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Original Research Article

Effect of a Dental Simulation Game on Reducing Pain and Anxiety During Primary Teeth Pulpotomy in Pediatric Patients: A Randomized Controlled Clinical Study

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Abstract: ***Aim:*** To investigate the effectiveness of a dental simulation game in reducing anxiety and pain during pulpotomy in primary teeth. ***Material and Methods:*** In this randomized clinical trial, a total of 44 children undergoing pulpotomy were randomly divided equally into a TSD control group and a dental simulation game group. Informed consent and ethics clearance were sought. Behavioral outcome measurements, pain, and anxiety levels were measured through standardized stages of treatment using standardized scales in conjunction with physiological variables. The analysis was carried out at a significance level of 0.05. ***Results:*** Children in the simulated game group showed significantly lower levels of anxiety and pain, as well as greater cooperation, than those in the TSD group, especially in response to local anesthesia and during pulpotomy. Heart rate was significantly lower in the game group, although the oxygen saturation levels were normal in both groups. ***Conclusion:*** The dental simulation game was found to be a more effective method than the traditional TSD procedure for enhancing behavioral responses and anxiolysis and analgesia during pulpotomy. The addition of electronic preparatory software could potentially increase the comfort and efficiency of pediatric dental care.

Keywords: Dental anxiety; Pulpotomy; Simulation game; Tell-Show-Do; Behavior management.

INTRODUCTION

Dental pain is complex and has sensory as well as emotionally driven aspects in relation to past dental experiences of an individual. In children, painful memories of dental care visits are known to increase fear responses that promote anxiety during subsequent visits to dental care facilities.(1)

Dental anxiety has been recognized as a common difficulty in pediatric dentistry and a significant challenge during dental treatment procedures. Many children feel fearful when exposed to unfamiliar instruments, sounds, and sensations, which may lead to crying, treatment refusal, and negative experiences that can influence their future attitude toward dental care. Therefore, effective anxiety management and

trust building are essential for successful pediatric dental practice.(2)

Among the non-pharmacological behavioral guidance techniques, the Tell-Show-Do (TSD) method remains one of the most widely used approaches. It helps children understand dental procedures through explanation, demonstration, and performance. However, TSD may not be sufficiently effective for very young or highly anxious children who struggle with verbal communication and anticipatory fear.(3)

Pulpotomy is one of the most common vital pulp therapies performed in primary teeth. Despite being a routine procedure, it involves local anesthesia, caries removal, and access to the pulp chamber, all of which may provoke anxiety due to associated sounds, visual stimuli, and vibrations. (4,5)This makes pulpotomy an ideal clinical model for evaluating anxiety-reduction strategies in children.

Recently, interactive and digital preparatory tools have gained increasing attention in pediatric dentistry. Visual and experiential learning can provide children with clearer understanding, greater predictability, and a stronger sense of control compared with verbal reassurance alone. Such approaches have been shown to reduce fear and improve cooperation before dental procedures.(6)

Accordingly, this randomized controlled clinical trial aimed to evaluate the effect of a smartphone-based interactive dental simulation game compared with the conventional TSD technique on anxiety, pain, behavior, and physiological responses during pulpotomy in children aged 4–7 years attending the Pediatric Dental Clinics, Faculty of Dentistry, Mansoura University.

Materials and Methods

Study Design:

This randomized controlled clinical trial (RCT) was conducted at the Pediatric dental Clinics.

Sample Size Calculation:

Sample size was calculated using G*Power software (version 3.1.9.7) based on data from previous studies, with an effect size of 0.955, α error of 0.05, and study power of 90%. The total calculated sample size was 44 children, equally divided into two groups (22 per group).

Inclusion Criteria:

1-Children aged 4-7 years requiring primary tooth pulpotomy.
2-Children with behavior rating score 2,3 according to Frankl's behavior rating scale.
3-Children with systemic diseases or special healthcare needs were excluded.

Randomization and Group Allocation:

Children were randomly allocated into two equal groups using a sealed-envelope randomization technique. Participant recruitment and allocation followed the CONSORT guidelines.

- Group I (Control group): Managed using the Tell-Show-Do (TSD) technique.
- Group II (Intervention group): Prepared using a smartphone-based dental simulation game via iPad Mini (5th generation).

Methods:

At the first visit for the control group (group 1), the TSD (Tell-Show-Do) technique group, children were managed with a verbal explanation and a friendly, non-threatening demonstration of the upcoming dental treatment. The "do" phase involved carrying out the dental procedure as per the prior explanation and demonstration.

For the experimental group (group 2), the dental simulation game, used the dental simulation game as educational game about the procedure, which introduced them to dental procedures such as anesthesia, cavity preparation, and pulp therapy in a virtual environment.

The pulpotomy procedure for both groups was performed during the second visit, two days after the initial preparation.

Clinical Pulpotomy Procedure:

All pulpotomy procedures were performed by the same operator under standardized clinical conditions using local anesthesia (articaine 4%), rubber dam isolation, caries removal, coronal pulp amputation, formocresol) application, and restoration with glass ionomer cement and zinc oxide eugenol where indicated.

Data recording:

All data for each group were recorded in the individual child data entry sheet.

Outcome Measures:

Outcome measures were recorded at multiple time points during the second visit.

1- Behavior:

The behavior of the child was assessed before treatment, after the administration of local anesthesia, and finally after pulpotomy using Frankl's behavior rating scale.

2-Anxiety:

The anxiety levels of each patient were assessed before treatment, after the administration of local anesthesia, and after the pulpotomy procedure was completed by pulse rate using a fingertip pulse oximeter and the Venham scale.

3-Pain:

Pain levels of child patients were assessed after the administration of local anesthesia , and finally after

pulpotomy using Wong baker scale.

Statistical Analysis:

The data was processed using the SPSS software (version 26). The normality test on the data was conducted using the Shapiro-Wilk test. The categorical data is presented in the form of frequency and percentage, whereas the quantitative data is presented in the form of Mean ± SD.

The following tests were used whenever appropriate: Chi-square test, Mann–Whitney U test, Wilcoxon signed-rank test, independent t-test, and paired t-test. The level of significance used in the tests was p-value ≤ 0.05.

RESULTS

Demographic Data:

The sample consisted of 44 children who were randomly assigned into two equal groups (22 in each). The mean age was 5.09 ± 1.11 years in the TSD group and 5.32 ± 1.04 years in the simulation game group, with no statistically significant difference between groups (p = 0.487), as illustrated in Table (1). Females represented 50% of the TSD group and 68.2% of the game group, with no significant difference in gender distribution (p = 0.220), as presented **in Table (1).**

Table (1): Comparison of demographic characters between studied groups.

	TSD group N=22	Doll group N=22	Test of significance
Age (years) Mean ±SD	5.09±1.11	5.32±1.04	t=0.701 P=0.487
Sex			
Males	11(50)	7(31.8)	χ^2=1.50
Females	11(50)	15(68.2)	P=0.220

t: Student t test χ^2= Chi-Square test .

Behavioral Outcomes (Frankl Scale):

A distinct behavioral trend existed throughout the treatment sessions. Prior to treatment, no significant difference in the scores of behaviors was found in either of the two groups. On the other hand, in the treatment and post-pulpotomy phase, the simulation game group had immensely better behavior than the TSD group (p < 0.001), as evident in **Table (2) and Figure (1).** Pairwise comparison indicated no significant change in behavior with respect to time in the TSD group, whereas there was behavior improvement in the game group (p = 0.03) compared with the baseline in the treatment phase and (p = 0.005) in the post-treatment phase. The integral level of this behavioral improvement was much better in the simulation game group, as evident **in Table (2) and Figure (1).**

Table (2): Comparison of behavior scale between studied groups and during follow-up.

Time	Behavior scale	TSD group N=22	Doll group N=22	Test of significance
Before TX	2	13(59.1)	9(40.9)	χ^2=1.46
	3	9(40.9)	13(59.1)	P=0.228
• **Mean ±SD**		2.41±0.50	2.59±0.50	t=1.19 p=0.238
During TX	2	15(68.2)	3(13.6)	χ^2=13.54
	3	7(31.8)	19(86.4)	P=0.001*
• **Mean ±SD**		2.32±0.47	2.86±0.35	t=4.32 p<0.001*
After Tx	2	13(59.1)	2(9.1)	χ^2=12.24
	3	9(40.9)	20(90.9)	P=0.001*
• **Mean ±SD**		2.41±0.50	2.91±0.29	t=4.02 P<0.001*
Significance with before Tx#		P1=0.329 P2=1.0	P1=0.03* P2=0.005*	
Mean difference 1		0.091±0.42	0.272±0.55	Z=2.35 P=0.019*
Mean difference 2		0.0±0.	0.318±0.476	Z=3.95

			P=0.001*

#: Paired t test, t:Student t test χ^2= Chi-Square test, Z :Mann Whiteny U test , *statistically significant , p1, mean difference 1: difference between Before TX versus During TX , p2, mean difference 2 :difference between Before TX versus after TX .

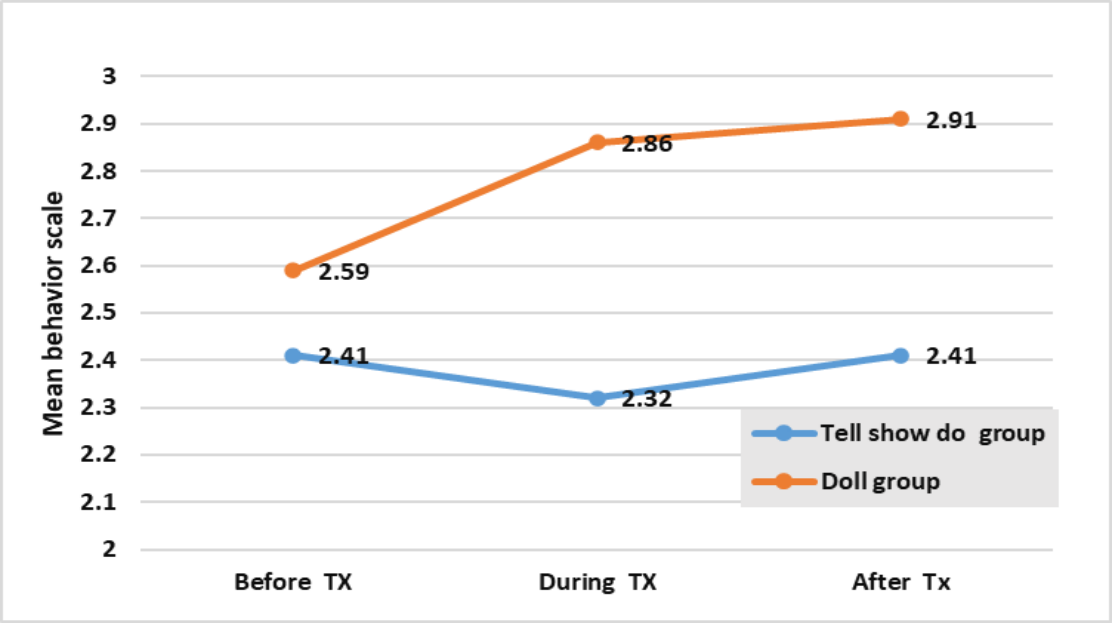

Figure (1): Behavior scale change during follow up among studied groups.

Anxiety Assessment (Venham Scale):

There was a marked observable shift in the pattern of anxiety. As seen from **Table (3),** there was no significant difference between the two groups with respect to baseline anxiety scores (p = 0.724). Subsequent to local anesthesia and pulpotomy procedures, there was a significant decrease in anxiety scores in the simulation game group as opposed to the TSD group (p = 0.001). Despite a marked reduction in anxiety scores in both groups, there was a substantially greater reduction in the simulation game group.

Table (3): Comparison of Venham anxiety scale between studied groups and during follow up.

Venham anxiety scale	TSD group N=22	Doll group N=22	Test of significance
Baseline	5.05±1.09	5.18±1.43	Z=0.355 P=0.724
After LA	2.36±1.32	0.727±1.52	Z=2.99 P=0.001*
After treatment	1.54±1.22	0.364±0.65	Z=3.98 P=0.001*
significance with baseline	P1=0.001* P2=0.001*	P1=0.001* P2=0.001*	
Mean difference 1	2.68±1.76	4.45±1.82	P=0.002*
Mean difference 2	3.50±1.89	4.82±1.50	P=0.014*

#: Wilcoxon signed rank test , Z :Mann Whiteny U test , *statistically significant p1, mean difference 1: difference between baseline versus After LA , p2, mean difference 2 :difference between Baseline versus After treatment.

Pain Assessment Using the Wong-Baker Scale:

Pain levels assessed by the Wong-Baker Faces Pain Rating Scale were compared between the studied groups at different follow-up intervals. When comparing the Tell-Show-Do group with the doll group, the doll group exhibited significantly lower mean pain scores following local anesthesia administration (0.909 ± 1.01) compared with the Tell-Show-Do group (3.32 ± 2.07), indicating a lower perceived level of pain. Similarly, after completion of treatment, the doll group continued to demonstrate significantly lower mean pain scores than the Tell-Show-Do group (0.818 ± 1.01 versus 2.64 ± 2.42, respectively).

Regarding comparisons across follow-up periods within each group, no statistically significant difference was detected between pain scores recorded after local anesthesia and those recorded after treatment in the Tell-Show-Do group (P = 0.084). Likewise, the doll group showed no significant difference between these two time points (P = 0.763). These findings are illustrated in Table (4) and Figure (2).

Table (4): comparison of Wong baker scale between studied groups and during follow up

Wong baker scale	Tell show do group N=22	Doll group N=22	Test of significance
After LA	3.32±2.07	0.909±1.01	Z=4.17 P=0.001*
After treatment	2.64±2.42	0.818±1.01	Z=2.86 P=0.004*
#	P=0.084	P=0.763	

#: Wilcoxon signed rank test , Z :Mann Whiteny U test , *statistically significant

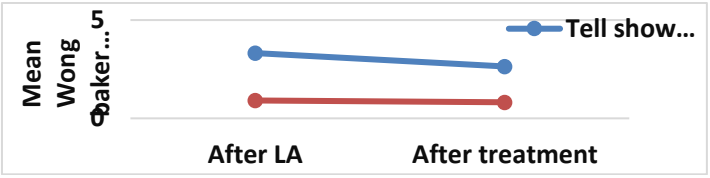

Figure (2): Wong Baker scale change during follow up among studied groups.

Oxygen Saturation:

There was a steady pattern observed in the oxygen saturation of the subjects undergoing the procedure. Based **on Table (5),** the initial values of oxygen saturation of both groups were similar. Following local anesthesia and during pulpotomy, oxygen saturation was slightly but significantly higher in the simulation game group compared with the TSD group. After treatment, no significant difference was detected between groups. The mean changes in oxygen saturation across all treatment stages also revealed no statistically significant differences.

Table (5): Oxygen saturation change during follow up among studied groups.

Oxygen	TSD group N=22	Doll group N=22	Test of significance
Before TX	98.64±0.66	98.72±0.45	t= 0.533 P= 0.597
After LA	98.36±0.90	98.91±0.42	t= 2.56 P= 0.014*
During pulpotomy	98.0±0.98	98.50±0.51	t= 2.13 P= 0.039*
After TX	98.27±0.94	98.50±0.51	t= 1.0 P= 0.323
significance with baseline#	P1=0.283 P2=0.016* P3=0.06	P1=0.104 P2=0.135 P3=0.135	
Mean difference 1	0.272±1.16	-0.18±0.50	Z=1.68 P=0.09
Mean difference 2	0.636±1.14	0.227±0.685	Z=1.45 P=0.155
Mean difference 3	0.364±0.847	0.227±0.685	Z=0.587 P=0.561

#: Wilcoxon signed rank test , Z :Mann Whiteny U test , *statistically significant p1, mean difference 1: difference between baseline versus after LA , p2, mean difference 2 :difference between Baseline versus during pulpotomy , p3 , mean difference 3 :difference between Baseline versus After treatment.

Heart Rate:

A clear shift in heart rate response emerged across treatment stages. **Table (6) and Figure (3) illustrates that** heart rate values were similar at baseline in both groups. After local anesthesia and during pulpotomy, the TSD group exhibited significantly higher heart rate compared with the simulation game group ($p < 0.05$). After treatment, heart rate returned to comparable levels in both groups. Although changes in heart rate over time were significant within each group, the overall mean change did not differ significantly between them.

Table (6): Pulse change during follow-up among studied groups.

Heart rate (b/min)	TSD group N=22	Doll group N=22	Test of significance
Before TX	104.82±7.59	101.23±8.36	t= 1.49 P= 0.144
After LA	109.68±8.69	100.50±6.19	t= 4.04 P =0.001*
During pulpotomy	110.45±9.35	104.91±6.38	t= 2.29 P= 0.027*
After TX	105.86±8.72	101.32±6.83	t= 1.92 P= 0.061
significance with baseline#	P1=0.02* P2=0.002* P3=0.417	P1=0.679 P2=0.006* P3=0.937	
Mean difference 1	-4.86±9.12	0.727±8.13	Z=1.55 P=0.120
Mean difference 2	-5.64±7.34	-3.68±5.60	Z=1.60 P=0.109
Mean difference 3	-1.05±5.92	-0.09±5.35	Z=0.344 P=0.731

#: Wilcoxon signed rank test , Z :Mann Whiteny U test , t:Student t test *statistically significant p1, mean difference 1: difference between baseline versus after LA , p2, mean difference 2 :difference between Baseline versus during pulpotomy , p3 , mean difference 3 :difference between Baseline versus After treatment .

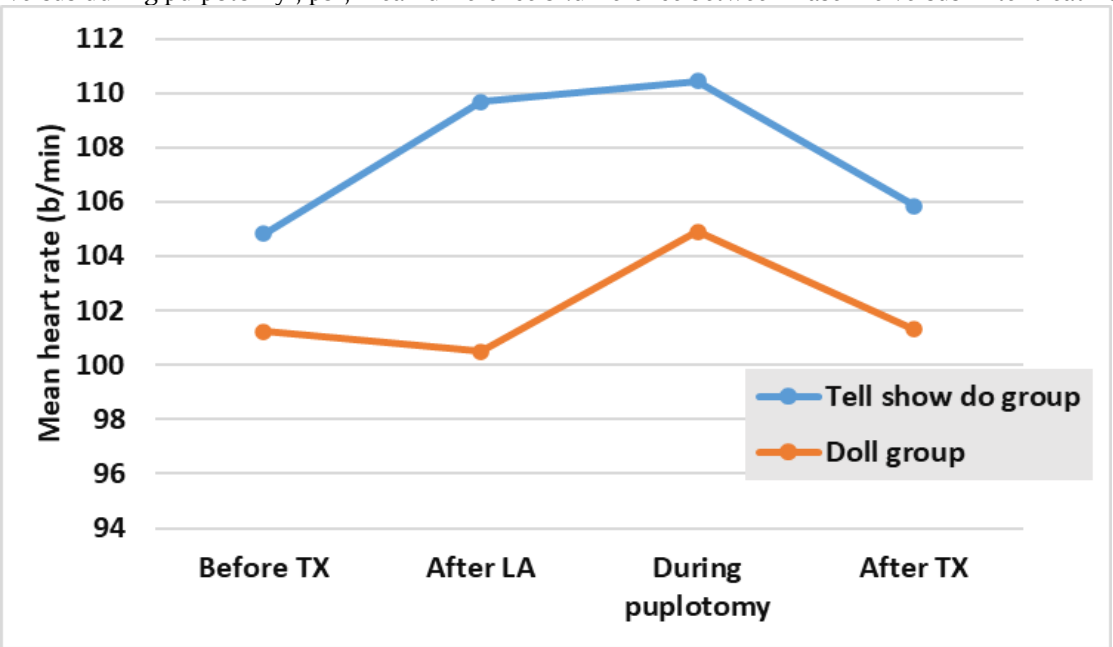

Figure (3): heart rate change during follow up among studied groups.

DISCUSSION

Opportunities for their use in health education and behavioral preparation. In pediatric dentistry, fear of the unknown, anticipation of pain, and exposure to unfamiliar sounds and instruments, particularly during invasive procedures such as pulpotomy, are major triggers of anxiety and uncooperative behavior.(7)

Given these challenges, digital simulation games offer a child-friendly medium that allows young patients to explore dental procedures virtually in a playful and non-threatening way, helping reduce uncertainty and emotional stress before clinical treatment. Because smartphones are widely accessible, familiar to children, and easy to engage with, they provide an ideal platform for delivering such preparatory tools. 6 For this reason, a smartphone-based application was selected for the present study, which aimed to evaluate whether this interactive digital approach could enhance children's behavior and reduce anxiety and pain during primary teeth pulpotomy compared with the conventional TSD technique.

The selection of children between the ages of 4-7 years was quite deliberate, since this is a developmental stage that represents an important period in which understanding and control are established, making behavioral interventions highly effective. This is advocated for by Maru et al. (2023) (8) All the volunteers were subjected to the same clinical procedure, thus any differences in outcomes were only attributable to the method of behavioral preparation, as supported by the findings of Tahersoltani et al. (2021)(7)

The results obtained from this study proved the effectiveness of the dental simulation game in enhancing post-pulpotomy behaviors in children compared with those treated with conventional TSD. The effectiveness can be accredited to the fact that the proposed dental simulation game has an educational feature capable of preparing the children with the procedural steps and sensations associated with the pulpotomy procedure prior to its performance. Uncertainty has been seen as an influential aspect in child cooperative behaviors according to the behavioral and cognitive model suggested by Klingberg & Broberg (2007).(9)This comes in agreement with the recent work by Carmen et al. (2023),(10) who similarly reported that digital dental education applications enhance cooperation with providing predictable virtual rehearsal.

However, the findings of the current study contradict the result attained by El-Taweil et al. (2023), (11) that TSD remains very effective when done by a trained professional in behavioral management. This study stressed the importance of the experience of the clinician in achieving success in TSD. The better results in terms of behavior can be explained by the simulated approach, resulting in children having more experience at the procedural level before the intervention.

Whereas the anxiety level was reduced in both groups at different stages of treatment, the reduction was considerably greater in the simulation-game group. This partly shows the contribution of procedural education to reducing anticipatory anxiety, thus partially supporting the theoretical models of preprocedural cognitive readiness described by Klingberg and Broberg (2007).(9)The game both learns the treatment procedure and familiarizes with the hospital setup, thereby neutralizing the threat. Such findings were corroborated by a study carried out by Shetty et al. (2019),(12) which found digital tools that integrate distraction and educational procedures to be helpful in the reduction of dental anxiety.

The present study showed that the reduction of anxiety was not uniform among children, and this variability could be explained by child related factors influencing dental anxiety. This interpretation comes in agreement with the findings of Cianetti et al. (2017)(13), who found that the temperament of a child, traumatic dental experiences, and certain fear-related traits influence a child's level of anxiety. These observations tend to establish the differential responses observed in our study, thus further confirming that children do not respond equally to anxiety reduction.

Pain levels were found to be significantly lower in the simulation game group as compared to the TSD group. Understanding the procedure decreases the fear of anticipation, while distraction greatly decreases the attention given to the pain stimulus. 13 The current results are in line with a recent clinical study conducted in Egypt by Hamdy et al. (2024)(14), which reported significant pain reduction in children exposed to virtual-reality–based distraction during dental treatment. Their study clearly indicated that immersive digital environments enhance environmental control and familiarity, leading to low pain scores compared with conventional behavior-guidance techniques. This aligns closely with the findings of the present study.

Oxygen saturation values remained in normal physiological ranges in both groups during all treatment stages. Although slightly more stable values were recorded in the simulation-game group than in controls after anesthesia and during instrumentation of patients. Dental anxiety is known to induce physiological responses like increased respiratory rates, elevated heart rates, and increased blood

pressures as cited by Susilo and Fauziah in (2018).(15)This helps explain why the more calm emotional state seen in the simulation-game group was able to persist with more stable physiological parameters.

Heart rate findings further reinforced the differences in anxiety and behavior. Children in the TSD group presented significant increases in heart rate after anesthesia and during pulpotomy, while the simulation-game group maintained comparatively lower values. Since heart rate is a sensitive physiological indicator of sympathetic activation and stress, this supports the conclusion that simulation-based preparation attenuates physiological arousal during treatment. These findings come in agreement with the findings of Khogeer et al. (2025)(16), who found significantly lower heart rate values in children treated using puppet play therapy than in those treated using TSD during invasive dental procedures.

On the other hand, the study by Kevadia et al. (2024)(17) reported that heart rate was not a reliable indicator of the variations in dental anxiety levels among the participants undergoing different behavior guidance techniques. Although the results showed that the anxiety levels were significantly reduced in the study, the values of pulse rate were not found to have any significant difference. This again emphasizes the complexity of the stress responses, thereby supporting the need to analyze the heart rate values in the context of behavioral responses.

Limitations

This study used only one variety of dental simulation game, which could eventually reduce the generalization for other digital platforms. Also, previous dental experiences of children were not stratified, which could have influenced the anxiety at the baseline level. Larger sample sizes with a broad age range and different digital preparation formats are required to further establish and refine the clinical effectiveness of simulation-based behavioral guidance.

Conclusion

The dental simulation game was also more effective in improving child cooperation, anxiety, and pain response during pulpotomy compared to traditional TSD. By integrating interactive education with engaging distraction, it created a more predictable and reassuring treatment environment with improved behavioral and physiological responses. These findings reinforce the inclusion of digital preparatory tools as an adjunctive aid of value in contemporary pediatric dental practice.

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