Effect of Virtual Reality Distraction on Pain and Anxiety During Dental Treatment in 5 to 8 Year Old Children

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Objective: *This study was aimed at assessing the impact of Virtual Reality (VR) distraction technique on pain and anxiety in 5–8-year-old children, during short invasive dental procedures.* ***Study design:*** *120 children, aged 5–8 years, scoring less than 25 on the SCARED questionnaire, scheduled to undergo short invasive dental procedures, were randomly divided into a control (without VR distraction) and study group (with VR distraction) of 60 each. State anxiety levels were assessed in the children from both groups using revised version of Modified Child Dental Anxiety Scale, before and after dental treatment. Pain perceived during treatment was assessed using Wong Baker Faces pain rating scale at the end of treatment. Salivary cortisol levels were also assessed before, during and after the dental procedure, in all children.* ***Results****: We observed a significant reduction in pain perception and state anxiety in children, using VR distraction ($p<0.001$, $p=0.002$). The decrease in salivary cortisol levels was significantly greater in children using VR distraction ($p<0.001$).* ***Conclusion****: Virtual Reality distraction can be used as a successful behavior modification method in children undergoing short invasive dental treatments.*

Keywords*:* ***Pain perception, Salivary cortisol, anxiety, Virtual reality***

INTRODUCTION

Negative dental experiences, especially those resulting from dental pain, can lead to the development of fear and anxiety, which in turn can lead to the avoidance of further dental treatment.[1] Thus, the fear of painful dental treatments and dental anxiety are confounding problems with which dentists must cope up.[2, 3]

"Behavioral management and prevention coupled with local anesthetic techniques when required, form the basis for delivery of pain-free dentistry."[1] Among the numerous behavior management strategies that have been reported to reduce dental pain and anxiety during treatment in children, distraction appears to be a relatively safe and inexpensive method, shown to provide an effective and relaxed experience during short, painful dental procedures.[4]

The application of distraction assumes that "the perception of pain has a large psychological component."[5] Thus, it is reasonable to assume that as the person's attention is drawn away from a noxious stimulus, the perception of pain is also reduced.[6]

An ideal distractor requires "an optimal amount of attention involving multiple sensory modalities (visual, auditory, and kinesthetic) and active emotional involvement that ensures patient participation, to compete with signals from noxious stimuli."[7, 8]

Virtual Reality (VR) refers to "a human-computer interface that allows the user to interact dynamically with the virtual world, which is essentially a computer-generated environment." The application of virtual reality as a distraction technique could possibly be superior to traditional distraction techniques because "it offers more immersive images via the occlusive headsets that project the images right in front of the eyes of the user." Depending on the model of VR device used, it may block out the real-world (visual, auditory, or both) stimuli. However, a literature review revealed sparse investigations on the potential application of VR distraction in the pediatric dental setting.[6]

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Dental treatment is generally considered anxiety provoking and stressful,[9-11] yet, very few studies have assessed the physiologic stress induced by dental procedures.[12,13] It is widely accepted that psychological stress could produce physiological effects like those produced by physical challenges in a variety of physiological systems.[14] The activation of the hypothalamus-pituitary-adrenocortical axis (HPA axis) causes an elevation in cortisol secretion from the adrenal cortex.[15,16]

Salivary cortisol levels have been shown to relate closely with serum cortisol concentrations and reliably reflect the HPA activity.[17] In children, the estimation of salivary cortisol levels has emerged as a potential biological measure of stress-related activities.[18]

Salivary cortisol has also been used as an outcome measure by some investigators to evaluate the effectiveness of interventions.[14,19,20] To our knowledge, till date, no study has explored the effect of VR distraction technique on salivary cortisol levels in children undergoing invasive dental treatment. Therefore, in this study we sought to examine the effect of Virtual Reality distraction technique on pain and anxiety in 5 – 8-year-old children during short invasive dental treatment. Changes in salivary cortisol levels during the procedure were also evaluated, with and without the use of Virtual Reality distraction.

MATERIALS AND METHOD

120 healthy children aged 5 – 8 years (scoring less than 25 in the SCARED questionnaire), requiring short invasive dental treatment (vital pulp therapy) and reporting to the Department of Pedodontics and Preventive Dentistry, A.B. Shetty Memorial Institute of Dental Sciences were selected. We included an equal number of boys and girls. A written informed consent was obtained from the parents of all the participants. Ethical clearance was also obtained from the institution (ABSM/EC/78/2013).

Inclusion Criteria

Children within the age group of 5 – 8 years, and belonging to ASA categories I and II. Children with at least one asymptomatic deep carious lesion in the primary mandibular molars.

Exclusion Criteria

Children who had a predisposition for childhood anxiety disorders, screened at their first attendance using SCARED questionnaire. Children with a previous history of painful invasive medical or dental procedures, or a record of negative dental behavior. Children with a history of epilepsy. Children who needed to be sedated and/or managed under general anesthesia. Children on medications, including corticosteroids, that could interfere with cortisol secretion.

Children with trait anxiety were screened using the SCARED questionnaire to assess the predisposition of the children to childhood anxiety disorders.[6] The Screen for Child Anxiety Related Disorders (SCARED) questionnaire is a screening tool designed to evaluate the likelihood of trait anxiety in a child. The parent version of this questionnaire was used to screen the children. Scores 25 and above on this scale indicated the presence of childhood anxiety disorders. [6] Such children were then excluded from the study.

In our study, anxiety was assessed using the Faces version of the Modified Child Dental Anxiety Scale–revised [MCDAS(f)-r] questionnaire,[6] which was revised from the Faces version of Modified Child Dental Anxiety Scale [MCDAS(f)] by replacing the last 3 questions of the questionnaire with questions more relevant to our study. The Faces version of the Modified Child Dental Anxiety Scale – revised [MCDAS(f)-r], is a self-reported questionnaire designed to evaluate state anxiety in children. This scale uses pictorial representation to grade the level of anxiety on a 5-point scale for 8 questions related to dental procedures. The overall score on this questionnaire may range from a minimum of 8 to a maximum of 40, such that scores lesser than 19 indicate low anxiety and scores higher than 31 indicate severe dental anxiety or phobia.[6]

Pain perceived during treatment was assessed using the Wong Baker faces pain rating scale.[21] The Wong Baker Faces Pain Rating Scale is a simple, versatile tool that can be used to assess pain perception during dental procedures. It is essentially a visual analogue scale using pictorial representations for grading the intensity of pain perceived by the child patient, from 0 (indicating no pain) to 10 (worst pain imaginable) at multiples of 2.

Virtual Reality distraction was administered to the children in the study group using the VR device (i-glasses 920HR, Ilixco Inc., Menlo Park, CA, USA). The device consists of an eyeglass system that projects the desired images in front of the eyes of the child and had occluding eye-pads that blocked out his/her visual field from the dental environment. The device also had ear-phones to deliver sounds from the virtual environment, limiting the sounds from the dental operatory.

Salivary cortisol levels were measured using the Salivary Cortisol ELISA kit (K210S, XEMA Co., Ltd.)

Methodology

A single visit pulpotomy was the pulp therapy done for all the children in our study. Children reporting with asymptomatic deep carious lesions in the mandibular primary molars were selected. Intraoral clinical examination of the children revealed no evidence of swelling, abscess or fistula associated with the tooth and absence of mobility. Radiographically, the teeth were seen to be free of any periapical/inter-radicular radiolucencies, as well as pathologic root resorption and internal resorption. Teeth that had more than one third of the root length resorbed were excluded from the study. Following removal of the coronal pulp, only teeth which showed easy control of bleeding from the amputated pulp stumps after application of pressure pack (within 5 minutes) were included in this study.

All patients with first appointments, irrespective of their anxiety levels were included, as our main objective was to reduce dental anxiety during treatment. However, at this initial visit we performed a clinical examination including radiographic evaluation followed by an oral prophylaxis. The parents of the children were administered the parent version of the SCARED questionnaire and 120 children scoring less than 25 who fulfilled the inclusion criteria were included in our study. At the second and subsequent visit, the children were randomly and equally divided into the control (group 1) and study (group 2) with equal distribution of girls and boys in both groups.

The MCDAS(f)-r questionnaire for evaluating state anxiety was shown and explained to all the children and their pre-treatment anxiety levels recorded. The children were then prepared to receive the dental treatment.

Every attempt was made to allay the anxiety of the children belonging to group 1 (control group) during the dental treatment, using conventional behavior management techniques (such as non-medical conversation, Tell-Show-Do, conventional distraction, voice control etc.)

The children in group 2 (study group) received the VR device (i-glasses 920HR, Ilixco Inc., Menlo Park, CA, USA), which was to be worn during the dental treatment. It was introduced to the children using Tell-Show-Do technique. These children were given a choice of episodes from their favorite cartoon shows (like Tom and Jerry, Chhota Bheem, ShinChan and Ben 10) and were asked to view them in the dental operatory for 5 minutes, before start of the dental treatment. The children were then asked to relax and continue watching their favorite shows while the dental treatment was carried out. Once the dental treatment was completed, the eye-glasses were removed.

The children were administered topical anesthesia at the site of injection and inferior alveolar nerve blocks were given to all children. A single visit formocresol pulpotomy was done for all children to standardize the type of treatment. Treatment was completed within 40 minutes. The dental procedures were carried out by the same Pediatric dentist to minimize inter-operator bias.

At the end of treatment, the MCDAS(f)-r anxiety rating scale was again administered to all the children to record their state anxiety and the pain perceived was assessed using the Wong Baker faces pain rating scale.

Measurement of Salivary Cortisol levels

Unstimulated saliva samples were collected from all children in both the groups, at 3 intervals – 10 minutes before the start of the dental treatment, 20 minutes after the start of the treatment, and after completion of dental treatment. Pooled, whole saliva from under the front of the tongue was collected using sterile, 2-inch adsorbent dental cotton rolls and expressed into a vial.[22] The whole, unstimulated salivary samples thus obtained were then centrifuged and adequate amounts of the sample required for salivary cortisol estimation were stored, based on requirements of the Salivary Cortisol ELISA kit (K210S, XEMA Co., Ltd.) used.

All participants were asked to refrain from eating or drinking anything 30 minutes prior to sample collection (i.e., before start of the study), to limit alterations in salivary cortisol levels due to food and drinks.

Data analysis

Pre-treatment and post-treatment anxiety scores, pain scores, and pre, intra and post-treatment salivary cortisol level estimations were tabulated and descriptive statistics were computed. Test for normalcy was carried out for each variable using Shapiro-Wilk test. The comparison of the distribution of pre- and post-treatment anxiety scores of children between group 1 and group 2 was performed using McNemar test. The distribution and statistical comparison of pain score ratings of all children between group 1 and group 2, according to Wong-Baker faces pain rating scale, was done using Chi square test for trend. Further, the comparison between the median change in salivary cortisol levels from pre-treatment to intra-treatment, intra-treatment to post-treatment and from pre-treatment to post-treatment time intervals was done using Mann Whitney U test. All statistical analyses were carried out using the SPSS v20 software.

RESULTS

120 children aged 5-8 years, equally divided into two groups were evaluated in our study. In group 1(without VR distraction), the mean and median pre-treatment anxiety scores among children were 16.82 (3.80) and 17 (14, 19), while the mean and median post-treatment anxiety scores were 16.47 (3.48) and 16 (14, 18). Similarly, in group 2(with VR distraction), the mean and median pre-treatment anxiety scores among children were 16.18 (3.84) and 15 (14, 17.75), while the mean and median post-treatment anxiety scores were 11.28 (3.51) and 10.5 (9, 13).

We further distributed and compared the anxiety scores of all children according to the severity of anxiety into three groups: <19, 19 – 31, and >31. In group 1, 6.7% reported an increase in the anxiety scores, from a score less than 19 (pre-treatment) to a score in 19-31 range (post-treatment), while 18.3% reported a decrease in anxiety scores, from a score in the range of 19-31 (pre-treatment) to a score less than 19 (post-treatment). A comparison of this distribution revealed no statistically significant difference (p=0.12) [Table 1].

Meanwhile, in group 2, 19.0% reported a decrease in the severity of anxiety, from a score in the range of 19-31 (pre-treatment) to a score less than 19 (post-treatment). We found no child reporting an increase in anxiety from pre- to post-treatment. A comparison of the distribution in anxiety scores revealed a statistically significant difference in group 2 (p<0.002) [Table 1].

Table 1: The comparison of the distribution of pre- and post-treatment anxiety scores of children between group 1 and group 2.

	Pre -Anxiety	Post -Anxiety		Total	Mc Nemar test
		<19	19-31		p-value
Group 1	<19	36 (60.0%)	4 (6.7%)	40 (66.7%)	0.12 (NS)
	19-31	11 (18.3%)	9 (15.0%)	20 (33.3%)	
	Total	47 (78.3%)	13 (21.7%)	60 (100.0%)	
Group 2	<19	45 (77.6%)	0	45 (77.6%)	0.002
	19-31	11 (19.0%)	2 (3.4%)	13 (22.4%)	
	Total	56 (96.6%)	2 (3.4%)	58 (100.0%)	

<19 – no state anxiety, 19-31 – low/mild state anxiety, >31 – phobic/severe state anxiety

p-value: >0.05 Not significant

In group 1, the mean and median pain scores obtained were 5.6 (1.22) and 6 (4, 6), while the mean and median pain scores obtained by the children in group 2 were 2.42 (1.47) and 2 (0.5, 2), respectively.

We further distributed and compared the pain perception of all children according to the scores from Wong Bakers Faces pain rating scale. A general trend towards reporting lower pain scores was observed in group 2. When comparison of this trend was carried out between group 1 and group 2, a statistically significant difference was obtained (p<0.001) [Table 2].

Table 2: The distribution of pain scores of all children according to Wong-Baker FACES pain rating scale (0 to 10).

Pain Score	Group 1	Group 2	Chi-square test (for trend)	p-value
Score 0	**0 (0.0)**	**14 (24.1)**	**67.79**	**≤0.001**
Score 2	**1 (1.7)**	**30 (51.7)**		
Score 4	**26 (43.3)**	**13 (22.4)**		
Score 6	**30 (50.0)**	**1 (1.7)**		
Score 8	**3 (5.0)**	**0 (0.0)**		
Score 10	**0 (0.0)**	**0 (0.0)**		

p-value: >0.05 Not Significant

In group 1, the mean pre-treatment, intra-treatment and post-treatment salivary cortisol levels were 78.35 (14.13) ng/ml, 70.72 (13.65) ng/ml and 62.13 (13.83) ng/ml, respectively. Similarly, the mean pre-treatment, intra-treatment, and post-treatment salivary cortisol levels in group 2 were 83.45 (12.03) ng/ml, 68.45 (13.03) ng/ml and 62.55 (13.28) ng/ml, respectively [Graph 1]. Statistically significant differences were seen between these values at all time intervals (p<0.001) [Graph 1].

Graph 1: Depicts the comparison between mean salivary cortisol levels (ng/ml) at the three time intervals within groups 1 and 2.

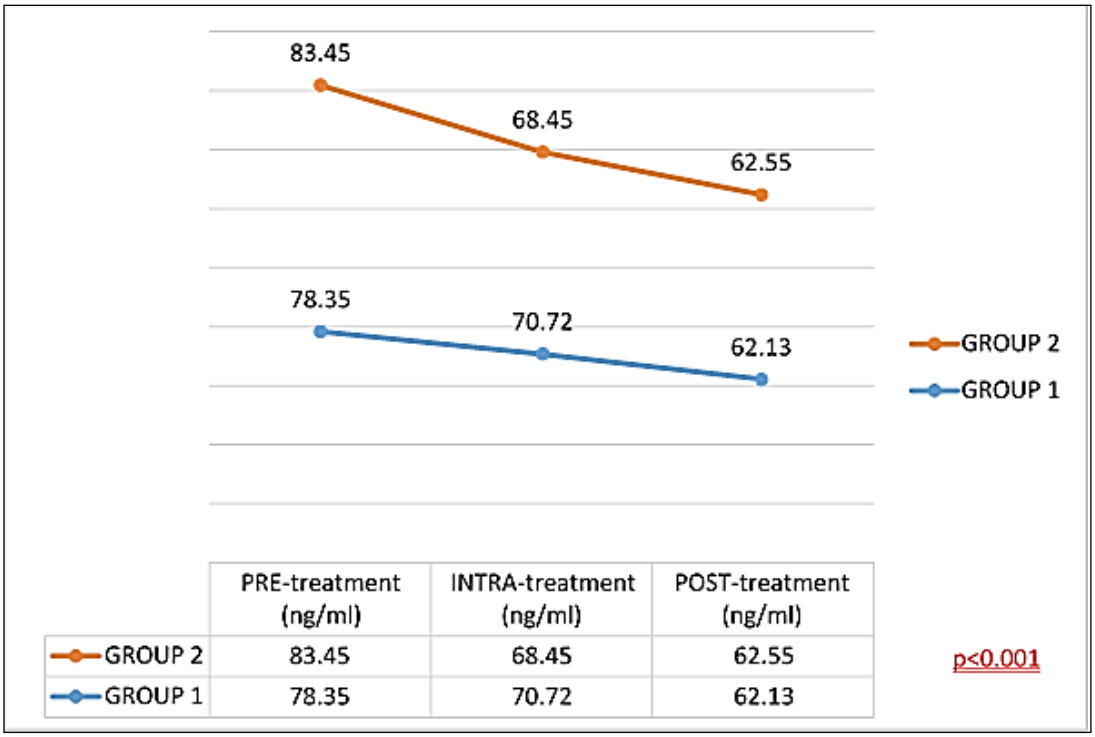

Table 3: Inter-group comparison of the change in salivary cortisol levels between the two groups at the different and corresponding time intervals.

Cortisol	Groups	N	Median (Q1-Q3)	U	p-value
Pre – Intra	1	60	7 ng/ml (5.25, 9.25)	500.50	≤0.001*
	2	58	15 ng/ml (11.00, 20.75)		
Intra – Post	1	60	7 ng/ml (5.00, 12.00)	2334.50	0.001*
	2	58	6 ng/ml (4.25, 7.00)		
Pre – Post	1	60	16 ng/ml (11.00, 20.00)	990.00	≤0.001*
	2	58	20 ng/ml (16.25, 26.00)		

P value : > 0.05 Not significant

We further compared the median change in salivary cortisol levels from pre-treatment to 20 minutes after start of treatment (intra-treatment), from intra-treatment to post-treatment, and the overall median change from pre-treatment to post-treatment, between group 1 and group 2. On comparison of these values, we observed statistically significant differences between the two groups at each of the different and corresponding time intervals (p<0.001) [Table 3]

DISCUSSION

In the past, major focus around patient pain and anxiety management was centered on pharmacological treatments, whereas the literature published during the last decade has increasingly focused on non-pharmacological techniques. One cognitive behavioral strategy is called distraction – a technique based on the notion of a human's limited capacity for attention. Distraction techniques range from passive to active interventions, with the belief that the more interactive the distraction technique, involving visual, auditory and tactile stimuli, the greater the potential for distraction from pain.[23] In recent years, virtual reality has become popular in clinical research studies as an innovative distraction technique.

The presence of trait anxiety, which is related to the personality and temperament of a child, was assessed in our study using the SCARED questionnaire, to screen those children who had a predilection for childhood anxiety disorders, during their initial examination. This was done to limit the confounding affect that a child's anxious personality trait might have over dental anxiety. It was also suggested by Dahlquist *et al* [24], that patients with higher levels of anxiety may not respond well to distraction techniques. In our study, we excluded children with a previous history of painful invasive medical or dental procedures since we did not want any child influenced by those experiences, which could have had an impact on their future behavior.

In our study, we observed that although children of both groups demonstrated lower anxiety scores post-treatment, results revealed that children in group 2 obtained significantly lower anxiety scores when compared to the children in group 1, which clearly demonstrates the effectiveness of VR distraction in reducing anxiety in 5–8-year-old children during short invasive dental treatment. ($p=0.002$ Table 1)

These results are in accordance with Aminabadi *et al* [6], where the authors showed that the use of VR distraction was effective in reducing state anxiety during routine dental treatment in children without any anxiety disorders. However; our results are not consistent with those of Sullivan *et al* [25], where they concluded that VR had no significant effect on the behavior or anxiety of children. We observed that only 2 children were not comfortable with the V R distraction which warranted removal of the device in our study. These children were subsequently excluded from the study.

With regards to pain perception, we observed that the children using VR distraction reported significantly decreased pain perception during the short invasive dental treatment ($p<0.001$ Table 2). This is in accordance with various studies done previously, wherein similar results were observed in children as well as adults.[5, 6, 26]

Our review of literature has revealed that the use of VR distraction has been associated with decreased stress levels in many subjects, in various studies.[4-6,] Even though previous studies have assessed the effect of virtual reality distraction on pain and anxiety during dental treatment in children, very little is known about changes in cortisol levels. Many publications have stated that salivary cortisol is an accurate measure of adreno-cortical function indicating the level of stress.[9,12,13,19,20] Our study evaluated the children's physiologic response to stress during short invasive dental treatment using salivary cortisol levels.

Measurement of salivary cortisol in pediatric age groups is feasible and advantageous as saliva can be collected easily and non-invasively, eliminating stress due to invasive sample collection methods.[14, 22] A potential disadvantage with using salivary cortisol is that invasive dental procedures could result in blood contamination of saliva samples, giving falsely elevated salivary cortisol values. Therefore, children undergoing dental extraction were excluded from this study, thus limiting the possibility of blood contamination from open extraction sites.

In our study, we observed that cortisol levels, in group 1, were highest at the start of treatment, then showed a steady but significant decline up to the end of treatment ($p<0.001$, Graph 1). The results of our study were consistent with the data from Miller *et al* [20], who found a decline in cortisol levels from beginning of treatment, for patients undergoing an examination, root canal and restorative procedure till the end of treatment. They found that cortisol levels decreased by 16%, 17% and 12% from the initial reading to completion of procedure.

Mean salivary cortisol levels in group 2 with VR distraction revealed that these children experienced a similar significant decline in cortisol levels ($p<0.001$, Graph 1). However, we observed that the changes in salivary cortisol levels from the start to end of treatment in both groups did not follow a 'normal-curve' distribution. Thus, we decided to use the median change in salivary cortisol levels for inter-group comparisons. We observed that the median of the overall decrease in salivary cortisol levels in group 2 was significantly greater from start of treatment to end of treatment ($p<0.001$, Table 3).

The marked decrease in salivary cortisol levels in the children using VR distraction further reinforces the effectiveness of the device in reducing stress in the children. We observed that, in children using the VR device, even when LA was administered, they barely showed any discomfort except for a few children who moved a little.

A limitation of the present study was that although the VR device provided the children with a novel experience, many children reported that certain sounds from the dental operatory were audible, at times. This might have resulted in suboptimal reduction in anxiety levels and stress in the children.

Wismeijer *et al* [5], in their review described "simulator sickness" as the result of proximity and lower quality images projected through the VR device. This is expected to cause nausea in sensitive individuals. While none of the children using the VR device reported nausea in our study, the incidence of headaches in few children indicates that VR distraction devices of better and higher quality are required for clinical use during prolonged dental procedures. In our study, we have included children of 5 – 8 years of age. However, since different age groups exhibit different cognitive characteristics and behavioral patterns, it is recommended that different age groups be evaluated in future studies.

CONCLUSION

The results of our study showed no significant decrease in state anxiety in children for whom conventional behavior modification techniques were used whereas a significant decrease in state anxiety was observed in children using Virtual Reality distraction technique. At the end of treatment, children using Virtual Reality distraction reported significantly lower pain perception than children in whom conventional behavior modification techniques were used. We also observed a significant decrease in salivary cortisol levels, in all children, at the end of treatment. However, the decrease in salivary cortisol was significantly greater in children using Virtual Reality distraction. Thus, Virtual Reality distraction can successfully reduce pain and anxiety during short invasive dental treatment in 5 – 8-year-old children.

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