

Application of Virtual Reality on Non-drug Behavioral Management of Short-term Dental Procedure in Children

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Research

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Abstract

Background: The inherent characteristics of immersion, imagination, and interactivity in Virtual Reality, it may be suitable for non-drug behavior management of children in dental clinics. The purpose of this trial was to measure the role of virtual reality distraction on the behavior management of short-term dental procedure in Children.

Methods: A randomized clinical trial design carried out on 120 children aged between 4 and 8 years to make clear the comparative efficacy of virtual reality and Tell-Show-Do in improve behavioral management of dental procedure. The levels of operative anxiety and pain were assessed using, respectively, Children's Fear Survey Schedule-Dental Subscale, Visual Analogue Score. Frankl Behavior Rating Scale was tested before and during dental procedure. The length of dental procedure was compared between the two groups after treatment.

Results: The average anxiety and behavioral score of virtual reality group were significant reduced than that of control. The decrease score of anxiety score of virtual reality group and control group were IQR 8(7,11) and 5(5,7), $p < 0.05$. The compliance scores of control group in the treatment time were 3(2,3), the same in virtual reality intervention were 3(3,4), $p = 0.02$. We observed a significant reduction in pain by using Virtual Reality distraction ($p < 0.05$). Comparing the length of dental procedure, we found that VR group (19.02 ± 5.32) had shorter treatment time than the control group (27.80 ± 10.40)

Conclusion: The use of virtual reality could significantly reduce the anxiety and pain of children, length of dental procedure and improve the compliance of children undergoing short-term dental procedure without adverse reaction.

Trial registration: Chinese Clinical Trial Registry : ChiCTR2000029802. Registered on 14th Feb, 2020.

Introduction

Behavioral management success may be related to the following two variables: dental anxiety is a psychological state can be modified and controlled with psychological techniques, pain is an unpleasant sensory and emotional experience [1]. For the children's cognition levels of dental procedure, it is necessary to conduct behavioral management, so that the children can cooperate with pediatrist to complete the treatment.

In Southwest China, a substantial proportion of children are unable to collaborate well with doctors and nurses because of dental anxiety. The augment of pain, tense and fear-related behaviors during dental procedures was defined as Dental Anxiety (DA), it can be expressed as rapid heart rate, muscle tension and even syncope [2]. Dental anxiety refers to a universal level of stress that is characteristic of an individual, that is, may has a constant level during the life span. The emotion interferes significantly with the personal daily life, career development or relationships. Various studies have found the incidence of

dental anxiety to be 20%–43% depending on the age of the child. In recent survey, dental anxiety have produced a majority of clinical trouble in pediatric dental treatment[3].

With regard to the treatment of dental anxiety, drug systematic was generally used in the Department of Anesthesiology of Stomatological Hospital affiliated to Chongqing Medical University, such as Nitrous oxide (N_2O) induced conscious sedation and sevoflurane inhalation anesthesia. The N_2O sedation can only be applied in children got 3 or 4 Frankl Behavior Rating (FBR) Scale. Because the children are awake and have no other way to distract their attention, many children do not cooperate with pedodontists in the course of dental procedure. In sevoflurane inhalation anesthesia, because the children and their families need to carry out general anesthesia-related preoperative preparation: appointment waiting, fasting and drinking, risk of apnea, recovery after anesthesia, etc. The child's parents may think twice about possible damage from general anesthesia on their children. As a result of the above various problems, some children did not receive timely treatment, result in lifelong poor oral health, even bring long psychological trauma[4]. Hence, timely and effective management of dental anxiety is central to improving the mental and physical health of children with oral diseases.

The virtual reality technology (VR) creates a highly realistic virtual, three-dimensional (3D) environment that provides various sense stimulate (sense of vision, sense of hearing, touch even includes sense of smell) for the user who escape the real world [5,6]. By stimulating visual, auditory and proprioceptive sensations, virtual reality acts as a distraction to interfere the user's handling of noxious stimuli[6]. In the last decades VR has applied in different health care. In particular, VR has reported in many clinical trials, such as trauma rehabilitation[7,8], burn care[9,10], cancer treatment[11], operation training[12] and weight-related disorders[13]. Sato K and Sarig-Bahat have performed VR on the Complex regional pain syndromes[14] and chronic neck pain [15].

The analgesic effects of VR-distraction reduce negative emotions (e.g. anxiety) and lead to positive emotions[16]. A part of studies supports VR distraction has been used to relieve both pain and anxiety [5,6,17-22]. Similarly, virtual reality as a distraction intervention to relieve pain during perioperative period in dental surgery[17,21]. The application of VR technology in behavioral management of children's dental procedure is not deeply studied. There have also been recent reports that could reduce pain and anxiety in the dental setting and procedures [23,24], but the type of dental procedure is single and the suitable duration of treatment remains to be explored. In this study, we measured the role of virtual reality in non-drug behavior management in children with short-term and simple dental procedure.

Methods

Setting and patients

This single crossover clinical trial recruited 120 preschoolers aged 4-8 years who came to the Stomatological Hospital of Chongqing Medical University for dental treatment. This study followed the

Declaration of Helsinki on medical protocol and ethics and the regional Ethical Review Board of the Stomatological Hospital of Chongqing Medical University approved the trial.

Inclusion Criteria

Consenting children(aged 4-8 years)with the Children's Fear Survey Schedule-Dental Subscale(CFSS-DS)questionnaire greater than to 19[25].Time of dental procedure(Caries treatment,Extraction of deciduous teeth,Incision of abscess,Root canal therapy) is expected within half an hour.

Exclusion Criteria

The exclude criteria cases were children or their families can't agree, and their families were concerned that VR will have an impact on the eyes of the child, as well as for other reasons to interfere with the cause of the wearing of the VR glasses, such as those with glasses already in myopia. Since VR may cause motion sickness in some users, we exclude children with a history of motor diseases, motor nausea or vomiting. The child with a history of epileptic or epileptic seizures were also excluded, as there were reports that VR had a theoretical risk of inducing seizures. Unpleasant treatment experience can increase anxiety and pain during the next dental sessions, resulting, in turn, to perceive more pain. Therefore, in the study subjects were excluded if they had previous serious dental experience[26].

If the child has serious fear or severe movement during the intervention, the trial will be terminated immediately. Fig. 1 shows the CONSORT flow chart for the trial.

Technical Specifications

The HTC 's VIVE VR helmet which was commercial, widely used, short delay time for video scenes, and was not prone to head vertigo. The VIVE comprises 32 sensors for 360 degrees motion tracking, two 2160 by 1200 combined resolution AMOLED screen, and a 90 Hz refresh rate. The helmet is connected to ASUS Game notebook with an Intel Core i7-8820K processor ,16 gigabyte RAM and a NVIDIA GeForce GTX 1070 graphics card. The virtual environment allows the user to navigate naturally, which is created through a 110 degrees field of view for immersion.

Procedure

Patients will be randomly allocated to two conditions by using the randomization software (STATA software version 15.1). Eligible children and their families have been informed about the trial by anesthetists, and signature of informed consent statement on preoperative. Once, they agreed to participate in the study, personal medical data were collected by researchers and baseline anxiety were assessed by CFSS-DS (T0 time after signing the consent). Next, the anesthetist nurse randomly allocated children to the VR intervention, or to the control group (children only received Tell-Show-Do as usual). Block randomization was performed by type of dental procedure: caries treatment, extraction of deciduous teeth, incision of abscess and root canal therapy. After randomization, the VR intervention have took place in a separate room under the guidance of the nurse anesthetist, children in the TSD group were admitted

to the other room. Both groups were treated by experienced pediatric dentists. Fig.2 shows an example of dental procedure using HTC 's VIVE helmet.

The assessment per time point was performed. Frankl Behavior Rating Scale was scored before intervention (T1 5 minutes before dental procedure) and re-measured at the moment of local anesthetic injection (T2). CFSS-DS and Patient Satisfaction (PS) scores were performed 5 minutes after the end of treatment (T3). Visual Analogue Score (VAS) was evaluated at both T2 and T3 points, and its score ranged from 0 to 10 (0, no pain; 10, extreme pain). Because VR intervention has the potential to cause adverse events, Dizziness, nausea, vomiting, and epilepsy which have been follow up throughout the course of treatment. We also measured changes in heart rate and peripheral capillary oxygen saturation between the two groups before, during and after the dental treatment.

Virtual reality intervention

Before the dental procedure, we show the patient the corresponding scenes, specific inducers and background music that joint development with psychologists, which can attract his attention to relax him. The child need lie down on the dental chair and not shake his head left and right, causing the treatment to be interrupted. The nurse anesthetist put the helmet and earphone on child, who enter a virtual world he can follow our set route and watch different information expressed in the scene. The story begins in the world of the seabed which is about to be devastated. Only when the undersea creatures share their most precious things to nourish a rare pearl can save the undersea world. At first, "I" am in a shell, and the little elf introduces the creatures of the sea and their precious spirit. Secondly, sea anemone protect the clown fish while the clown fish reduce the surface precipitation of the anemone, and they share this precious friendship of helping each other (Fig. 3a). Next, for children to introduce the ancient precious and tenacious vitality of animals: turtles (Fig. 3b). And then, introduce the parrot fish solidarity (Fig. 3c) and dolphin helpful spirit (Fig. 3d). Scene switching for children to introduce beautiful and dangerous jellyfish, it shares his valuable storm prediction ability (Fig. 3e). Finally, the pearl was born from the precious spiritual nourishment of thousands of marine creatures,, and the undersea world restores its former peace and tranquillity. (Fig. 3f). Meanwhile, The virtual environment was also displayed on the ASUS notebook, so the accompanying families could see what the child was viewing.

Statistical Analyses

Data were performed using SPSS software version 22 ((IBM, Chicago, USA). The statistical significance difference was set at $p < 0.05$. Chi-square Test was used to assess gender difference, ASA physical status ,type of dental procedure and local anesthetic between the two groups. All quantitative variables were presented as mean \pm SD (standard deviation), and the analysis of variance or nonparametric test was performed for comparisons in accordance with the data distribution. Mann-Whitney U tests were used to compare the downtrend level of anxiety scale and Frankl Behavior Rating scale.

Results

The trial comprised 25 girls and 35 boys in VR group and 32 girls and 28 boys in TSD group, respectively. The mean ages of the trials in group VR and TSD were 5.59 ± 0.92 and 5.66 ± 0.99 years, $p=0.69$. Similarly, with no significant differences between the two groups in the means of regarding gender, ASA physical status, type of dental procedure and local and type of dental procedure (Pearson chi-square test, $p>0.05$; Table 1).

The mean anxiety scores were decreased significantly after VR distraction. In VR group: the Children's Fear Survey Schedule-Dental Subscale was 34.17 ± 5.81 before intervention, which decreased to 24.77 ± 6.98 after VR distraction. Meanwhile, in TSD group: the anxiety scores were 34.08 ± 8.42 and 27.98 ± 7.41 , respectively ($n=60$). The anxiety score between VR-intervention and TSD were statistically difference after dental procedure (Table 2). Table 2 also shows the downtrend of anxiety score variations between the two groups and the differences were statistically significant.

The Mann-Whitney U tests of Frankl Behavior Rating scores of VR group in the time of Pre-intervention were 2(2,3). Same in the time T2 of VR distraction treatment were 3(3,4), which represented that VR distraction have improved the patient compliance. In control group, the FBR scores before intervention and the time of the maximum procedure pain were 2(2,3) and 3(2,3), respectively. Those indicate that virtual reality could Increase the compliance ($P=0.02$; Table 2).

A total of 5 children (8.33%) in VR group had severe intraoperative anxiety and stopped treatment in fear, compared with 11 cases (18.33%) in TSD group ($p < 0.05$). The CFSS-DS score of the children after the exclusion of the above person were found VR interference relative to the control group can still significant alleviate the anxiety of the children, $p < 0.05$. The FBR score of both groups at T2 has no statistical difference.

During the operation, we observed that the pain score of the VR group (1.58 ± 1.08) was lower than that of the control group (2.86 ± 0.96). Meanwhile, the results showed that the VR intervention at the end of treatment, relating to the control of operation pain, worked best ($p < .001$) in patients. Comparing the length of dental procedure, we found that VR group (19.02 ± 5.32) had shorter treatment time than the control group (27.80 ± 10.40). The results of this trial also have indicated the decrease of treatment time was particularly significant in caries treatment and root canal therapy and was statistically significant ($p < .001$). Table 2 also shows the overall patient satisfaction of dental procedure of VR intervention (88.33 ± 7.15) was significantly higher than group TSD (76.78 ± 8.49).

After monitoring Physiological signs, we found that VR group decreased heart rate while the control group did the opposite ($p < 0.05$; Fig.4). There was no significant difference in the SPO_2 , which was detected before- and after-intervention between the two groups.

Discussion

Our group has been engaged in oral-related sedation and analgesia for a long time, so we consider whether we can use new methods to relieve dental anxiety in this group of children [27-29]. Thus, the trial

has focused on the effectiveness of compliance changes in the VR distraction in 4-8-year-old children during short invasive dental treatment [4]. This results of the trial support that virtual reality would be associated with a greater decrease in behavioral avoidance compared to who received Tell-Show-Do-intervention. The anxiety score of the two groups before and after the intervention, the VR group have decreased more than the control group, but the compliance score of the children increased. Asl Aminabadi N et al. reported that virtual reality eyeglasses can successfully decrease pain perception and state anxiety during dental treatment in 4-6 years old children [30]. Similarly, Shetty V observed that Virtual Reality distraction can be used as a successful behavior modification method in 5 to 8 Year Old children undergoing short invasive dental treatments[31]. Therefore, the trial further strengthens that immersing a virtual environment can help control dental anxiety during pediatric dental treatment on children. Researchers have showed that the effect of VR technique on pain perception is beyond simple distraction[32]. In addition, By diverting attention from an unpleasant environment setting to a pleasant and absorbing virtual world, VR also obviously diminish a patient's physical pain experience[8,33,34]. By relieving anxiety and reducing pain, children can markedly cooperate with treatment which have be like with Caries treatment, Root canal therapy.

Meanwhile, we observed that the treatment time of VR group had significantly shorter than the control group. In our previous clinical treatment, general anesthesia with inhaling sevoflurane have be an invasive medical method which has been used to most children, whom have difficult to adapt to Tell-Show-Do behavioral induction. A part of children maybe had delayed treatment because of family concerns about general anesthesia or their lack of cooperation with behavioral induction, resulting in poor prognosis and long-term teeth problems. This trial suggests that the customized VR content as applied in the present study produces children to be treated as quickly as possible, maybe reduce the frequency of patients to seek medical treatment, reduce the number of outpatients. In China, the ratio of health workers to people is significantly lower than the global average, especially pediatricians[35]. This is beneficial for both doctors and patients.

The present trial has several limitations that should be noticed. Firstly, we could not assess the different clinicometric tools and self-assessment. The corresponding scores of anxiety and pain in children were relatively single. Secondly, we did not think deeply about other factors that affect children's behavior. Some researchers reported that several factors, such as age, sex, type of dental treatment, parental anxiety and socioeconomic status were associated with anxiety will be assessed because these may influence the efficacy of VR[36]. Despite evidence reported that older children considered VR technique as a very simple game, have lower level of distraction [32]. This study shows five children who were uncomfortable with VR distraction and terminated the trial, considering that some of them were possible terminated for these reasons. but, An average age analysis of the five children found that was not statistically significant. In addition, their anxiety score were higher than 35 before and after treatment. Thirdly, we could not blind the pedodontists or the patients to the interventions due to the apparent difference between the two group. During the next experiment, the deficiency was overcome by watching different VR animation in different groups. Fourthly, the VR in this trial have only one animation content, it may be considered a limitation because the stimuli that trigger dental anxiety may differ for each individual. Based on the

current data of using virtual reality, anxiety score, and using mobile Internet APP to collect family members' awareness and anxiety about dental diseases, to replace fewer generic intervention scenarios, the next step is hierarchical customization of VR content. We hope that virtual reality will be improved in the process of being widely used in children's department of Stomatology, and finally form a set of intelligent bio-feedback mechanism to achieve closed-loop control of anxiety and pain in children, so that children can get rapid, timely and comfortable oral treatment.

The trial has focused on the effectiveness of compliance changes in the VR distraction in 4-8-year-old children during short-term invasive dental procedure. The VR-distraction is purely non-intrusive methods, therefore, the children receive less invasive treatment than general anesthesia. Even with dental treatment time after time, parents and children are much more receptive than other methods.

Declarations

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Author Contribution

* LR and NZ make a common contribution.

LR: collection of data; drafting of the manuscript; final approval of submitted manuscript. NZ: analysis and interpretation of data; drafting of the manuscript; final approval of submitted manuscript. LF: collection of data; final approval of submitted manuscript. PZ: collection of data; final approval of submitted manuscript. CZ: interpretation of data; final approval of submitted manuscript. CY: conception and design; drafting and revision of the manuscript; final approval of submitted manuscript.

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Availability of data and materials

The ethical approval does not permit the sharing of the entire data that we have Acquired, but the information required is already provided in the main manuscript.

Conflicts of interest

The authors declare no conflict of interest.

Ethics approval and consent to participate

The trial followed the Declaration of Helsinki on medical protocol and ethics and the Ethical Review Board of the Stomatological Hospital of Chongqing Medical University approved the trial. Written and verbal consent was obtained from all participants before the start of VR distraction.

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Tables

Table 1. Patient and dental procedures.

	VR ^a n=60,%	TSD ^b n=60,%	<i>p</i>
Age (year)	5.59±0.92	5.66±0.99	.69
Sex			.20
Male	35(58.33)	28(46.67)	
Female	25(41.67)	32(53.33)	
ASA^c physical status			.53
I	43(71.67)	46(76.67)	
II	17(28.33)	14(23.33)	
Dental procedure			.63
Caries treatment	27(45.00)	20(33.33)	
Extraction of deciduous teeth	12(20.00)	15(25.00)	
Incision of abscess	11(18.33)	13(21.67)	
Root canal therapy	10(16.67)	12(20.00)	
Local anesthetic			.39
Primacaine	48(80.00)	46(76.67)	
Not used	12(20.00)	14(23.33)	

^aVR Virtual Reality group;

^bTSD: Tell-Show-Do group.

^cASA: American Society of Anesthesiologists.

p value < 0.05 statistically significant

Table 2. Anxiety, pain, patient Satisfaction and time of dental procedure in both groups

	VR ^a (n=60)	TSD ^b (n=60)	<i>p</i>	VR(n=55)	TSD(n=49)	<i>p</i>
Anxiety						
CFSS-DS ^c						
Pre-intervention(T0)	34.17±5.81	34.08±8.42	.95	33.15±4.82	31.45±5.97	.11
Post-intervention(T3)	24.77±6.98	27.98±7.41	.02*	23.34±5.23	25.43±5.20	<0.05*
Downtrend (T0-T3)	8(7,11)	5(5,7)	<.001*	8(7,12)	5(5,7)	<.001*
FBR ^d						
T1	2(2,3)	2(2,3)	.26	2(2,3)	2(2,3)	.12
T2	3(3,4)	3(2,3)	.02*	3(3,4)	3(3,3)	.11
Pain						
VAS ^e						
T2(observed)				1.58±1.08	2.86±0.96	<.001*
T3((self-reported)				1.62±1.13	3.59±1.19	<.001*
PS ^f (T3,score 0-100)				88.33±7.15	76.78±8.49	<.001*
Length of dental procedure(min)						
T1 to T3				19.02±5.32	27.80±10.40	<.001*
Caries treatment				19(16,22)	30(25,30)	<.001*
Extraction of deciduous teeth				14.75±2.77	19.93±9.01	.07
Incision of abscess				22.40±3.89	26.09±6.80	0.15
Root canal therapy				23.57±4.39	42.43±8.40	<.001*

^aVR:Virtual Reality group.^bTSD:Tell-Show-Do group.^cCFSS-DS:Children's Fear Survey Schedule-Dental Subscale.^dFBR: Frankl Behavior Rating Scale.^eVAS: Visual Analogue Scale. ^fPS:Patient Satisfaction. T0: signature of informed consent statement.T1: before intervention.T2: the moment of local anesthetic injection. T3: the end of treatment. **p* value<0.05 statistically significant.

Figures

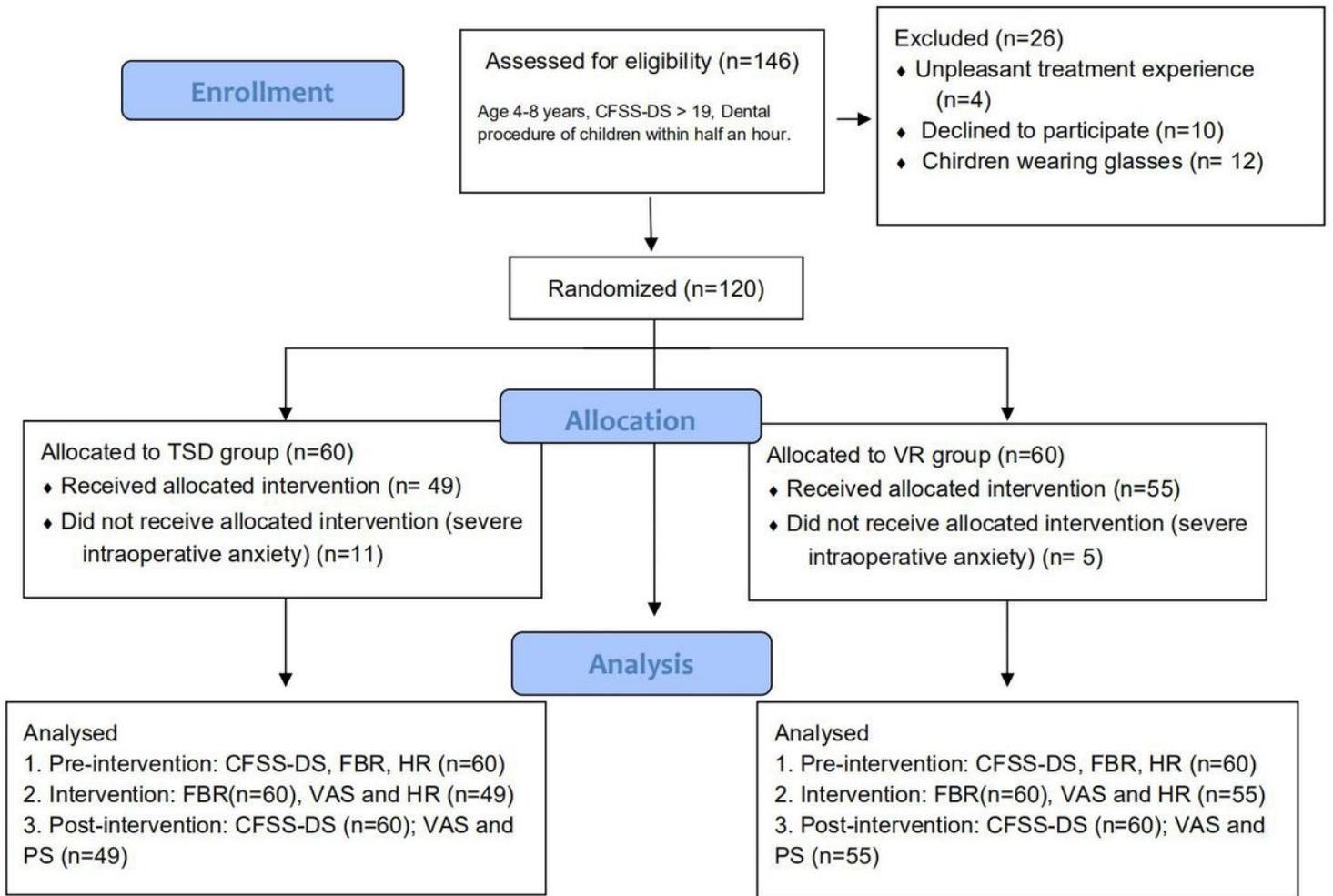


Figure 1

CONSORT flowchart for the randomized trial. CFSS-DS :Children’s Fear Survey Schedule-Dental Subscale . TSD:Tell-Show-Do. VR:Virtual Reality.TSD:Tell-Show-Do. FBR:Frankl Behavior Rating scale.VAS:Visual Analogue Score.HR:Heart Rate.PS: Patient Satisfaction.



Figure 2

A scene in which HTC's VIVE VR helmet is being used in dental procedure.

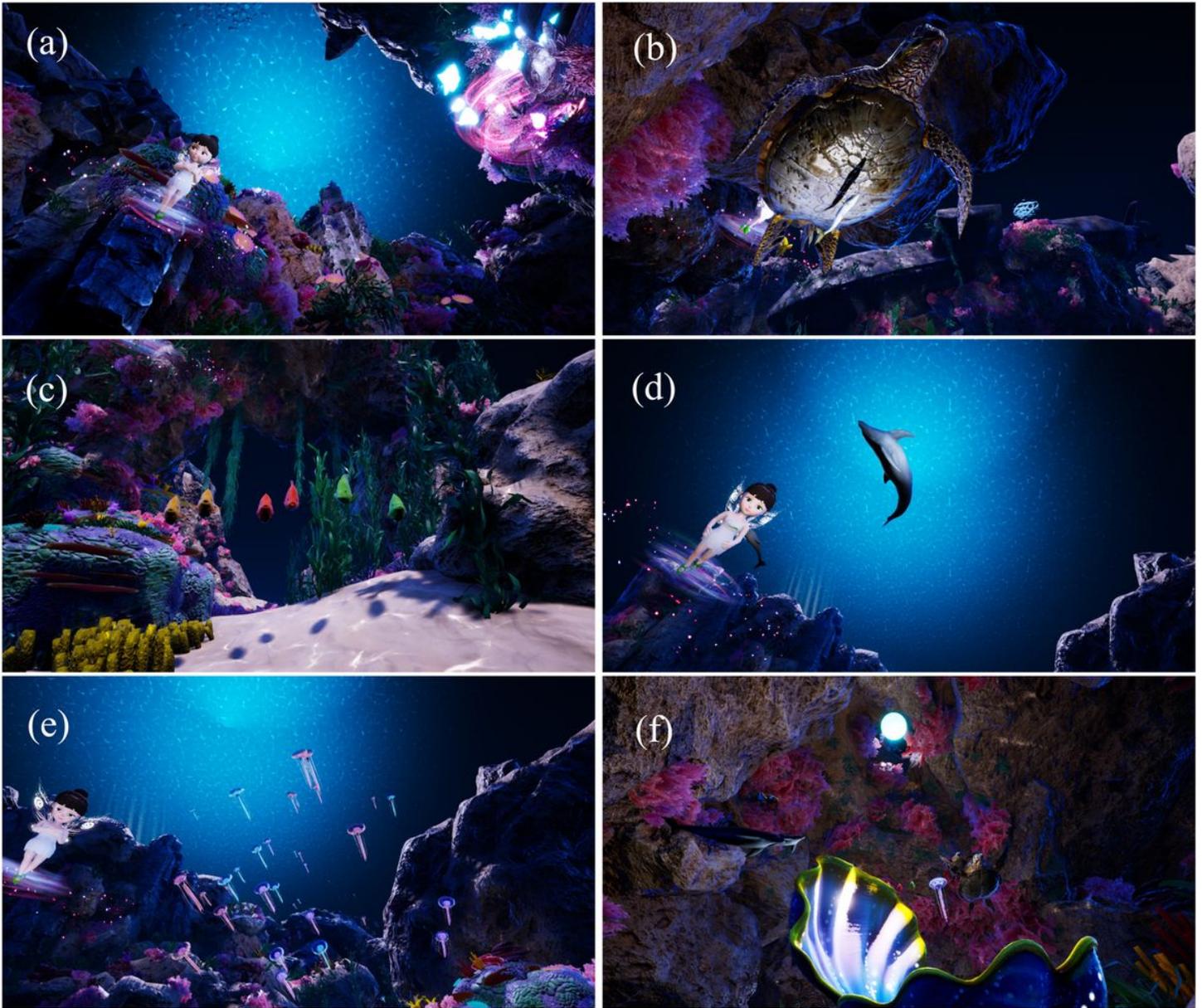


Figure 3

Screenshot of custom scenario.

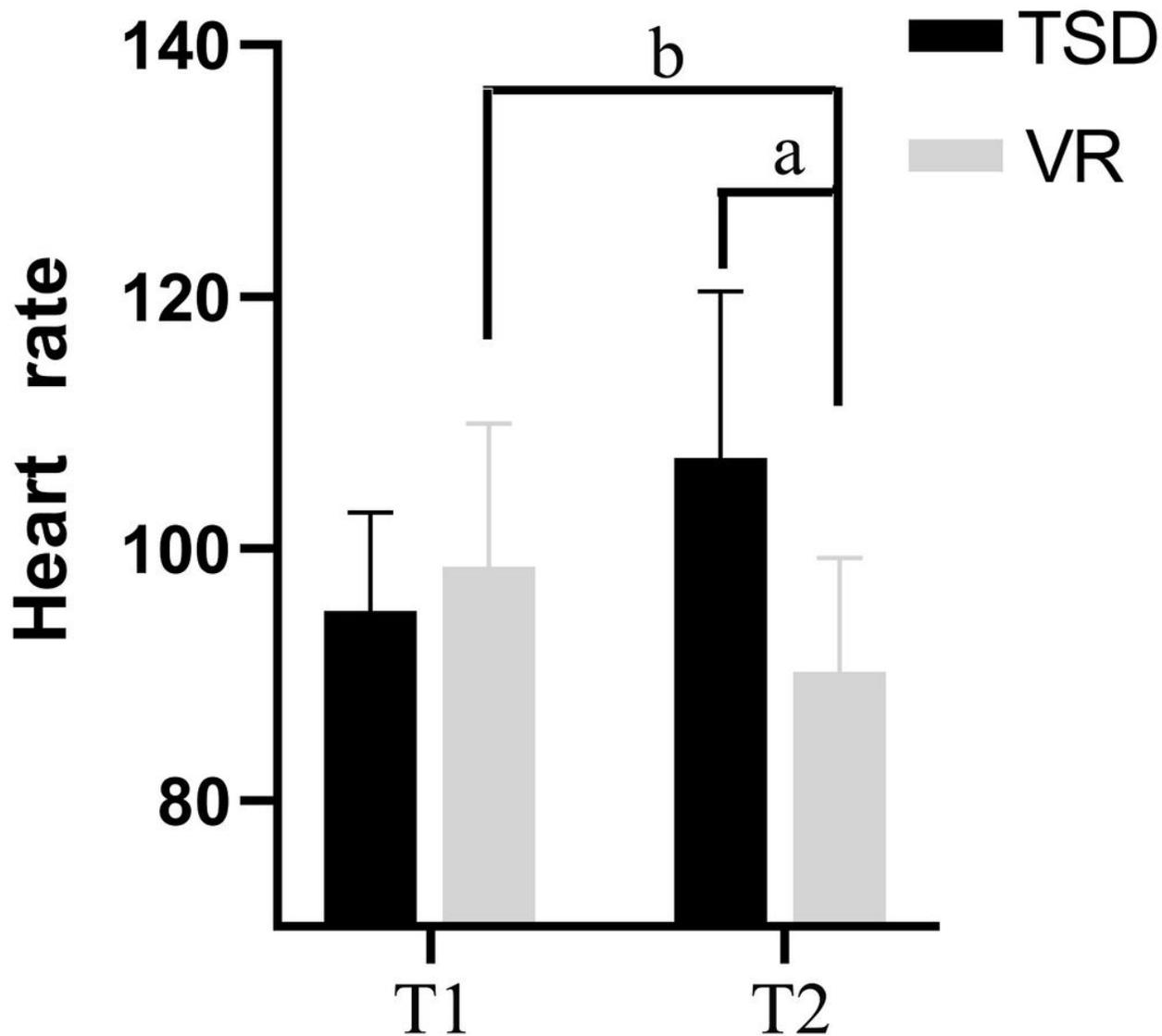


Figure 4

Changes in heart rate before and during the dental treatment between the 2 groups. VR:Virtual Reality group.TSD:Tell-Show-Do group.T1: before intervention.T2: the moment of local anesthetic injection.a,b p <0.05

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [CONSORT2010Checklist.docx](#)