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EFFICACY OF A VIBRATION SYSTEM IN REDUCING INJECTION PAIN AND ANXIETY DURING LOCAL ANESTHESIA IN PEDIATRIC DENTAL PATIENT

HADEEL ALI ABDELMAWLA ABOELENEEN*

Dentist at General Authority of Heath Care in Ismailia. Pediatric Dentistry, Preventive Dentistry and Dental Public Health Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
*Corresponding Author Email: hadeelmawla92@gmail.com

MOHAMED SHERIEF MOHAMED SALAH ALDEEN FARAG

Professor of Pediatric Dentistry, Preventive Dentistry and Dental Public Health Faculty of Dentistry, Suez Canal University, Ismailia, Egypt. Email: msherifsfarag@gmail.com, mohamed_salah@dent.suez.edu.eg

REHAM AHMED OSAMA ELNEMR

Associate Professor of Pediatric Dentistry, Preventive Dentistry and Dental Public Health Faculty of Dentistry, Suez Canal University, Ismailia, Egypt. Email: reham_elnemr@dent.suez.edu.eg

Abstract

This study aimed to compare the effectiveness of an intraoral dental vibration system versus 20% benzocaine topical gel in reducing injection-related pain and anxiety in children receiving local anesthesia for vital pulp therapy. **Materials and Methods:** An in vivo randomized split-mouth clinical trial was conducted on 30 children aged 6–8 years with bilateral deep carious primary molars requiring vital pulp therapy. Children were divided according to anesthesia type into Group I: maxillary infiltration anesthesia, and Group II: mandibular inferior alveolar nerve block. Each group received two pain-control interventions: dental vibrator and 20% benzocaine topical gel, with a one-week washout period. Heart rate and oxygen saturation were recorded at baseline, during injection, and after injection. Pain was assessed using the Visual Analogue Scale (VAS), while anxiety and behavior were assessed using the Venham Anxiety and Behavioral Rating Scale. **Results:** During injection, the dental vibrator produced significantly lower heart rate values than topical gel in both infiltration anesthesia and nerve block groups. Oxygen saturation remained within normal clinical limits in all groups, with significantly better values during nerve block when the vibrator was used. The highest pain and anxiety scores were observed in children receiving nerve block with topical gel, while the lowest scores were recorded in children receiving infiltration anesthesia with the dental vibrator. **Conclusion:** The intraoral dental vibration system was more effective than 20% benzocaine topical gel in reducing injection pain, anxiety, and physiological stress responses in children undergoing local anesthesia.

Keywords: Dental Vibrator; Topical Anesthesia; Pediatric Dentistry; Injection Pain; Dental Anxiety; Local Anesthesia.

INTRODUCTION

Dental fear and anxiety represent significant barriers to effective oral healthcare, particularly in pediatric populations. Pain experienced during local anesthetic injection is widely regarded as one of the primary triggers of this anxiety [1]. In children, dental anxiety manifests as uncooperative behaviors, which not only diminish treatment tolerance but also prolong clinical procedures. Moreover, it fosters avoidance behaviors that can disrupt future dental visits, perpetuating a cycle of poor oral health outcomes [2].

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These challenges underscore the need for reliable, non-invasive strategies to mitigate injection-related pain, thereby improving patient cooperation and long-term dental compliance.

Numerous techniques have been explored to alleviate pain during local anesthetic administration. These include the application of topical anesthetics, optimizing needle bevel orientation, employing small-gauge needles, and low-level laser therapy [3]. One such promising technique leverages vibratory or pressure stimuli-applied manually or via specialized devices-adjacent to the injection site. The theory posits that pain perception is not a direct consequence of nociceptor activation but is instead modulated by interactions between large-diameter myelinated fibers (conveying non-noxious tactile input) and small-diameter fibers (transmitting painful stimuli). Large-fiber activity effectively "closes the gate" in the spinal cord's substantia gelatinosa, inhibiting the transmission of pain signals to higher brain centers.

This balance between innocuous (large-fiber) and noxious (small-fiber) inputs dynamically regulates pain perception [4]. By stimulating large fibers through vibration, clinicians can preferentially activate inhibitory pathways, thereby attenuating the subjective experience of injection pain. In pediatric dentistry, vibrating devices have garnered attention as a behavior guidance tool during invasive procedures involving local anesthesia. Early studies have produced encouraging, though sometimes conflicting, results. For instance, Hassanein et al. demonstrated significant pain reduction during mandibular nerve block injections in children using an intra-oral Dental Vibrator [5]. Similarly, it was reported that children (both males and females) in the Dental Vibrator group experienced markedly lower pain levels compared to those receiving conventional injections [6,7]. These findings align with the gate control mechanism, where vibration-induced tactile input overrides nociceptive signals from the needle insertion.

The present study addresses this gap by evaluating and comparing the effect of a dental vibrator on injection pain management and child behavior during vital pulp therapy. By quantifying pain scores and behavioral responses, we aim to provide robust evidence on its clinical efficacy, potentially establishing it as a standardized, non-pharmacological adjunct in pediatric dentistry. This could enhance treatment success rates, reduce procedural times, and foster positive dental attitudes in young patients. This study aimed to evaluate the vibration system versus topical gel on injection pain and anxiety management in children undergoing local anesthesia, using heart rate, oxygen saturation, VAS, and VCARS.

MATERIALS AND METHODS

Research Setting and Ethical Approval

This in vivo randomized controlled clinical trial with a split-mouth design was conducted at the Outpatient Clinic of the Pediatric, Preventive Dentistry and Dental Public Health Department, Faculty of Dentistry, Suez Canal University, from July to December 2022. Approval was obtained from the Research Ethics Committee (REC approval no.

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343/2021). Informed consent was secured from parents/caregivers after explaining study procedures, benefits, and risks (Appendix II).

Sample Size Calculation

Sample size was calculated per Jaykaran and Tamghna (2013) using:

Where (at),, and , yielding (30 children, split equally into two groups).

Participant Selection

Thirty children aged 6–8 years (both genders) with bilateral deep carious primary molars (D/E stage) indicated for vital pulp therapy were enrolled (initially 35; 5 excluded for panic, pain, or missed appointments). Eligibility was confirmed via medical history, clinical (under dental unit illumination), and radiographic exams.

Inclusion Criteria [8-10]

The research encompassed apparently healthy children aged 6–8 years (both genders)with no prior dental experience; Frankl scale score 2–3 who have bilateral deep carious maxillary/mandibular primary molars requiring local anesthesia for vital pulp therapy (AAPD, 2020) and Parental consent obtained.

Exclusion Criteria [12]

Exclusion criteria for the study were determined based on clinical evaluations and medical history .chidren who have allergies to study materials; emergency dental needs, intraoral swelling or vibration device application issues,Radiographic: root resorption, furcation radiolucency, or periapical pathology were not included.Children were familiarized with equipment (dental vibrator, pulse oximeter, handpiece) using "tell-show-do."

Grouping and Randomization

Participants were divided by anesthesia type into **Group I** (n=15): Bilateral maxillary primary molars; infiltration anesthesia (30 sides).and **Group II** (n=15): Bilateral mandibular primary molars; inferior alveolar nerve block (IANB; 30 sides).and each group was subdivided by pain control method into **Subgroup A** (n=15 sides): Dental vibrator and **Subgroup B** (n=15 sides, control): 20% benzocaine topical gel.

Sides were randomized via lottery (15 red/blue balls in a jar; red=right, blue=left). Vibrator was used first visit; gel second visit (1-week washout).

Clinical Procedures

- Preoperative: Record baseline heart rate (HRT0) and oxygen saturation (SpO_2T0) via pulse oximeter on index finger [13,15].
- **Subgroup A (Vibrator)**: Intraoral Dental Vibrator [15,16] positioned near injection site for 1 min (15 s post-injection). Assistant held device (covered by disposable sleeve). Maxillary: lip retraction; mandibular: cheek/ramus retraction.
- **Subgroup B (Topical gel)**: Dry mucosa; apply benzocaine 20% for 1–2 min [17].

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Anesthesia protocol ([18], Lidocaine 2% with epinephrine 1:80,000):

- **Infiltration (Group I)**: 30G ultra-short (12 mm) needle; bevel toward bone; supraperiosteal at root apex [19].
- **IANB (Group II)**: 27G long (35 mm) needle; 1.5 ml solution; syringe out of sight; insertion at pterygomandibular raphe [19].
- **Before injection(T0):** Record Record HRT0, SpO_2T0 using pulse oximiter.
- **During injection (T1)**: Record HRT1, SpO_2T1 (independent examiner), Venham's scale (VCARST1; operator/supervisor via video; [20]), VAST1 (self-report).
- **Post-injection (T2, profound anesthesia)**: Record HRT2, SpO_2T2, VCARST2, VAST2.

Vital pulp therapy and stainless steel crowns followed standard one-visit protocol.

Evaluation Methods

Assessments at T0, T1, T2:

Physiological (objective):

- Pulse oximeter (HR: 75–118 bpm normal; SpO_2: 95–100%; [13, 21].

Psychological

- **VCARS** (objective; 0–5 scale; higher = greater anxiety; Table 1; [20]).
- **VAS** (subjective; 0=no pain to 10=worst; child points to face; [20]).

Table 1: Venham's Anxiety and Behavioral Rating Scale

Rating	Description
0	Relaxed, smiling, conversing.
1	Uneasy; brief protest; tense.
2	Scared; verbal protest; tense hands.
3	Reluctant; pronounced crying; interferes.
4	Out-of-contact crying; body movement.
5	Uncontrollable; no coping.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Continuous parametric variables (heart rate, oxygen saturation, VAS, and VACARS scores) were expressed as mean ± standard deviation (Mean ±SD).

Prior to inferential testing, data normality was assessed using the Shapiro-Wilk test, and homogeneity of variance was confirmed via Levene's test. To evaluate intra-group changes across time points (T0, T1, and T2 for physiological parameters; T1 and T2 for behavioral and anxiety scores), repeated-measures Analysis of Variance (ANOVA) or paired-samples t-tests were conducted.

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Inter-group comparisons between treatment groups (GI [Infiltration] vs. GII [N.B]) and subgroups (A [vibrator] vs. B [topical]) at each time point were analyzed using independent-samples t-tests and one-way ANOVA. Post-hoc pairwise comparisons were performed using Tukey's Honest Significant Difference (HSD) test with Bonferroni correction for multiple comparisons. p-values <0.05 were considered statistically significant (*p<0.05, **p≤0.01, ***p<0.001).

RESULTS

The results are presented according to demographic characteristics, physiological measurements, and psychological assessments, with reference to the corresponding Tables and Figures.

• Demographic Parameters (Age and Gender)

30 patients with overall age ranged between 6-8 years old with mean age (7.04±0.43). GI was presented by 15 patients with mean age (6.75±0.56), while GII was presented by 15 patients with mean age (7.32±0.59), with non-significant difference between the two groups, (p=0.88) as revealed by chi-square test. According to gender**,** GI included 7 boys (46.7 % and 8 girls (53.3%), and GII included 6 boys (40%) and 9 girls (60%).

Results showed that there was no significant difference between them as revealed by chi-square test, (p=0.965).

Physiological Measurements (Heart rate and Oxygen Saturation)

Heart Rate: For group GI (Infiltration), both vibrator (99.75±4.50 to 100.75±5.97) and topical (100.67±6.7 to 102.50±7.51) subgroups showed statistically significant changes in heart rate across time points (p=0.01 and p<0.001, respectively). Similarly, group GII (N.B) exhibited highly significant changes across time for both GIIA (99.75±4.68 to 107.00±1.7) and GIIB (100.00±7.8 to 108.67±3.40) subgroups (p<0.001).

While overall differences were non-significant at baseline (T0, p=0.395), overall heart rates showed highly significant differences at T1 (p=0.001) and T2 (p=0.001).

Oxygen Saturation: In group GI (Infiltration), oxygen saturation changed significantly over time in the topical subgroup (98.50±2.38 to 96.75±6.08, p=0.03), whereas the vibrator subgroup showed a near-significant change (p=0.051). In group GII (N.B), changes across time points were not statistically significant for either GIIA (p=0.48) or GIIB (p=0.38) subgroups.

Overall comparisons showed no significant difference at baseline (T0, p=0.841) but revealed statistically significant differences at both T1 (p=0.02) and T2 (p=0.01).

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Table 2: Intra-Group and Inter-Group Comparisons of Mean Heart Rate and Oxygen Saturation Levels ("Mean±SD) in Infiltration (GI) and Nerve Block (GII) Groups Using Vibratory (A) Versus Topical (B) Adjuncts

Heart rate between GI &GII					
Groups	**subgroups**	**T0**	**T1**	**T2**	**P**
Heart Rate					
GI(Infiltration)	GIA (vibrator)	99.75±4.50a	103.25±6.08a	100.75±5.97ab	0.01**
	GIB(topical)	100.67±6.7b	107.25±7.72a	102.50±7.51b	<0.001***
	T test P value	0.871	0.735	884	
GII (N.B)	GIIA(vibrator)	99.75±4.68b	105.67±4.4a	107.00±1.7a	<0.001***
	GIIB(topical)	100.00±7.8 [b]	110.67±6.4 [a]	108.67±3.40 [a]	<0.001***
	T test P value	0.892	0.758	0.945	
P VALUE OVERALL		0.395ns	0.001**	0.001**	
oxygen saturation					
GI(infiltration)	GIA (vibrator)	98.75±0.52a	96.00±6.0ab	97.92±4.04a	0.051 ns
	GIB (topical)	98.50±2.38a	95.25±5.91ab	96.75±6.08b	0.03* s
	P value	0.994	0.937	0.819	
GII(N.B)	GIIA(vibrator)	98.67±0.58a	98.00±1.41a	97.50±1.73a	0.48 ns
	GIIB (topical)	98.33±0.58a	95.67±0.58a	97.27±0.57a	0.38 ns
	P value	0.968	0.764	0.899	
P VALUE OVERALL		0.841ns	0.02*	0.01*	

Superscript letters were utilized to designate post-hoc statistical groupings ($p<0.05$). Two-tailed p-values <0.05 were considered statistically significant (*$p<0.05$, **$p\leq0.01$, ***$p<0.001$).

Psychological Measurements

Visual Analogue Scale (VAS)

In group GI (Infiltration), VAS scores decreased significantly from T1 to T2 in both the GIA vibrator subgroup (0.33±1.5 to 0.20±0.00, p=0.03) and the GIB topical subgroup (4.67±2.08 to 0.84±0.56, p=0.001). Similarly, in group GII (N.B), a significant reduction in VAS scores over time was observed for both GIIA vibrator (0.450±2.36 to 0.25±0.50, p=0.03) and GIIB topical (5.00±2.24 to 1.00±0.36, p=0.001) subgroups. Direct comparisons via t-test revealed that the vibrator subgroups (GIA and GIIA) had significantly lower VAS scores compared to their respective topical counterparts at both T1 ($p<0.001$) and T_2 ($p\leq0.001$). Overall comparisons between groups were statistically significant at both T1 ($p<0.001$) and T2 (p=0.025).

Venham Anxiety and Behavioural Rating Scale (VACRS)

For the VACARS variable, both GI subgroups (GIA vibrator: 1.53±1.15 to 0.60±0.57; GIB topical: 3.0±1.0 to 1.8±0.57) and both GII subgroups (GIIA vibrator: 2.46±0.96 to 1.00±0.50; GIIB topical: 4.5±0.96 to 2.18±1.0) demonstrated highly significant decreases from T1 to T2 ($p<0.001$ for all subgroups). At both time points, the vibrator subgroups achieved significantly lower anxiety scores than the topical subgroups within both main groups ($p<0.001$). Furthermore, overall differences across groups were highly significant at both T1 and T2 ($p<0.001$).

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Table 3: Assessment of Pain Severity (VAS) and Anxiety Levels (VACARS) Showing Temporal Changes (T1 vs. T2) and Comparative Efficacy between Vibratory and Topical Administration Technique

Comparison between Groups I&II for VAS and VACARS				
Groups	**subgroups**	**T1**	**T2**	**P value**
Visual Analog Scale (VAS):				
GI(infiltration)	GIA (vibrator)	0.33±1.5 b	0.20±0.00c	**0.03***
	GIB (topical)	4.67±2.08 a	0.84±0.56b	**0.001****
	T test P value	**<0.001****	**0.001****	
GII (N.B)	GIIA(vibrator)	0.450±2.36 b	0.25±0.50c	**0.03***
	GIIB((topical)	5.00±2.24 a	1.00±0.36a	**0.001****
	T test P value	<0.001**	<0.001***	
P value overall		**<0.001****	**0.025****	
Venham Anxiety Scale (VACARS				
GI (infiltration)	GIA (vibrator)	1.53 ±1.15 c	0.60 ±0.57 d	<0.001**
	GIB (topical)	3.0 ±1.0 a	1.8 ±0.57 b	**<0.001****
	T test P value	**<0.001****	**<0.001****	
GII (N.B)	GIIA (vibrator)	2.46±0.96 b	1.00±0.50 c	<0.001**
	GIIB (topical)	4.5±0.96 a	2.18±1.0 a	**<0.001****
	T test P value	<0.001***	<0.001***	
P value overall		<0.001***	<0.001***	

Superscript letters were utilized to designate post-hoc statistical groupings ($p<0.05$). Two-tailed p-values <0.05 were considered statistically significant (*$p<0.05$, **$p\leq0.01$, ***$p<0.001$).

*Significant difference<0.05, **highly significant $p<0.01$, ***Very highly significant $p<0.001$,

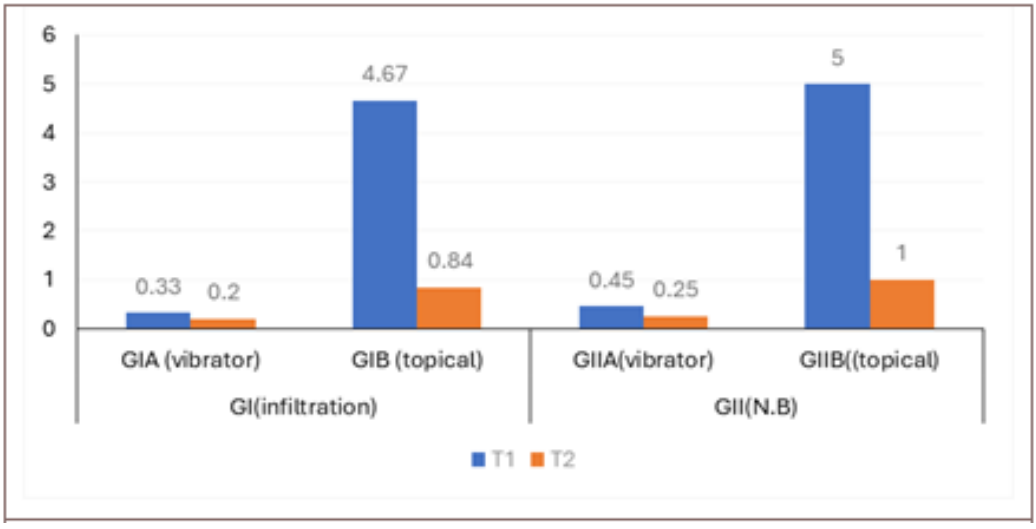

Figure 1: Comparison between Groups I&II for VAS

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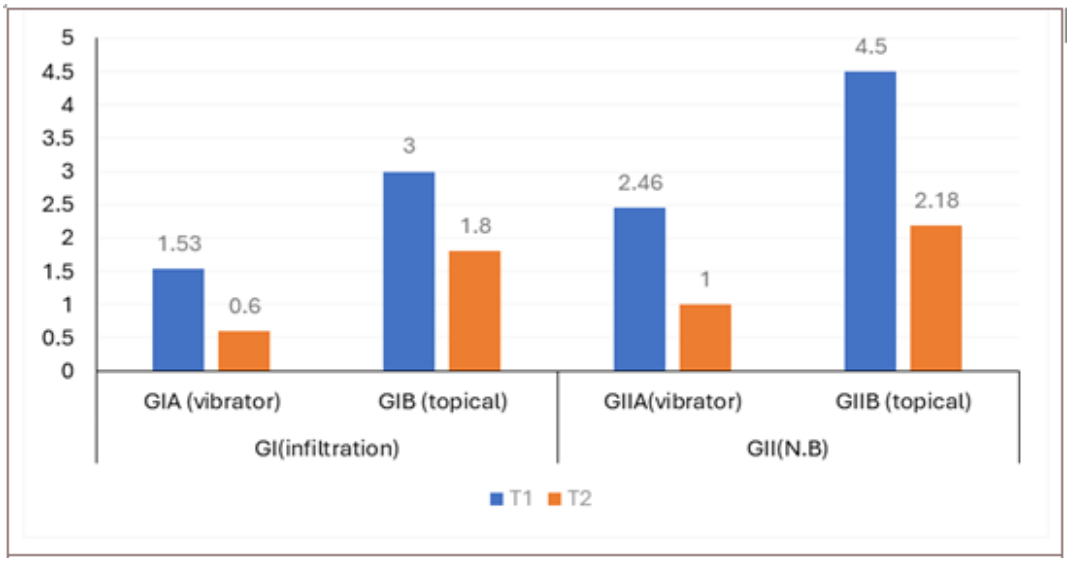

Figure 2: Comparison between Groups I&II for VACRS at T1 &T2

DISCUSSION

This randomized splitmouth clinical trial showed that adjunctive use of a dental vibration device significantly reduced pain and anxiety associated with local anesthetic injections in children compared with conventional topical anesthetic gel, for both maxillary infiltration and inferior alveolar nerve block techniques.

The primary finding of the present study was that children receiving local anesthesia with a dental vibrator consistently exhibited lower heart rate reactivity, higher or more stable oxygen saturation, and significantly lower VAS and VACRS scores than those treated with topical gel alone, indicating superior control of both pain and procedural anxiety. These results directly address the clinical need to minimize injectionrelated discomfort, which is a major driver of dental fear and avoidance in children and anxious patients, as highlighted in previous literature on dental anxiety and injection pain [1,23,24]. The observed reduction in pain and anxiety with vibration support the concept that simple, lowcost adjuncts can materially improve pediatric patient cooperation and potentially increase acceptance of necessary dental care.

Our findings are in agreement with several previous clinical trials that have demonstrated the efficacy of vibratory or combined coldvibration devices in reducing injection pain and anxiety in pediatric dentistry. Prabhakar et al. [25] reported significantly lower pain scores with an intraoral vibration device in a splitmouth design, and Hegde et al. [26] similarly observed reduced heart rate and pain ratings in children receiving local anesthesia with a vibrator compared to topical gel. In contrast, Felemban and Oghli [27] found no significant benefit of a dental vibrator for buccal infiltration anesthesia in children, underscoring that device design, vibration parameters, positioning, and patient selection may influence outcomes.

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The age range of 6–8 years was deliberately selected to capture children with sufficient cognitive development to understand rating scales while still being highly susceptible to dental fear and behavioral disruption [28]. Moreover, including both boys and girls before the onset of puberty related hormonal changes avoids potential sex based hormonal influences on pain and stress responses and allows the observed differences to be more confidently attributed to the interventions [29]. Oxygen saturation, although less sensitive to transient anxiety than heart rate, provided complementary safety and physiological data. In agreement with Olivieri et al. [30], De Camargo Smolarek et al. [31], SpO_2 remained within normal limits in all children, reassuring that neither the procedure nor the adjunctive device compromised respiratory status. The modest but significant differences in SpO_2 between subgroups at T1 favoring the vibrator device mirror the lower anxiety and pain scores and echo the observations of Joshi et al. [32], who found higher oxygen saturation in children receiving vibratory distraction during local anesthesia. In the present study, operator training and calibration, including supervised review of recorded sessions, helped ensure consistent application of Venham ratings. The markedly lower VAS and Venham scores in the vibrator subgroups at both T1 and T2 support the hypothesis that vibration not only reduces immediate nociceptive perception but also diminishes procedural anxiety and improves cooperation throughout the visit. These findings parallel those of Pruegsadee [33], who showed significant reductions in both anxiety and pain when an external vibrating device was used during anesthetic injections. Clinically, the results indicate that dental vibration devices represent a practical, drugfree, and costeffective adjunct for managing injection pain and anxiety in pediatric patients. They could reduce reliance on higher doses of topical anesthetics, thereby lowering the risk of local or systemic adverse effects associated with topical agents and unpleasant taste, as noted by Malamed [34]. By improving the child's experience during one of the most feared aspects of dental treatment, such devices may help prevent the development of longterm dental phobia and avoidance behaviors, with potential benefits extending beyond the immediate procedure [24].

LIMITATIONS

This study has several limitations. First, reliance on self-reported measures of pain and anxiety may introduce bias, as responses can be influenced by individual perceptions and expectations. Second, the dental faculty clinic setting included anxiety-inducing environmental factors that could confound patient responses, complicating isolation of intervention effects. Third, children initially feared the vibration intervention; although demonstrating its use on their hands improved tolerance, this may have influenced comfort levels.

CONCLUSION

This study demonstrates that the vibration system outperforms topical gel in reducing injection pain and anxiety during local anesthesia in pediatric dental patients. Demographic factors, including sex and age, showed no significant influence on treatment efficacy. Physiologically, the vibration technique yielded greater reductions in heart rate

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and lower VAS and VACRS scores compared to topical gel, alongside improvements in oxygen saturation. These findings highlight the vibration system's superior role in mitigating pain and anxiety, supporting its recommendation as a preferred non-pharmacological adjunct in pediatric dentistry.

Recommendations

Our study recommended that using dental vibrator in Reducing Injection Pain and Anxiety during Local Anesthesia in Pediatric Dental Patient is very efficient and preferable than the normal technique where it reduces the heart rate, improves the oxygen saturation level and decreases the pain level with improvement of the local anesthetic level.

Authors' contributions

M.S.M. conceptualized the project; R.A.O. and M.S.M. planned the methodology; H.A.A. and M.S.M. worked on the software. Validation was done by R.A.O. Formal analysis was executed by H.A.A. and M.S.M.;., H.A.A., and R.A.O. performed the investigation. H.A.A. collected resources; data curation was done by M.S.M.; H.A.A., R.A.O., and M.S.M. prepared the original draft; H.A.A., R.A.O., and M.S.M. Conducted the review and editing; H.A.A. executed the visualization; H.A.A. secured the funding. All authors reviewed and approved the final manuscript.

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest:

The authors declare no conflict of interest.

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