girls. The very joyful face scored a one, whereas the very miserable face scored a five on the scale. The participants were asked to select the face that best matched how they felt at that moment on the RMS pictorial scale [18].

3) Wong–Baker Faces Pain Scale (WBFPS)

A type of facial image pain scale is considered one of the simplest pain assessment tools used in pediatric dental practice. Furthermore, studies have demonstrated its reproducibility in children as young as three years of age. The scale consists of six facial images. Each image is designated from 0 to 10, where zero represents "no hurt" and 10 represents "hurts worst." Children were shown the scale and asked to select the picture that most accurately depicted their level of pain at that time [19].

4) Statistical analysis

A Microsoft Excel Spreadsheet 2016 was used to complete the data. SPSS was used to perform statistical analysis (version 21.0; Windows, SPSS Inc., NY, USA). Intergroup assessment of heart rate was performed using the Kruskal–Wallis test. Intragroup assessment of heart rate was performed using a post hoc test. The Wilcoxon signed-rank test was used to evaluate changes in anxiety and pain scores among the three groups according to the RMS-PS and WBFPS. Statistical significance was set at $P < 0.05$.

RESULTS

1. Demographic data

In Fig. 4, the Consolidated Standards of Reporting Trials flow diagram illustrates the children who met all inclusion criteria and were randomly assigned (30 boys and 36 girls) to three groups. An equal distribution of

Table 1. Demographic data of the study populations

Variable	Group 1	Group 2	Group 3	P value
Age (Mean ± SD)	6.21 ± 1.80	6.89 ± 1.72	6.56 ± 1.88	0.44
Gender				
Boys	10 (45.45%)	10 (45.45%)	10 (45.45%)	0.54⁺
Girls	12 (54.55%)	12 (54.55%)	12 (54.55%)	

⁺: Chi-square test. SD, standard deviation.

Table 2. Comparison of the heart rates within the groups

Interval	Groups						P value⁺
	Group 1		Group 2		Group 3		
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	
Before	101.71 ± 7.74	89–114	99.85 ± 6.92	88–115	102.98 ± 6.81	89-114	0.24
During	105.03 ± 5.14	98–115	105.38 ± 6.72	99-127	105.30 ± 6.22	99-129	0.78
After	100.02 ± 6.34	88–120	99.51 ± 5.63	89-119	101.21 ± 5.23	94-119	0.92

⁺: Kruskal–Wallis test. SD, standard deviation.

Table 3. Comparison of heart rates within groups

Groups	Variable	Before vs during	During vs after	Before vs after
Group 1	Z	3.12	4.41	1.57
	P value	0.002	< 0.001	0.13
Group 2	Z	4.79	5.61	1.29
	P value	< 0.001	< 0.001	0.22
Group 3	Z	2.94	5.49	3.59
	P value	0.003	< 0.001	< 0.001

⁺: Post hoc test (Bonferroni correction)

male and female children (10 boys and 12 girls) was observed in each group (Table 1).

2. Intergroup comparison of heart rate, RMS, and WBFPS

Table 2 presents the mean heart rate scores of the kaleidoscope, VR, and video game groups. There were no significant differences in the values within the groups prior to the intervention ($P > 0.05$). During the intervention phase, the mean scores for each group increased slightly compared with those before the intervention. However, there were no significant differences in the values within the groups during the intervention ($P > 0.05$). After the intervention, there were no significant differences in heart rate values among the three groups ($P > 0.05$). Among the three groups, the VR group had a lower mean heart rate score. Table 3 shows the mean RMS and WBFPS values for each group before and after the intervention. There was a slight increase in the RMS scores from before to after the intervention in Group 1, but the difference was not statistically significant ($P = 0.83$). However, in Groups 2 and 3, the RMS scores decreased after the intervention, but the variance was not significant ($P > 0.05$). The pain scores among the three groups showed a statistically significant reduction in pain in Group 2. However, this change was not statistically significant in Groups 1 and 3 ($P > 0.05$).

3. Intragroup assessment of heart rates

Table 4 presents the intragroup assessment of heart rates in the three groups (Kaleidoscope, VR Box, and Video Game) before, during, and after the intervention. A statistically significant difference was observed before versus during ($P = 0.002$) and during versus after the intervention ($P < 0.001$) in Groups 1 and 2. However,

Table 4. Comparison of the RMS-PS scales and Wong Baker Faces Pain Rating Scale (WBFPRS) scores for pain assessment within the groups

	RMS-PS						WBFPS					
Groups	Interval	Min	Max	Median (IQR)	Score (Mean ± SD)	P-value+	Interval	Min	Max	Median (IQR)	Score (Mean ± SD)	P-value+
Group 1	Before	1	5	2 (2,3)	2.36 ± 1.40	0.83	Before	0	10	2 (2,6)	3.82 ± 3.7	0.48
	After	1	5	2 (2,3)	2.45 ± 1.33		After	0	10	2 (2,6)	3.09 ± 3.14	
Group 2	Before	1	5	2 (2,3)	2.09 ± 1.54	0.16	Before	0	10	2 (2,6)	2.36 ± 3.67	0.02*
	After	1	5	2 (1,2)	1.55 ± 0.91		After	0	10	0 (0,2)	0.545 ± 0.93	
Group 3	Before	1	5	2 (2,3)	2.27 ± 0.63	0.83	Before	0	10	2 (2,6)	3.82 ± 3.03	0.50
	After	1	5	2 (2,3)	2.19 ± 1.66		After	0	10	2 (2,6)	3.18 ± 3.28	

+: Wilcoxen sign rank test; *: Significant; IQR, Interquartile range (Q1, Q3); Max, Maximum; Min, Minimum; RMS-PS, Raghavendra, Madhuri, and Sujata Pictorial Scale; SD, standard deviation; WBFPRS, Wong Baker Faces Pain Rating Scale.

in Group 3, statistically significant differences were observed at three different intervals (before vs. during, during vs. after, and before vs. after).

DISCUSSION

Uncooperative behaviors during treatment and the potential to avoid future dental appointments were causally related to previous unfavorable dental experiences, particularly the use of local anesthesia [20]. Therefore, dental professionals must establish a comfortable dental environment for patients to provide comprehensive and consistent optimal oral health care [21]. Diverse behavioral guidance techniques have been accepted by dentists and parents, notably distraction, which is a contemporary approach that can effectively reduce anxiety in children by keeping them involved during their first dental visit [22]. The ideal distractors would demand the maximum amount of focus in various sensory modalities (auditory, visual, and kinesthetic) as well as the child's active emotional involvement and participation to counter signals from unpleasant stimuli [23]. The most common sources of distraction, such as TV, music, and mobile devices, may not be sufficiently prominent to compete for children's attention [24]. Therefore, it is essential to use specific approaches to distract attention. Thus, this study aimed to analyze the effects of different distraction techniques on children's anxiety levels during local anesthesia administration. The present study selected children aged 6–9 years based on their developmental considerations and susceptibility to dental anxiety [25]. Children in this age range are at a crucial stage of cognitive and emotional development, during which they can experience heightened anxiety and fear of the unknown [26]. In addition, older children are more receptive to distraction techniques than younger age groups, making them ideal candidates for intervention [8]. Stress elevates heart rate during dental procedures and is a direct indicator of physiological arousal. During their first dental visit, it is likely that their reactions to dental stimuli included fear or anxiety. Consequently, using a finger pulse oximeter to measure heart rate is an objective method for assessing a child's level of anxiety [3]. In the present study, an intergroup comparison of heart rate showed a non-significant reduction in all three groups. However, there was an increase in the heart rate among the groups during local anesthesia administration. This is because the autonomic nervous system controls the pulse rate and signals a person's state of relaxation or stress [27]. An increase in heart rate may be caused by sympathetic activation and catecholamine release in anticipation of the injection, which is in accordance with a study conducted by Shekhar et al. [8]. The RMS-PS measures the subjective assessment of anxiety in addition to objective assessment. Children may understand and find it easier to relate to this scale than to black-and-white cartoons because of their vivid graphics and clear visual depictions. This indicates that the RMS-PS is a good tool for measuring dental anxiety [18]. In the present study, there was a slight increase in RMS scores before and after the intervention in Group 1, whereas in Groups 2 and 3, there was a decrease in RMS scores from before to after the intervention, but the difference was not significant ($P > 0.05$). This is due to sensory shielding, which uses increased sensory input from VR distractions to divert a child from the potential stimulus [28]. This technique has been shown to be efficient in lowering stress and anxiety in children with sensory processing issues. By providing a more engaging and immersive experience, VR can help children focus their attention away from the overwhelming stimuli. Koepp et al. (1998) found that engaging in goal-directed motor tasks, such as playing video games, leads to the production of endogenous dopamine. Dopamine subsequently attaches to receptors in the human striatum [29]. This is consistent with the results of Attar et al. and Nunna et al. [30,13]. Buldur and Candan conducted a study in Turkey to assess the effects of VR on children's dental fear, discomfort, and behavior. The study included children aged 7–11 years. The mandibular molars underwent composite restoration under anesthesia. The VR group demonstrated a significant decrease in dental pain and anxiety based on heart rate values [31]. Similarly, in a clinical study conducted in Riyadh, Saudi Arabia, Khotani et al. investigated the impact of audiovisual distraction on children's behavior during dental treatment. According to their findings, the audiovisual group had less dental anxiety, and there was a significantly lower PR when a local anesthetic was administered [32].

Self-reported pain methods are generally considered the gold standard for measuring pain in pediatric patients because they are the most accurate means of measuring pain [33].

In the present study, pain assessment was performed using the WBFPS, a facial image pain scale, and one of the most basic tools for evaluating pain in pediatric dentistry. Furthermore, researchers identified it as replicable in young children (three years of age) [34]. In the current study, the pain scores of Group 2 were significantly lower than those of Groups 1 and 3. VR analgesia occurs via the intercortical modulation of pain matrix communication channels through focus, feelings, recollection, and other modalities (such as auditory, touch, and visual) [35]. VR keeps the brain occupied with information, reducing the amount of attention available for processing pain signals [36]. This is in accordance with the investigations conducted by Gold et al. and Aztori et al. [35,36]. The limitations of the current study include the small sample size and the inaccessibility of VR boxes of different sizes.

From the aforementioned observations, we can conclude that VR is a better behavioral guidance technique to alleviate dental fear, anxiety, and pain perception while administering local anesthesia to children than kaleidoscopy and video games.

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Niharika Reddy Elicherla: Investigation, Project administration, Validation
Shaik Rahul: Data curation, Investigation, Resources
Sivakumar Nuvvula: Supervision, Writing - review & editing

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