Immersive and Non-Immersive Virtual Reality Distraction on Pain Perception to Intraoral Injections

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Objective: *To evaluate the efficacy of immersive VR (IVR) and non-immersive VR (NIVR) distraction on perceived pain during intraoral injections in children undergoing dental procedures. The objective was to introduce 3-dimensional nature of virtual reality during the provoking phase of dental treatment as a means of distraction in children.* ***Study design:*** *A total of 200 children were selected for the study, 100 for IVR group and 100 for NIVR group. After randomization, children were introduced to Oculus Go Standalone equipment; MCDAS (f), VAS, WBFRS and the treatment procedure using tell show do technique. Group I children were introduced to oculus go standalone headset with hand held controller to play temple run or roller coaster game while in group II, children watched cartoon movies of their choice. Pre-operative & post-operative MCDAS scores were obtained using MCDAS (f) questionnaire in local language. Post-operatively, VAS and WBFRS scores were also obtained. The data was analyzed using independent t-test and chi-square analysis.* ***Results:*** *Pre-operatively, the mean MCDAS scores were similar in both the groups viz. Group–I (29.20 ± 3.197) and Group–II (29.09 ± 3.803) and is statistically not significant. Post-operatively, the mean MCDAS scores were higher in non-immersive group (20.72 ± 2.822) as compared to immersive group (10.99 ± 2.227). VAS score was higher in non-immersive group (2.72 ± 0.99) as compared to immersive group (0.75 ± 0.88). WBFRS scores were higher in non-immersive group (2.78 ± 1.097) as compared to immersive group (0.82 ± 1.104).* ***Conclusion:*** *Three-dimensional virtual reality was found to be an effective means of distraction in children undergoing dental procedures and especially during the provoking phase. The significant difference obtained clearly indicates irrespective of immersiveness of virtual reality, anxiety had been decreased and on comparison the pain perception to intraoral injection is less in immersive virtual reality environment. Immersive VR distraction technique can serve as an adjunct to traditional behavior management strategies already available to the pediatric dentist.*

Keywords: *Anxiety, distraction, immersiveness, injection, oculus go, pain perception, virtual reality*

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INTRODUCTION

The pediatric dentist's cardinal priority while delivering care is to mitigate pain and discomfort while encouraging good dental health. An early, disastrous injection experience can create anxiety that can render the subsequent injection episode even worse, leading to a revolving loop of children's heightened anxiety, fear as well as pain. A second explanation for this is that children might not be prepared to deal with the discomfort or pain caused by injections.

Modulating the pain perception and affective agitation by the act of diverting focus /concentration from the nociceptive signals are pivotal factors of these approaches.[1] McCaul &Mallot's[2] cognitive affective attention model states that patient perception to pain decreases when there is distraction from stimulus. Attention towards pain increases the pain experience, whereas distraction reduces it.[3] The gate control theory postulated by Melzack and Wall[4] validates that CNS actions (e.g., attention, emotion, memory) play a pivotal role in sensory perception. Therefore, attention diversion was used to change interpersonal ideas by adding delightful mental images

and requiring attempts to solve problems. Distraction is, according to McCaffery *et al* [5], a kind of sensory shielding in which one is exempted from perception of the pain by focusing solely on and increasing the insight of stimuli unrelated to the pain.

Various existing ways of distraction have been used to modify pain perception with single sensory to multiple sensory modalities such as music[6], model presentation[7], tell show do[8], verbal communication[9] and visual media[10]. Visual provocation may involve the implementation of the video games, portable television, personal computers with CD-ROM and virtual reality systems (VR). VR is a non-invasive simulation masquerade that helps a viewer to converse with an environment which is computer generated [11], in the three dimensions (depth, height and width). It combines the audio-visual and kinaesthetic sensory modalities. It uses wide field view of head mounted device (HMD), three dimensional displays and motion sensing systems that assess the position of user's head and hand. It can be immersive or non-immersive.[12] The non-immersive VR (NIVR) environment corresponds to the slightest intrusive system of VR strategies in which in 2-dimensional interface system can communicate with the VR environment without fully immersing into the domain.[13] It is considered immersive when the amet is contemplated through a HMD device to generate the thought that person is usually within the environment and allows interaction which is 3-dimensional in nature.

The reliability of diversion strategy is attributed along with the standard of VR immersiveness, which solely relies on VR experiences and equipment. The results of the study by Furman et al [14] indicate that interactive virtual reality (IVR) is more effective than watching a movie (non-immersive) as a form of pain management during scaling and root preparation procedures. IVR produces an enthrallment that enables virtual component and digital pictures to feel legitimate even though a virtual scenario in the actual realm is unlikely.[15] Although diversion from non-immersive virtual reality (NIVR) proven to be effective in mitigating childhood dental anxiety in children, IVR remains an unexplored arena. There is less evidence regarding the efficacy of immersive VR in paediatric dentistry and there is no study available in the literature comparing IVR and NIVR. The current study was undertaken to evaluate the efficacy of IVR and NIVR on pain perception to intra oral injections in children undergoing dental procedures and the objective was to introduce 3-dimensional nature of virtual reality during the provoking phase of dental treatment as a means of distraction in children.

MATERIALS AND METHOD

The institutional ethics committee reviewed the study protocol and gave its approval vide Ref. No. TMDCRC/IEC/18-19/PPD2 dated 22/1/2019. Prior to the beginning of this study, legally accountable person or parents of the sorted-out participants gathered were educated about the risks, benefits, and alternatives of a given procedure or intervention and inscribed a notified consent form, allowing their children to participate in the study. A minimum of 192 children (96 for each group) were required to the estimate mean difference in pain score between two groups by 0.41 with S.D of 01.12 at 95% confidence and 80% power with one sided test.

Inclusion criteria [16]

Two hundred healthy children of 6–12-year-old and graded under the standard of American society of anaesthesiologist's physical status 'I', classified under Frankel's class III or IV behaviour ratings, requiring local anaesthesia (infiltration/block) for various dental procedures and had the ability to recognize the study priorities as well as could bring forth informed consent were included in the study.

Exclusion criteria [17,18]

Children whose parents were not willing to give consent to the study; patients having significant behavioral problems; memoir of phobia or irksome dental episodes kindered to dental or medical environment; children with visual or auditory defects; conditions such as dementia, epilepsy and other neurological problems which may hinder the use of VR equipment; sensitivity to the motion or flash light or having accidents in the eyes, face, neck, or arms that prohibit the efficient usage of VR were excluded.

All the participants were randomly apportioned to one of the two groups i.e., Group I- Immersive VR [Oculus Go Stand Alone headset with controller (Facebook technologies, LLC, California, U.S.A)] and Group II–Non-immersive VR group [Oculus Go Stand Alone headset only. (Facebook technologies, LLC, California, U.S.A)] (Figure – 1{A}). The randomization proceedings for the current study was accomplished by the children sorting one of the two colored balls out of an opaque bag which carry the name of method (i.e. either head set VR with hand held controller or with only head set VR) on the day of procedure with an allocation ratio of 1:1.The recruited children in both the groups were introduced to the VR device (Oculus Go) using tell show do technique and also be familiarized with the MCDAS (f) Questionnaire[19] i.e., Modified Child dental anxiety scale (Faces version), Visual analog scale[20], WBFPRS i.e., Wong Baker Faces Pain Rating Scale[21] and treatment procedures including intraoral injections. The MCDAS (f) questionnaire used here was translated into local language. Patient's anxiety level was assessed pre-operatively using MCDAS (f) in both groups.

Group I (Immersive VR environment group)

(Figure – 1{B})

During immersive VR intervention, children were allowed to play a videogame of their choice with the hand-held controller. Most of the children played temple run and roller coaster games. The controller is the orientation-tracked input device for the Oculus Go.[22] Using the controller, the patients were able to explore the VR world by controlling the direction and gaze of the avatar in an immersive, 3-dimensional, 360-degree interactive environment.

Group II (Non-immersive VR environment group)

(Figure – 1{C})

During non-immersive VR intervention, children were given a choice of five cartoon movies (adventure /super-hero and princess stories).

All the participants were given a few minutes to get accustomed to the VR headset/controller prior to the beginning of the treatment. Then topical anesthetic gel (Lidocaine Topical Aerosol USP 15%w/w, Nummit Spray, ICPA Health Products, Mumbai) was placed at the injection site for 1 minute. After successful negative aspiration, injectable local anesthesia (Lignocaine with

Fig. 1 **A- Oculus Go Standalone device (Head mounted virtual reality device with hand controller)**

B- Administration of local anesthesia in a patient playing Temple run game using Oculus Go Standalone device

C- Administration of local anesthesia in patient watching movie of her choice i.e., Barbie using Oculus Go Standalone device

2% Adrenaline, W.I. Remedies Limited, India) was administered, progressively throughout a stretch mostly of one minute for the nerve block. For infiltration technique the time period was stretched to only 25-30 seconds. After deposition of the solution, the needle was then removed slowly.

Immediately after the local anesthesia injection, study staff retrieved the VR equipment and the child's perception to pain was assessed using Visual Analog Scale, Wong Baker Faces Pain Rating Scale (by patient), and anxiety was assessed using MCDAS (f). The faces version of the Modified Child Dental Anxiety Scale (MCDAS (f)) was structured by the addition of the animated cartoon confronts rating scale to the original numerical format already available. Dental anxiety score was obtained by asking the children directly about their anxiety with the assistance of rating scale of scoring. The precedence of maneuvering this semblance of self is that it is somewhat less time consuming and convenient to implement. As required, various dental procedures such as pulp therapies, full coverage restorations, extractions etc. were then accomplished. Between the patients, the device/equipment was cleaned/disinfected as per manufacturer's instruction.

Statistical analysis

The data was analyzed using Statistical package for social sciences software (SPSS, IBM Corporation, USA) version "22". To compute the age difference, 'Independent t- test' was employed and chi-square test was utilized to ascertain gender discrepancy between the two groups. The pre and post MCDAS scores between the groups was analyzed using independent t- test and within the group paired t-test was utilized. Independent t-test was also used for the comparison of post-operative Visual analog scale (VAS) score and Wong-Baker faces pain rating scale between the groups. The level of significance was predetermined at p-value ≤ 0.05.

RESULTS

The comparison of mean age between the groups is shown in Table –1 and no difference was observed. Table–2 shows gender distribution and chi-square analysis showed no statistically significant difference. Table – 3 shows comparison of pre-operative and post-operative MCDAS scores between the groups. Pre-operatively, the mean MCDAS scores were similar in both the groups viz. Group–I (29.20 ± 3.197) and Group–II (29.09 ± 3.803). Post-operatively, the mean MCDAS scores were higher in non-immersive group (20.72 ± 2.822) as compared to immersive group (10.99 ± 2.227). The independent "t" test manifested no statistically tangible difference with respect to pre-operative MCDAS scores (p =>0.05), whereas there had been a substantial statistical disparity observed with respect to post-operative MCDAS scores (p=0.00) indicating the efficacy of IVR in mitigating the levels of anxiety.

Table–4 shows the comparison of post-operative mean VAS scores and WBFPRS scores between the groups. Post-operatively, VAS score was higher in non-immersive group (2.72 ± 0.99) as

Table 1: Comparison of the mean age between the groups (Result of independent "t" test)

Groups	Minimum	Maximum	Mean	Std. Deviation	Mean diff	p value
Group I (Immersive) n =100	6	12	8.55	1.898		
Group II (Non-Immersive) n=100	6	12	8.66	1.843	-0.11	0.67 (N.S)

N.S- Not significant

Table 2: Gender-wise distribution and comparison between the groups (Result of Chi square analysis)

		Group I (Immersive)	Group II (Non-Immersive)	
Females	Count	49	50	99
	Percent	24.5%	25.0%	49.5%
Males	Count	51	50	101
	Percent	25.5%	25.0%	50.5%
Total	Count	100	100	200
	Percent	50.0%	50.0%	100.0%

Chi-square value- 0.02

p value- 0.88 (N.S) N.S- Not significant

compared to non-immersive group (0.75 ± 0.88). Independent "t" test showed statistically significant divergence with respect to post-operative VAS scores (p=0.00).Post-operatively, WBFRS scores were higher in non-immersive group (2.78 ± 1.097) as compared to immersive group (0.82 ± 1.104). Independent "t" test manifested statistically consequential difference with respect to post-operative WBFPRS scores (p=0.00). This table also shows the efficacy of immersive VR in reducing the pain perception to injections when compared to non-immersive VR. Table–5 shows the comparison of pre-operative and post-operative mean MCDAS scores within the groups. In Immersive group, the mean pre-operative scores were higher (29.09 ± 3.803) as compared to post-operative scores (10.99 ± 2.227). Similarly, in non-immersive group, pre-operative scores were higher (29.20 ± 3.197) as compared to post-operative score (20.72 ± 2.822). Paired "t" test proclaimed statistically remarkable variance with respect to both scores (pre-op and post-op) score in immersive group (p=0.00) and the non-immersive group (p< 0.05).

Both immersive and non-immersive VR distraction were proclaimed to be effectual in mitigating pain perception to injection in children who underwent various dental procedures, but immersive VR environment was found to better when compared to non-immersive VR environment and the difference was statistically significant.

DISCUSSION

Diversionary tactic is a feasible approach of deflecting the attentiveness of the individual from what had been considered as an vexatious stratagem.[23]The objectives of distraction are to decrease the perception of unpleasantness and avert negative or avoidance behavior.[8] Hoffman *et al*,[24] collated the analgesic efficacy of virtual reality and opioids. They found that virtual reality or opioid alone decreases the pain score however when opioid and VR combined together, the mitigated pain is exponentially significant. This study explored the effectiveness of virtual reality as a potential method of distraction. Secondarily there is no research regarding the immersiveness of Oculus Go Standalone virtual reality device. Dahlquist *et al* [25] stated that, while both were effective, interactive distraction is exponentially better than passive distraction. They culminated in their study that games not merely invigorate visual and auditory sensations, but could also provoke tangible and kinesthetic agitations as the frolics are played, thusly, upsurge the attentional requisition, which is compliant with the "khaneman's theory attention i.e., capacity theories of attention"[25].

When an individual donned a "Head Mounted Display" that further obstructs their vision of unfeigned environment, ersatz the visual images/ figure and the sound effects which were computer generated. "Stereoscopic or monoscopic views" are used , that further provides divergent degrees pertaining to domain of vision.[15] VR might

Table 3: Comparison of mean pre-operative and post-operative MCDAS scores between the groups (Result of independent sample "t" test)

		Minimum	Maximum	Mean	Std. Deviation	Mean diff	p value
Pre-op	Group I (Immersive)	15	34	29.09	3.803	-0.11	0.82 (N.S)
	Group II (Non-Immersive)	18	34	29.20	3.197		
Post-op	Group I Immersive	7	18	10.99	2.227	-9.73	0.00*
	Group II (Non-Immersive)	12	25	20.72	2.822		

Table 4: Comparison of post-operative VAS and WBFRS scores between the groups (Result of independent sample 't' test)

		Minimum	Maximum	Mean	Std. Deviation	Mean diff	p value
VAS	Group I (Immersive)	0	5	.75	.880	-1.97	0.00*
	Group II (Non-Immersive)	0	4	2.72	.996		
WBFRS	Group I (Immersive)	0	4	.82	1.104	-1.96	0.00*
	Group II (Non-Immersive)	0	4	2.78	1.097		

*significant

Table 5: Comparison of mean pre-operative and post-operative MCDAS scores within the groups. (Result of independent sample "t" test)

		Minimum	Maximum	Mean	Std. Deviation	Mean diff	p value
Group I (Immersive)	Pre-operative MCDAS score	15	34	29.09	3.803	18.1	0.00*
	Post-operative MCDAS score	7	18	10.99	2.227		
Group II (Non-Immersive)	Pre-operative MCDAS score	18	34	29.20	3.197	8.48	0.00*
	Post-operative MCDAS score	12	25	20.72	2.822		

*significant

be also engaged towards the innate ability of an individual to "escape" from agonizing circumstances.[26] The brain is so pre-tenanted with concocting lore conferred through the virtual reality, that the individual has diminished heed accessible to interpret received pain signals.[26] Young children retaliate subliminally and moralistically to perceptible pertinent and mesmeric means for instance IVR in mechanism that is different from the adults.

Sharar *et al* [27] maneuvered a HMD (i.e., head mounted device) and had unearthed that children of the age sixteen to eighteen years of age delineated exorbitant extent of "pervasiveness and realness" of a ostensible environs when correlated with adults of the age group of nineteen to sixty-five years. Ingersoll *et al* [28] obtained 44% reduction in uncooperative behavior after the contingent (i.e.,reinforcement) in but did not find any significant differences when it was used as distraction. Sullivan *et al* [29] found no significant difference on behavior or anxiety viewing of cartoon film when virtual reality eyeglasses were used in children undergoing restorative procedure. The Oculus Go equipment looks bulkier as shown and this VR device was utilized only for injection purpose. After administration of local anesthesia, the device was retrieved and was not *in situ* while delivering the intended treatment procedure. In the current study, statistically significant difference in post-operative MCDAS (f) scores was observed between immersive VR and non-immersive VR i.e. 10.99 ± 2.227 and 20.72 ± 2.822 (Table -5). The reason could be in IVR there is more space towards enhanced appearance and authenticity.[15] Even in non-immersive environments, the young children may interpret dossier through a pragmatic persona that has been implicitly reliant and they served the virtuous personae as a living being, furthermore vindicates that ethos personae could discern them.[30]

The leverage point of this study is the use of different device and techniques we employed. Oculus Go standalone along with controller avoid the use of mobile phone, headphone as in other VR devices. Avoidance of headphone makes the child to hear operator instructions such as opening or closing the mouth. The VR games like temple run and roller coaster in Oculus Go doesn't encourage head and body movement as observed in this study since children are so much occupied in completing the task presented to them while using this VR device. In this study we haven't experienced any unwanted head movement while working with this device and all children readily accepted wearing it. We highlight that the children were very much into this device irrespective of immersive/non-immersive nature of this equipment. The Oculus Go equipment used in this study is different from the devices that are already existing in the literature. It works even without internet services, thus can be used as distraction device even in remote locations as it doesn't require internet connectivity after installation of the required content. Secondarily, for most of the children it is unique that had made them anxious to know the device thus for time being the child is diverted from the surrounding environment. In this study, the patient chose the choice of distraction i.e., to watch movie (non-immersive) according to Klein and Winklestein [31]and Prabhakar *et al.* [32] This will provide assistance to the child to further procure distressful provocation and this may indulge a sense/ perception of these amicable in environs.[31]

Based on the observations of this study, when a videogame is played by an individual and is exhibited through a VR helmet which further reckons receptive interception directed towards the multi-sensorial rendezvouses ingrained to videogames. Ram *et al* [33] and Aminabadi *et al* [16] evaluated audio-visual eye glasses during local anesthesia administration and various dental procedures. They found iPad being the active distraction technique more effective than audio visual eye glasses. Van Twillert *et al* [34] in a randomized control trial found that both virtual reality and television showed significant pain reduction in burn patient, however VR manifests added upshot on pain and is not consequential but in the present study IVR showed significant decrease in pain perception and the reason being the precedence of virtual reality immersiveness and that reckon on the standard of the VR encounter, and the aspect of the VR gadget. Hoffman *et al* [35]concluded that a better-quality VR helmet would be more effective in mitigating discomfort than a lower quality VR helmet.

In a study done by Bensten *et al*,[36] the severity of pain and unpleasantness was rated by patients on VAS after the preparation of the cavity and found no statistically significant effect on the perceived pain ($p=0.90$). In the current study post-operatively VAS score was higher in non-immersive group (2.72 ± 0.99) than immersive group (0.75 ± 0.88). The precedence of MCDAS (f) self-appraised compute requires minimum amount of time and is easy to implement.[37] The questions should indeed be interpreted distinctly and the children's of as old as 3 year perchance to the prong with the suitable faces expressions on the caliber to show their level of anxiety.[38] The questionnaire; by older children i.e. 8 years or more than that are proficient in completing it without any support.[37] In addition, for the children of the age five to twelve years and the one with cognitive functioning the MCDAS(f) is more flexible to be maneuvered to ascend dental anxiety across a broader range .[39]The translated MCDAS (f) questionnaire in local language helped in obtaining unbiased data from children.

This study has some limitations first, although we have compared results between the immersive (IVR) and non-immersive (NIVR) on perceived pain but we were left with the time taken for immersiveness and gender dependent comparison. Secondly, comparison of the patient education, social status to pain perception after wearing VR. The size/bulkiness of this device may be a matter of concern and future studies can be directed with varying sizes available in the market / convincing the manufacturers of such devices to reduce the bulkiness so that it can be applicable for all age groups. This study is one of its kind as per our belief in comparing the immersiveness/non-immersiveness nature of virtual reality in clinical Pediatric Dentistry. However, none of the patients in this study reported cyber sickness such as headache, motion sickness, dizziness, nausea and other visual abnormalities and is mostly because of this device is light with short reaction time to help in perverting symptoms like cyber sickness. The main aim of VR device is to block out the visual and auditory stimuli so that the child focuses on the virtual world and his/her attention is diverted from the most provoking phase of dental procedure i.e., during injection. Patients were sensitized regarding this device pre-operatively and definitely eye contact will be lost during the important phase of dental treatment especially in children but it comes with an added advantage of achieving painless anesthesia as observed in this study. Like all VR devices having this disadvantage, to prevent loss of eye contact during this phase also, we suggest the introduction of see through glasses along with display/presentation of VR environment and at the same time maintaining eye contact by the pediatric dentist. Keeping in mind cyber sickness and duration, gender related VR immersiveness, future studies should be planned. Based on the observations of this study, Immersive VR is better than non-immersive VR in both reducing perceived pain and anxiety and the difference is statistically significant.

CONCLUSIONS

The conclusions drawn from the present study are:

1. Three-dimensional virtual reality was found to be a means of distraction in children undergoing dental procedures and especially during the provoking phase.
2. Both IVR and NIVR types of VR were effective in mitigating the perceived pain in children during intraoral injections.
3. In comparison, immersive VR was more effective than non-immersive VR and the difference is statistically significant.
4. To conclude, immersive VR distraction technique can serve as an adjunct to traditional behaviour management strategies already available to the paediatric dentist.

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