

The Effectiveness of Virtual Reality Distraction on Dental Anxiety During Local Anaesthesia among Adolescents – A Randomized Controlled Trial

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ABSTRACT

Objective: To determine the impact of the clinical use of virtual reality distraction in reducing anxiety levels in adolescents during local anaesthetic (LA) administration.

Methods: This was a randomized controlled study. Study participants comprised of adolescents aged 10 -17 years attending the Paediatric Dentistry outpatient Clinic of University of Benin Teaching Hospital, Benin City. One hundred and fifty-eight adolescents who presented for treatment and met inclusion criteria were included and randomly divided into two groups; a control group without distraction and a study group with distraction using a Quest Oculus VR headset. Anxiety was assessed using subjective (MDAS) and physiologic (pulse rate, heart rate, oxygen saturation, respiratory rate and temperature) methods respectively, pre-treatment and post treatment. The IBM SPSS version 20 was used to analyze the data. The level of significance was set at $p < 0.05$.

Results: A total of 156 participants with a mean age of 13.56 ± 1.682 years were recruited in the study. The mean scores for MDAS after the administration of LA for the control and study group was 14.74 ± 3.35 and 10.09 ± 1.90 and this was statistically significant ($P < 0.001$). PR had a mean value of 88.06 ± 11.19 and 93.56 ± 10.10 in the control and study group respectively before LA and was statistically significant ($P = 0.002$). However, after the administration of LA, the mean values were 97.08 ± 10.96 and 89.19 ± 10.17 showing a significant rise in the control group and decrease in the study group respectively ($P < 0.001$). Temperature, systolic BP and SpO_2 showed slight changes between the control and study groups before and after administration of LA but these were not statistically significant. The sociodemographic factors which played a role in anxiety levels (as recorded in PR variation) following linear regression analysis were position in family, study group and site of administration ($P = 0.018$; 0.003 and < 0.001) respectively.

Conclusion: Virtual Reality distraction significantly reduced pain and anxiety during administration of local anaesthesia in adolescents undergoing dental treatment.

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INTRODUCTION

Over the past two decades, the use of virtual reality (VR) for medical and dental purposes has been gaining attention. What initially began as a form of entertainment has expanded its application into a variety of areas. In this context, VR has been investigated and clinically applied as an advanced form of distraction (Hoffman et al., 2006). Simpler, empirically supported forms of distraction include imagery, relaxation, and positive thinking (Hoffman et al., 2006). More technology-specific distracters, such as television and video games, have also been explored as means to reduce distress associated with needle prick during immunization (Cassidy et al., 2002). VR distraction is unique in that it is immersive and engaging, integrating many sensory experiences, and thus capturing a greater degree of attention. This becomes possible through the use of interactive virtual environments (VEs) with head-tracking systems, visually stimulating scenery, and audio and tactile feedback.

VR enables users to become active participants in a "virtual world." Participants enter the virtual world through a combination of a head-mounted display (HMD), headphones with sound/music and noise reduction, and a joystick, rumble pad, or another device for manipulation/ navigation of the VE (Hoffman et al., 2006). This combination of visual, auditory, and tactile stimuli helps immerse the user in the VE, creating a sense of presence and could serve as a distraction from reality.

Managing dental anxiety is recognized as an important issue in dental practice, since many people avoid or delay dental care because they experience fear and anxiety, and the expectation of pain is seen as a major barrier to seeking dental care (Dionne et al., 1998). Patients with dental fear tend only to go to the dentist when they experience pain, thereby increasing the chance that their visit to the dentist will involve pain and exacerbating their anxiety. Dentists themselves suffer from heightened discomfort when treating anxious patients (Hill et al., 2008). Alleviating dental anxiety may also reduce perceived pain and unpleasantness, which may facilitate the work of dentists. Dental anxiety and anxiety-related avoidance of dental care thus create a significant problem for both patients and the dental profession. Reduction of pain and distress during dental procedures would likely increase the frequency of visits of avoidant patients. It is ironic that local anaesthesia allows virtually pain-free treatment, yet is associated with many anxious

thoughts and misconceptions in young patients (Dionne et al., 1998).

Despite the potential benefits of VR technology, there is a striking gap in the literature concerning the outcomes of immersive VR technology on dental anxiety. Apparently, there is a need for further research on the effectiveness of VR technology, if it is to be used as an effective solution for reducing anxiety levels in adolescents during administration of local anaesthesia. The objective of the study was to determine the impact of the clinical use of virtual reality distraction in reducing anxiety levels in adolescents during local anaesthetic administration.

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MATERIAL AND METHODS

The Institutional Research and Ethics Committee at the University of Benin Teaching Hospital, Benin City; approved this study (ADM/E 22/A/VOL. VII/1483057). The parents of all the study participants were given both written and verbal information about the study before including them in the study. Only those who gave both verbal and written consent were finally included in the study.

Study participants

The study population in this study were children visiting the Paedodontics clinic of the University of Benin Teaching Hospital, Benin City for a dental procedure involving the administration of local anaesthesia before exodontia or a restorative procedure via inferior alveolar nerve block or infiltration technique. The children in this study were aged between 10 and 17 years. The sample size was calculated using the Krejcie and Morgan estimation formula using the clinic's average quarterly patient turnout of 200 and a degree of accuracy of 0.05 (Milgrom et al., 1997). The calculated sample size of 136 in both groups (study and control groups) was found to be sufficient to detect a statistically significant difference between study and control groups at a significant level of 5%. To make provisions for non-response or drop-outs, 10% attrition was incorporated to get a total of 146 study participants.

The inclusion criteria to be selected for the study were: 1. Procedures requiring the use of local anaesthetic injections 2. Patients with good general, physical, and mental health 3. Patients presenting for dental treatment for the first time.

The exclusion criteria to be selected for the study were: 1. Patients with a seizure disorder, as Head Mounted Display (HMD) can trigger an episode 2. Patients on psychotherapy 3. Patients suffering from claustrophobia and thus unable to tolerate the virtual; reality environment. 4. Patients whose parents did not give consent

Study design

This prospective randomized controlled trial was carried out between February 2022 and August 2022. A systematic random sampling technique was used to select the 146 participants. The randomization was performed by a trained dental surgery assistant using a pre-determined and consistent interval based on the sample frame of all those given numbers to be seen in the clinic each day, with every first patient and odd-numbered patients who met the inclusion criteria getting the virtual reality headset and the second set (even numbered patients) serving as the control group and managed the conventional way.

A pilot study was carried out on 14 selected patients (10% of the sample size) who were not part of the main study. This was useful in adjusting some parameters in the questionnaire and also in getting acquainted with the use of the virtual reality distraction technique. The results of the 14 participants were not included in the main work.

Intervention

The VR (Virtual Reality) environment for this study consisted of a simulated urban environment. The Oculus Quest VR headset was used in this study. It has a stand-alone design, which means it doesn't connect to a phone or personal computer. It includes dual hand controllers, and it's studded with four wide-angle tracking cameras, which allow the user to walk around a fairly large space in the virtual environment. The Oculus Quest VR headset used in this study was purchased online from the Amazon website.

Two groups (Study and Control group) formed the study population. The participants in the study group wore VR goggles and used dual hand controllers to navigate the environment while participants in the control group were treated the standard way without the use of VR technology.

Methods

At the appointment, after ensuring the study participant met the inclusion criteria, the study participant was seated on the dental chair, a Modified Dental Anxiety Scale (MDAS)

questionnaire was completed before and after the procedure for both the control and study groups. For the study and control group, the procedure and gadgets were first explained to the participant using tell-show-do, a pulse oximeter was then placed on the child's index finger while pulse rate, blood pressure, and temperature were measured using a digital sphygmomanometer and a digital thermometer. For the study group only, three-dimensional virtual reality glasses (Oculus Quest) were placed on the participant. The participant was to view a five-minute movie during the simultaneous application of topical xylocaine before administration of the local anaesthetic agent via inferior alveolar block or infiltration techniques using one capsule of 2 percent lidocaine with 1:100,000 epinephrine local anaesthetic agent. The glasses were then removed after five minutes, parameters (pulse rate, respiratory rate, SPO₂, blood pressure, and temperature) were measured again and the participant was required to complete another questionnaire. The questionnaires at all times were interviewer-administered.

For the control group, topical xylocaine was applied to the injection site for the inferior alveolar block or infiltration techniques. The study participant was then anesthetized with one capsule of 2 percent lidocaine with 1:100,000 epinephrine local anaesthetic agent using non-pharmacological behaviour management techniques. Parameters (pulse rate, respiratory rate, SPO₂, blood pressure and temperature) and questionnaires were also measured and administered pre and post op, same as the study group.

Patient assessment

Pulse rate and blood pressure were documented before and after the administration of the local anaesthetic agent using a digital sphygmomanometer applied to the left-hand side of the participant. The batteries of the sphygmomanometer were changed weekly or when they were considered weak to ensure the accuracy of its reading. The temperature of study participants was measured using a digital thermometer placed under the armpit. For respiratory rate, the number of breaths for an entire minute was counted and recorded before and immediately after the administration of local anaesthetic. The partial pressure of oxygen (SPO₂) was recorded using a pulse oximeter placed on the left thumb.

The Modified Dental Anxiety Scale (MDAS) questionnaire consist of 5 questions and each

question has a 5-category rating scale ranging from 'relaxed' to 'anxious'. A minimum score of 5 or a maximum score of 25 was obtained. The higher score indicated higher dental anxiety while lower scores indicated lower dental anxiety. Coker et al. (2012) set the cut-off for dental anxiety at a score of 11 and the same was set for the current study.⁶ The tool has been reported as a useful instrument for measuring dental anxiety among Nigerians because of its reliability, validity, brevity, and ease of administration (Coker et al., 2012). Recruitment, informed consent, randomization, and local anaesthetic administration were carried out by the principal investigator. Before and after measurements of dental anxiety parameters were carried out by a trained research assistant who was blinded from group allocation.

Statistical analysis

The IBM SPSS version 20 statistical software (IBM SPSS Version 20 for Windows, SPSS, Chicago) was used to analyze the data. The normality of the data was tested with the Shapiro–Wilk test. Descriptive data were reported as frequencies, means, and standard deviation (SD). For analysis of group differences in frequencies, the Chi-square test was used. For analysis of group differences in variables, an independent t-test was used. The significance level was set at $p < 0.05$.

RESULTS

Socio-demographic characteristics of study participants

A total of 200 participants were eligible to participate in the study but only 156 participants completed the study (79 in the study group and 77 in the control group) giving a 78% participation rate (Table 1). More than half of the study participants 86 (55.1%) were between the ages of 14-17 years. The mean age and standard deviation (SD) for the control and study groups were 13.64 ± 1.69 and 13.48 ± 1.68 respectively. The overall mean age and standard deviation (SD) was 13.56 ± 1.68 years. More than half the participants were males (53.8%), while females accounted for 46.2%. The majority (60.9%) of the local anaesthetic given was in the mandibular arch. No significant difference was found between the study and control groups in terms of age ($P = 0.411$), gender ($P = 0.863$), number of siblings ($P = 0.855$), position in the family ($P = 0.248$), class in school ($P = 0.333$). Parents' income earning status ($P = 0.763$, 0.445) and site of local anaesthesia (maxilla versus mandible) ($P = 0.971$) (Table 1).

Effectiveness of VR distraction in reducing anxiety levels among study participants

Anxiety scores as measured with MDAS (Modified Dental Anxiety Scale), Pulse rate (PR), Temperature, Systolic blood pressure, SpO_2 and Respiratory rate are shown in Table 2.

The mean MDAS before local anaesthesia in the control and study group was 14.44 ± 2.58 and 14.35 ± 2.46 respectively, while the mean scores for MDAS after the administration of LA for the control and study group was 14.74 ± 3.35 and 10.09 ± 1.90 and this was statistically significant ($P < 0.001$).

Pulse rate, which is also a measure of anxiety had a mean value of 88.06 ± 11.19 and 93.56 ± 10.10 in the control and study group respectively before local anaesthesia and was statistically significant ($P = 0.002$). However, after the administration of local anaesthesia the mean values were 97.08 ± 10.96 and 89.19 ± 10.17 showing a significant rise in the control group and decrease in the study group respectively ($P < 0.001$).

The respiratory rate before the administration of local anaesthesia was 14.16 ± 1.79 and 14.51 ± 1.75 for the control and study groups respectively and this was not statistically significant ($P = 0.219$) but following the administration of local anaesthesia a statistically significant ($P < 0.001$) change was seen in the control group compared to the study group. Temperature, systolic blood pressure and partial pressure of oxygen (SpO_2) showed slight changes between the control and study groups before and after administration of local anaesthesia but these were not statistically significant (Table 2).

Comparative evaluation of the impact of virtual reality distraction on dental anxiety

Before the administration of local anaesthesia, all the study participants (both control and study groups) had some degree of anxiety with the majority ranging from low to moderate anxiety (35.3% and 35.3%) respectively only 2 (1.2%) exhibited extreme anxiety (Table 3). Graphical representation after the administration of local anaesthesia showed many of the study group participants reported low anxiety while others had moderate anxiety. Comparatively, majority of the control group had high anxiety while fewer reported moderate and less, low anxiety respectively. Figures 1 and 2.

Table 1: Socio-demographic characteristics of study participants

Variables	CG-group n (%)	SG-group n (%)	Total n (%)	p-value
Individuals	77 (49.4)	79 (50.6)	156 (100.0)	
Gender				
Male	42 (26.9)	42 (26.9)	84 (53.8)	0.863
Female	35 (22.5)	37 (23.7)	72 (46.2)	
Age				
Mean (SD)	13.64 (1.693)	13.48 (1.678)	13.56 (1.682)	0.411
Min - max	10 - 16	10 - 17	10 - 17	
10 - 13 years	32 (20.5)	38 (24.4)	70 (44.9)	
14 - 17 years	45 (28.9)	41 (26.2)	86 (55.1)	
Number of siblings				
0 - 3 siblings	44 (28.2)	44 (28.2)	88 (56.4)	0.855
4 - 6 siblings	33 (21.2)	35 (22.4)	68 (43.6)	
Position in family				
1 st - 3 rd position	65 (41.7)	61 (39.1)	126 (80.8)	0.248
4 th - 6 th position	12 (7.7)	18 (11.5)	30 (19.2)	
Class in school				
JSS 1 - 3	34 (21.8)	41 (26.3)	75 (48.1)	0.333
SS 1 - 3	43 (27.6)	38 (24.3)	81 (51.9)	
Father's income earning class				
Low income earning	28 (17.9)	26 (16.7)	54 (34.6)	0.763
Middle income earning	24 (15.4)	29 (18.6)	53 (34.0)	
High income earning	25 (16.1)	24 (15.3)	49 (31.4)	
Mother's income earning class				
Low income earning	34 (21.8)	39 (25.0)	73 (46.8)	0.445
Middle income earning	24 (15.4)	27 (17.3)	51 (32.7)	
High income earning	19 (12.2)	13 (8.3)	32 (20.5)	
Site of procedure				
Maxilla	30 (19.2)	31 (19.9)	61 (39.1)	0.971
Mandible	47 (30.2)	48 (30.7)	95 (60.9)	

SD: standard deviation; SG: study group; CG: Control group.

Effect of Sociodemographic variables on anxiety levels

Figure 3 showed the comparison of MDAS scores by gender. More boys showed low anxiety compared to girls while more girls showed moderate anxiety. More boys also showed high anxiety than girls while only girls showed extreme anxiety. For the subjective and physiological measurements of dental anxiety, only pulse rate was statistically significant and was subjected to further multiple linear regression to assess which factors were predictors. Age, gender, number of siblings, class and site of the procedure before and after administration of local anaesthesia were not statistically significant ($P = 0.292, 0.417, 0.061, 0.415$ and 0.168) respectively (Table 5). Position of the child in the family was a predictor of changes in pulse rate, with children in the 1st to 3rd position being more likely to record these changes compared to children in the 4th to 6th position before the administration of local anaesthesia

($P = 0.018$) although it was not after administration of local anaesthesia ($P = 0.601$) and this difference was statistically significant ($P = 0.001$). Another predictor of changes seen in the pulse rate was the group the study participant belonged to with those in the study group more likely to have reduced or normal pulse rate during the administration of local anaesthesia when compared to the control group and this was statistically significant ($P < 0.001$), and was also statistically significant before and after the administration of local anaesthesia ($P = 0.003$ and < 0.001) respectively. The site of the procedure (mandible compared to maxilla) where the local anaesthesia was administered also was a predictor of the changes seen in the pulse rate before and after administration of local anaesthesia and this was statistically significant ($P < 0.001$ and 0.005), however the pulse rate difference between the groups was not statistically significant ($P = 0.168$). (Table 5).

Table 2: Inter-group comparison of mean values of subjective and physiologic parameters

Variables	Group	Mean	SD	P-value
Subjective (MDAS)				
Before	CG	14.44	2.58	0.829
	SG	14.35	2.46	
After	CG	14.74	3.35	<0.001 [*]
	SG	10.09	1.90	
Physiologic (Pulse rate)				
Before	CG	88.06	11.19	0.002 [*]
	SG	93.56	10.10	
After	CG	97.08	10.96	<0.001
	SG	89.19	10.17	
Physiologic (Temperature)				
Before	CG	36.49	0.28	0.475
	SG	36.52	0.28	
After	CG	36.51	0.24	0.329
	SG	36.55	0.21	
Physiologic (Systolic BP)				
Before	CG	107.08	5.41	0.168
	SG	108.14	4.09	
After	CG	108.00	6.11	0.632
	SG	108.43	5.05	
Physiologic (SpO₂)				
Before	CG	97.27	1.38	0.148
	SG	96.94	1.50	
After	CG	97.52	0.98	0.116
	SG	97.27	1.02	
Physiologic (Respiratory rate)				
Before	CG	14.16	1.79	0.219
	SG	14.51	1.75	
After	CG	16.00	2.55	<0.001 [*]
	SG	14.56	1.54	

*P < 0.05-statistically significant; Study group (SG); Control group (CG); MDAS – Modified Dental Anxiety Scale; WBFPS – Wong-Baker Pain Rating Scale; VAS – Visual Analogue Scale; SD – Standard Deviation

Table 3: Categorization of patients based on MDAS scores

MDAS score range	Number	Percentage
0 – 5 (Not anxious)	0	0%
6 – 10 (low anxiety)	55	35.3%
11 – 14 (moderate anxiety)	55	35.3%
15 – 18 (high anxiety)	44	28.2%
19 – 25 (extreme anxiety/phobic)	2	1.2%
Total patients	156	100.0%

* MDAS – Modified Dental Anxiety Scale

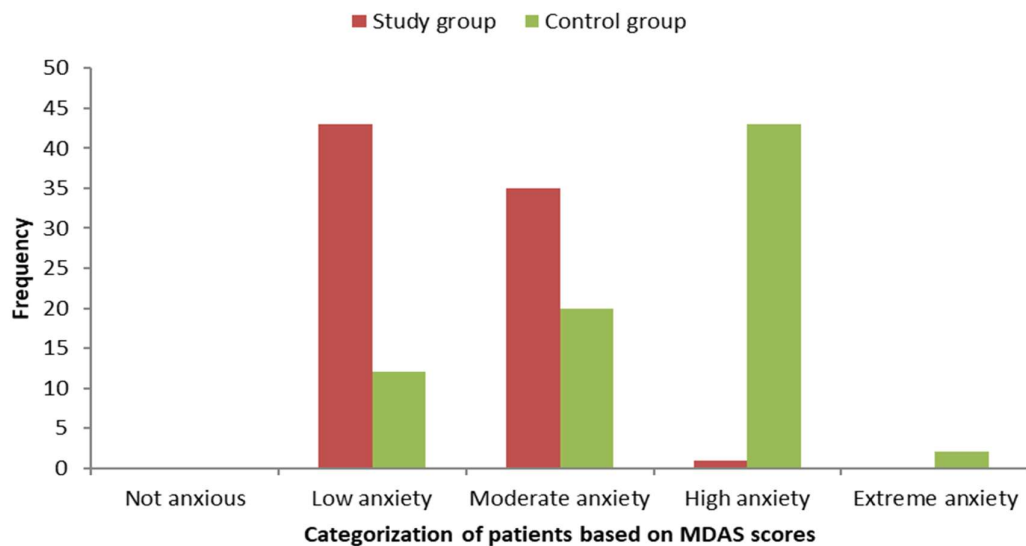


Figure 1: Comparison by group using the categorized variables of MDAS scores

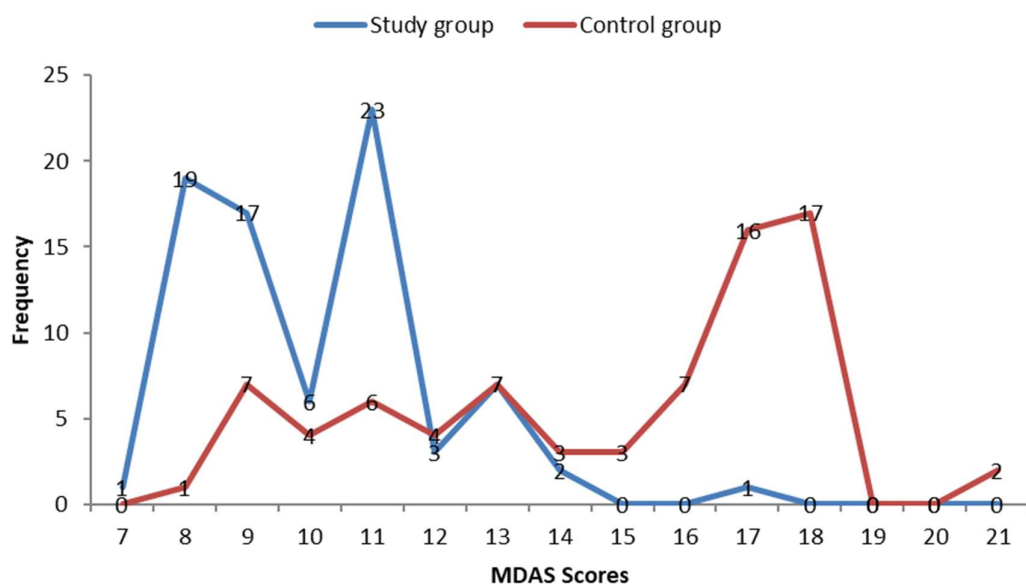


Figure 2: Comparison of MDAS scores by study and control groups

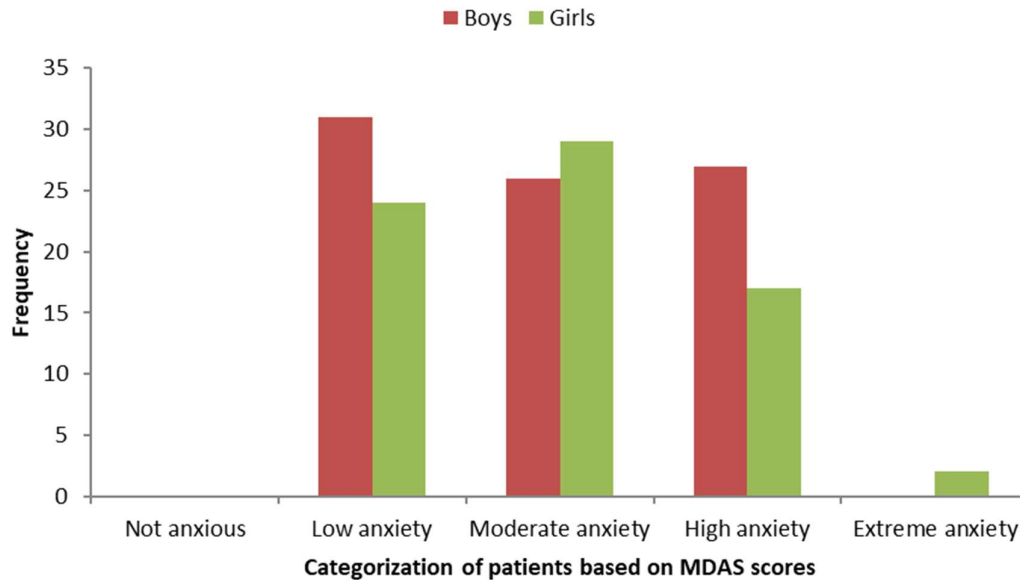


Figure 3: Comparison by gender using the categorized variables of MDAS scores

Table 4: Mean differences in subjective parameters between boys and girls

Gender	Group	MDAS (before) Mean \pm SD	P-value	MDAS (after) Mean \pm SD	P-value
Boys	CG	14.52 \pm 2.361	0.120	14.86 \pm 3.128	0.953
	SG	13.69 \pm 2.101		9.88 \pm 1.877	
Girls	CG	14.34 \pm 2.859	0.120	14.60 \pm 3.648	0.953
	SG	15.11 \pm 2.643		10.32 \pm 1.916	

*P < 0.05-statistically significant; Study group (SG); Control group (CG); MDAS – Modified Dental Anxiety Scale; WBFPS – Wong-Baker Pain Rating Scale; VAS – Visual Analogue Scale

DISCUSSION

Effect of virtual reality distraction on reducing dental anxiety levels

Several methods were chosen to assess dental anxiety both subjectively and physiologically among which were the MDAS as a subjective measure and pulse rate, systolic blood pressure, respiratory rate, SPO₂ and temperature. The physiologic parameters measured could also be used affected in the presence of pain. These values were taken before and after the administration of local anaesthesia. This study reported a statistically significant difference in the subjective measure of dental anxiety using the MDAS between the control and study groups. For the physiologic assessment of dental anxiety between the control and study groups before and after local anaesthesia administration, the pulse rate and respiratory rates were the only statistically significant measures recorded. Pulse rate is considered a valid and sensitive measure for the assessment of anxiety in adolescents during

various dental procedures; furthermore, the use of pulse rate to measure and detect changes in the degree of anxiety in adolescents during dental treatment, especially in the research of children's dental behaviour, is increasing (Jimeno et al., 2011). The use of virtual reality in alleviating dental anxiety among dentists is still relatively new as a recent study showed the inadequate level of knowledge and experience with its use (Orhue et al., 2020). Findings of this study revealed that VR was effective in reducing dental anxiety in adolescents during administration of local anaesthesia. This is comparable to a previous study where a simulation done by Tanja-Dijkstra et al, reported that the usage of VR as a distraction technique had the potential to influence the patient's perception of the anxiety-inducing procedure (Tanja-Dijkstra et al., 2014). Armfield et al. (2007) also concluded that the usage of VR alleviates anxiety by blocking the development of vivid memories.

Table 5: Multiple linear regression analysis for the prediction of pulse rate changes

Variable	Category	PR (Before*)	PR (After**)	PR difference (After – Before)
		$\beta \pm SE$ (95% CI) p-value	$\beta \pm SE$ (95% CI) p-value	$\beta \pm SE$ (95% CI) p-value
Age	10 – 13 years	0.001 \pm 0.01 (-0.01 to 0.02) 0.885	0.01 \pm 0.01 (-0.01 to 0.03) 0.305	0.01 \pm 0.01 (-0.01 to 0.02) 0.292
Gender	14 – 17 years	Reference	Reference	Reference
	Boys	-0.04 \pm 1.74 (-3.49 to 3.39) 0.978	-1.25 \pm 1.77 (-4.75 to 2.24) 0.478	-1.21 \pm 1.48 (-4.14 to 1.72) 0.417
Number of siblings	Girls	Reference	Reference	Reference
	0 – 3 siblings	-0.04 \pm 0.045 (-0.13 to 0.04) 0.300	0.02 \pm 0.04 (-0.06 to 0.12) 0.575	0.07 \pm 0.04 (-0.01 to 0.15) 0.061
Position in family	4 – 6 siblings	Reference	Reference	Reference
	1 st – 3 rd position	0.18 \pm 0.07 (0.03 to 0.34) 0.018***	-0.04 \pm 0.08 (-0.19 to 0.12) 0.601	-0.23 \pm 0.07 (-0.36 to -0.09) 0.001***
Class	4 th – 6 th position	Reference	Reference	Reference
	JSS1 – 3	-0.69 \pm 3.93 (-0.84 to 7.08) 0.860	2.05 \pm 4.01 (-5.86 to 9.96) 0.609	2.74 \pm 3.36 (-3.89 to 9.39) 0.415
Group	SS1 – 3	Reference	Reference	Reference
	Study group	-4.79 \pm 1.61 (-7.96 to -1.61) 0.003***	-7.18 \pm 1.63 (-10.41 to -3.97) <0.001***	2.39 \pm 1.37 (1.02 to 3.76) <0.001***
Site of procedure	Control group	Reference	Reference	Reference
	Mandible	-6.96 \pm 1.71 (-10.35 to -3.58) <0.001***	-4.94 \pm 1.74 (-8.38 to -1.49) 0.005***	2.02 \pm 1.46 (-0.86 to 4.91) 0.168
	Maxilla	Reference	Reference	Reference

*Before local anaesthetic administration, ** After local anaesthetic administration, *** Statistically significant

Dental anxiety can arise due to multiple factors such as previous negative experiences, exposure to frightening portrayals of dentists in the media and by relatives and peers, and the reclined position in a dental chair. Anxiety can also be provoked by triggers such as the sight of needles, sound of drilling and screaming, and various smells in the dental clinic. Some common fears giving rise to dental anxiety are fear of pain, blood-injury fears, fear of radiation exposure, fear of choking or gagging. Byrne et al identified four different groups of anxious patients based on their origin or source of fear (Roy-Byrne et al., 1994). They were anxious about specific dental stimuli, distrust of the dental personnel, generalized dental anxiety, and anxious about catastrophe. It was found that the more invasive types of stimuli were ranked as highly anxiety-provoking, whereas stimuli related to the dental office, the dental team, and their

equipment were found to be the least fear-provoking.

The study participants in the control group underwent administration of anaesthesia without the use of VR and the patients in the study group underwent the same with the use of VR. Statistically significant results were obtained for the study group after administration of local anaesthesia.

In the present study, we compared the VR distraction to a control and found that the use of VR distraction had a much added-benefit on PR and anxiety reduction, during infiltration and inferior alveolar nerve block anaesthesia when compared with the control without any form of distraction. Similar studies found a positive impact of VR distraction on anxiety (Aminabadi et al., 2011; Panda, 2017). A study by Aminabadi et al. (2011) showed a significant decrease in anxiety scores in

younger pediatric patients while being distracted using VR goggles.

In the case of pediatric dentistry, the anxiety-inducing appearance of the dental equipment and the continuous focus of the child on all the details of the procedure that is being carried out, are the most important reasons for stress associated with dental procedures in children. Therefore, the positive effects of VR distraction on the pain perceived by children in this study, are attributed to the complete blockage of children's visual fields by the VR device, and consequently, to a successful distraction technique.

The results of this study however differ from that of Sullivan et al. (2000) who found that the use of VR during dental treatment had no significant effect on the behaviour using the Frankl behaviour rating scale and anxiety using the Koppitz method, however, they reported that it significantly reduced the pulse rate on injection of local anaesthesia in children wearing VR glasses when compared to children without VR glasses (Sullivan et al., 2000). The difference in results could be due to the difference in the measuring scales used. A limitation of the Sullivan et al. (2000) study was the subjective interpretation of children's drawings by the examiners. The authors pointed out that there was a risk of over and under prediction by the examiners depending upon the cultural and developmental experiences and skills of the child. The significant decrease in pulse rate of the children on injection of local anaesthesia in that study does indicate lowering of anxiety in the children which is comparable to the findings in this study.

Effect of the Use of Virtual Reality Distraction on Pulse Rate

The results of our study showed that, although the subjects were randomly allocated, the mean PR in the study group was higher than in the control group just before local anaesthesia administration. This difference in mean values agrees with a previous study in which PR was higher among study participants when compared to participants in the control group (Calvert & Tan, 1994). The level of PR among the study group participants could be by chance and the fact that the participants were informed during tell-show-do that they were going to put on a headset during the procedure resulted in excitement as they had no previous exposure to VR devices.

Nevertheless, the mean levels of PR were significantly lower in the study group after the local anaesthesia procedure compared with the control group, the amount of change in PR from before to after time points was statistically significantly

different between the two groups. The regression analysis of PR change indicated that VR increased the change in PR. This indicates that VR caused a significant decrease in PR during local anaesthesia administration in comparison with no distraction used in the control group. These results are in agreement with two previous studies, which showed that PR decreased with the use of VR distraction, and their control group received treatment with no distraction just like this study (Hua et al., 2015; Kaur et al., 2015). Two recent meta-analyses showed conflicting results, that by Liu et al. showed that audiovisual distraction did not significantly change pulse rate (Liu et al., 2019), also that by Custodio et al. (2020) comparing virtual reality glasses to other distraction techniques during local anaesthesia administration revealed that there was no significant difference in pulse rates.

This study reported no statistical significance with the physiological parameters other than pulse rate and respiratory rate parameters used in assessing the effect of virtual reality on dental anxiety. Similar to this study, Khanapurkar et al. (2018) reported non-significance in SpO_2 before, during and after local anaesthetic injection. Also, Al-Khotani and colleagues reported no statistical significance in systolic and diastolic blood pressure between control and study groups in their study (Al-Khotani et al., 2016). Same result was observed with body temperature changes (Lauderdale, 2017). This finding is probably due to the shortness of the local anaesthesia procedure used in this study as it was completed under 7 minutes, thus not allowing enough time for significant changes in most of the physiological parameters. Another reason is the fact that the study participants were children whose physiological response to stress is still largely understudied.

Role of sociodemographic factors on dental anxiety levels

This study is in agreement with Chaves et al who also concluded that there were no significant changes between anxieties for both genders (Chaves et al., 2006). Although our study reported no relationship between age and dental anxiety, other studies have reported that dental anxiety decreases with increase in age (Liddell & Locker, 1997; Udoye et al., 2005; Egbor & Akpata, 2014). Participants with fewer siblings and those in 1st to 3rd position in family reported lower pain scores during local anaesthesia administration in this study.

CONCLUSION

In conclusion, children using Virtual Reality distraction had significantly lower dental anxiety levels during the administration of local anaesthesia. Comparatively, virtual reality had a significant impact on the study participants' level of dental anxiety when compared with the control group. Thus, virtual reality distraction can successfully reduce dental anxiety during short invasive dental treatment in 10 – 17-year-old adolescents.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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