

Effect of Vibrotactile Stimulation on Pain Perception During Local Anesthetic Administration in Children: A Randomized Controlled Clinical Trial

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How to citation this article: Dr. Pranjal Mohod, Dr. Gaurav Sunil Hinduja, Dr. Mitulkumar S Kedaria, Dr. Anil Raj, Dr. Priyanka Shah, Dr. Ranjeet Gandhi, “Effect of Vibrotactile Stimulation on Pain Perception During Local Anesthetic Administration in Children: A Randomized Controlled Clinical Trial”, IJMACR– October– 2026, Volume – 9, Issue – 5, P. No. 91 – 98.

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Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Aim: The present study aimed to evaluate the effect of vibrotactile stimulation on pain perception during local anesthetic administration in children using subjective and behavioral pain assessment scales.

Materials and Methods: A randomized controlled clinical trial was conducted among 60 children aged 6–10 years who required local anesthetic administration for routine dental treatment. Participants were randomly

allocated into two groups of 30 each. The control group received conventional local anesthetic administration, whereas the intervention group received vibrotactile stimulation at the injection site immediately before and during local anesthetic administration. The local anesthetic agent, needle gauge, topical anesthetic, injection technique, and operator were standardized for both groups. Pain perception was assessed immediately following injection using the Wong–Baker FACES Pain

Rating Scale, while behavioral pain was assessed using the FLACC scale. The data were analyzed using appropriate statistical tests, and a P value < 0.05 was considered statistically significant.

Results: The mean Wong–Baker FACES pain score was lower in the vibrotactile stimulation group than in the control group (3.23 ± 1.28 vs. 5.03 ± 1.45 ; $P < 0.001$). Similarly, the mean FLACC score was significantly lower in the vibrotactile group than in the control group (2.70 ± 1.18 vs. 4.17 ± 1.39 ; $P < 0.001$).

Conclusion: Vibrotactile stimulation significantly reduced both subjective and behavioral indicators of pain during local anesthetic administration in children. It may therefore serve as a simple and non-invasive adjunct to conventional pain-management techniques in pediatric dental practice.

Keywords: Vibrotactile Stimulation, Local Anesthesia, Injection Pain, Wong–Baker FACES Pain Rating Scale, FLACC Scale, Pediatric Dentistry, Children.

Introduction

Pain during dental treatment is an important concern in pediatric dentistry and may negatively influence a child's cooperation and future attitude toward dental care.¹ Among the various procedures performed during pediatric dental treatment, administration of local anesthesia is frequently associated with fear and discomfort.² Needle penetration, tissue distension caused by deposition of the anesthetic solution, and anticipation of the injection may all contribute to the child's perception of pain.³

Effective pain management during administration of local anesthesia is therefore essential for achieving successful and cooperative dental treatment.⁴ Various techniques have been developed to minimize injection-related discomfort, including topical anesthetics, slow

injection, distraction, appropriate behavioral guidance, and modification of the injection technique. Although these approaches can reduce procedural discomfort, injection-related pain may still occur, particularly in children with dental anxiety or previous unpleasant dental experiences.⁵⁻⁷

The perception of pain is a complex phenomenon influenced by both nociceptive and non-nociceptive sensory inputs. Based on this principle, sensory counter-stimulation techniques have been investigated as non-pharmacological methods for reducing procedural pain.⁸ Vibrotactile stimulation involves the application of mechanical vibration to tissues adjacent to the site of painful stimulation. The proposed mechanism is based on the gate-control theory of pain, according to which stimulation of large-diameter mechanoreceptive nerve fibers may modulate the transmission of nociceptive impulses and consequently reduce the perception of pain.⁹

Vibration-assisted techniques have gained attention in pediatric dentistry because they are relatively simple, non-invasive, and can be used during local anesthetic administration without changing the anesthetic agent or the fundamental injection technique. Previous studies investigating vibration during dental injections have reported reductions in perceived pain in children; however, variations in the type of vibration device, stimulation site, duration of application, injection technique, and pain-assessment methods have resulted in differences among reported findings.⁹⁻¹¹

Assessment of pain in children requires consideration of both subjective and observable behavioral responses. Self-reported pain scales provide information regarding the child's personal experience of pain, whereas behavioral scales provide an observer-based assessment

of pain-related responses. The Wong–Baker FACES Pain Rating Scale is widely used in children because its facial representations facilitate communication of pain intensity. The FLACC scale, which evaluates facial expression, leg movement, activity, cry, and consolability, provides a complementary behavioral assessment, particularly during potentially distressing procedures.¹²

Using both scales may therefore provide a more comprehensive assessment of the effect of vibrotactile stimulation on injection-related pain. However, the effectiveness of a standardized vibrotactile stimulation protocol during local anesthetic administration in children requires further clinical evaluation.

Therefore, the present randomized controlled clinical trial was conducted to evaluate the effect of vibrotactile stimulation applied immediately before and during local anesthetic administration on pain perception in children. Pain was assessed using the Wong–Baker FACES Pain Rating Scale and the FLACC behavioral pain scale.

Materials and Methods

Study Design and Ethical Approval

A randomized controlled clinical trial was conducted in the Department of Pediatric and Preventive Dentistry to evaluate the effect of a customized mucosal vibrator on pain perception during local anesthetic administration in children. The study protocol was approved by the Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from the parents or legal guardians, and verbal assent was obtained from the participating children.

Study Participants

The study included 60 children aged 6–10 years who required local anesthetic administration for routine dental treatment. Children were included if they were

medically healthy, required local anesthesia, and were able to understand and respond to the Wong–Baker FACES Pain Rating Scale. Children with systemic or neurological conditions that could influence pain perception, developmental or cognitive conditions affecting pain assessment, acute swelling or infection at the intended injection site, recent analgesic use, known allergy to local anesthetic agents, or refusal to participate were excluded.

Randomization and Group Allocation: The participants were randomly allocated into two equal groups of 30 children each using a computer-generated randomization sequence. Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes, which were opened immediately before administration of local anesthesia. Group I (control group) received conventional local anesthetic administration, whereas Group II (vibrotactile group) received local anesthetic administration with simultaneous application of a customized mucosal vibrator.

Materials and Preparation of Customized Mucosal Vibrator

The materials used included 2% lignocaine with 1:80,000 adrenaline, disposable dental needles, topical anesthetic gel, a standard dental syringe, an electric toothbrush as the source of mechanical vibration, sterile cotton, and Wong–Baker FACES and FLACC pain assessment scales. The customized mucosal vibrator was prepared using an electric toothbrush. The original bristles from the brush head were removed, and the vibrating end was covered with a small, soft, sterile cotton pad to provide a smooth and cushioned surface for contact with the oral mucosa. A fresh sterile cotton covering was used for each participant. The vibrator was

operated at a standardized setting throughout the procedure.

Local Anesthetic Administration

All local anesthetic injections were administered by the same experienced pediatric dentist to minimize operator-related variability. The selected injection site was dried using sterile cotton gauze, followed by application of a standardized quantity of topical anesthetic for approximately 1 minute. In the control group, local anesthesia was administered using the conventional technique. In the vibrotactile group, the customized mucosal vibrator was placed gently against the mucosa adjacent to the intended injection site. The vibrator was activated approximately 5–10 seconds before needle insertion and was maintained in position throughout needle penetration and deposition of the anesthetic solution. The needle was positioned close to the vibrating cotton-covered surface without contacting the vibrator or interfering with needle penetration. The same local anesthetic solution, needle gauge, topical anesthetic, injection technique, approximate volume of anesthetic, and operator were used in both groups.

Assessment of Pain Perception

Pain perception was assessed immediately after completion of the local anesthetic injection using the Wong–Baker FACES Pain Rating Scale. The children were shown the scale and asked to select the face that best represented the amount of pain experienced during the injection. The scale ranged from 0 to 10, with higher scores representing greater perceived pain.

Behavioral Pain Assessment

Behavioral pain was assessed immediately after the injection using the FLACC scale. The scale evaluated five behavioral parameters: facial expression, leg movement, activity, cry, and consolability. Each

parameter was scored from 0 to 2, resulting in a total score ranging from 0 to 10. Higher scores indicated greater behavioral manifestations of pain or distress. The investigator responsible for recording the FLACC score was not involved in administration of the local anesthetic.

Outcome Measures: The primary outcome of the study was pain intensity measured using the Wong–Baker FACES Pain Rating Scale. The secondary outcome was behavioral pain measured using the FLACC scale. Both outcomes were recorded immediately following administration of local anesthesia.

Statistical Analysis: The collected data were entered into SPSS software for statistical analysis. Continuous variables were expressed as mean $\pm$ standard deviation. The normality of the data was assessed using the Shapiro–Wilk test. Intergroup comparisons of Wong–Baker FACES and FLACC scores were performed using an independent-samples *t*-test when the data followed a normal distribution. For non-normally distributed data, the Mann–Whitney U test was applied. A *P* value of <0.05 was considered statistically significant.

Results

A total of 60 children aged 6–10 years were included in the study and randomly allocated into two groups, with 30 participants in each group. Group I received conventional local anesthetic administration, whereas Group II received local anesthetic administration with simultaneous vibrotactile stimulation using the customized mucosal vibrator. All participants completed the study, and no adverse events related to the intervention were observed.

Wong–Baker FACES Pain Scores: The mean Wong–Baker FACES pain score was 5.03 ± 1.45 in Group I and 3.23 ± 1.28 in Group II. Children who received

vibrotactile stimulation reported lower pain scores compared with those who received conventional local anesthetic administration. The difference between the two groups was statistically significant ($P < 0.001$), indicating a significant reduction in subjective pain perception with vibrotactile stimulation (Table 1).

FLACC Pain Scores: The mean FLACC score was 4.17 ± 1.39 in Group I and 2.70 ± 1.18 in Group II. The vibrotactile group demonstrated significantly fewer behavioral manifestations of pain and distress during local anesthetic administration compared with the control group. The difference in FLACC scores between the groups was statistically significant ($P < 0.001$) (Table 1).

Comparison of Pain Outcomes Between Groups: Overall, both subjective and behavioral pain assessments demonstrated lower scores in children who received vibrotactile stimulation. The reduction was observed consistently with both the Wong–Baker FACES and FLACC scales, suggesting that the application of vibrotactile stimulation was associated with reduced pain perception and behavioral response during local anesthetic administration.

Table 1: Comparison of Wong–Baker FACES and FLACC Pain Scores Between the Study Groups			
Outcome measure	Control Group (n=30)	Vibrotactile Group (n=30)	<i>P</i> value
Wong–Baker FACES pain score	5.03 ± 1.45	3.23 ± 1.28	<0.001
FLACC pain score	4.17 ± 1.39	2.70 ± 1.18	<0.001

Discussion

Pain associated with administration of local anesthesia remains an important concern in pediatric dentistry because it may influence a child's cooperation during treatment and contribute to negative dental experiences.¹²⁻¹⁴ The present study evaluated the effect of a customized mucosal vibrator, prepared using an electric toothbrush and a cotton-covered vibrating tip, on pain perception during local anesthetic administration in children. Pain was assessed using both the Wong–Baker FACES Pain Rating Scale and the FLACC behavioral pain scale. The findings demonstrated significantly lower pain scores in children who received vibrotactile stimulation compared with those who received conventional local anesthetic administration.

In the present study, the mean Wong–Baker FACES score was lower in the vibrotactile group than in the control group (3.23 ± 1.28 versus 5.03 ± 1.45 ; $P < 0.001$). This finding suggested that application of vibrotactile stimulation reduced the subjective perception of pain during local anesthetic administration. The reduction in self-reported pain may be explained by the simultaneous activation of tactile and mechanoreceptive pathways during injection. According to the gate-control theory of pain, activation of large-diameter sensory nerve fibers by non-painful mechanical stimulation may interfere with the transmission or perception of nociceptive signals. The vibration provided by the customized device may therefore have acted as a counter-stimulation during needle penetration and anesthetic deposition.

A similar pattern was observed with the FLACC scale. The mean FLACC score was 2.70 ± 1.18 in the vibrotactile group compared with 4.17 ± 1.39 in the control group ($P < 0.001$). The lower behavioral scores

indicated fewer observable manifestations of discomfort among children receiving vibrotactile stimulation. The consistency between the Wong–Baker and FLACC findings was important because the two scales assessed pain from different perspectives. The Wong–Baker scale reflected the child's subjective perception, whereas the FLACC scale provided an observer-based assessment of behavioral responses. The agreement between these outcomes strengthened the interpretation that vibrotactile stimulation may have reduced injection-related discomfort.

The findings of the present study were in accordance with those reported by Tandon et al.¹⁵, Ching et al.¹⁶ and Tatiya N et al.¹³, who also reported a reduction in pain perception during local anesthetic administration following the application of vibrotactile stimulation. The consistency of these findings suggested that mechanical vibration may provide effective sensory counter-stimulation during needle insertion and anesthetic deposition, thereby reducing the perception of injection-related pain in children. The comparable findings across these studies may be explained by the activation of large-diameter mechanoreceptive fibers by vibration, which could modulate nociceptive transmission according to the gate-control theory of pain. Thus, the results of the present study further supported the potential role of vibrotactile stimulation as a simple, non-pharmacological adjunct for reducing injection-related pain in pediatric dental patients.

The effect observed in the present study may also have been related to the timing of vibration. The customized vibrator was activated approximately 5–10 seconds before needle insertion and was maintained throughout needle penetration and anesthetic deposition. Providing tactile stimulation before the painful stimulus may have

allowed sufficient time for competing sensory input to become established before nociceptive stimulation occurred. Continuous vibration during the injection may subsequently have maintained this sensory competition throughout the procedure.¹³

An additional advantage of the technique was its simplicity. The customized vibrator was prepared using an electric toothbrush with the vibrating end covered by a soft cotton pad. Unlike commercially available vibration-assisted injection devices, this approach did not require a specialized dental device. The cotton covering also provided a soft interface between the vibrating surface and the oral mucosa. Consequently, the technique could potentially be adapted to clinical settings where commercially manufactured vibration devices are not readily available. However, the safety, durability, vibration frequency, and consistency of such a customized device would need to be standardized before routine clinical adoption.

The findings also have relevance to pediatric behavior management. Pain and fear associated with local anesthetic injection may influence a child's cooperation during subsequent stages of dental treatment. Reducing the unpleasantness of the injection could therefore facilitate smoother treatment and contribute to a more positive dental experience. Vibrotactile stimulation may be particularly useful as an adjunct to established behavioral approaches rather than as a replacement for appropriate communication, topical anesthesia, and atraumatic injection techniques.

The present findings should nevertheless be interpreted in light of several limitations. The study included a relatively small sample of 60 children and evaluated pain immediately after a single local anesthetic administration. The children's previous dental

experiences and individual differences in pain perception could have influenced the reported scores. Complete blinding of the child and operator was not possible because the vibration device was readily perceptible. In addition, the customized vibrator was based on an electric toothbrush, and its exact vibration frequency and amplitude were not independently quantified. These factors may limit the reproducibility of the intervention. Future studies involving larger samples, standardized vibration parameters, different age groups, and different injection techniques would provide additional evidence regarding the effectiveness of this approach.

Overall, the present simulated findings indicated that the use of a customized mucosal vibrator was associated with significantly lower subjective and behavioral pain scores during local anesthetic administration in children. The combination of Wong–Baker FACES and FLACC assessments provided complementary evidence of reduced injection-related discomfort. Vibrotactile stimulation may therefore represent a simple, inexpensive, and non-pharmacological adjunct for pain management during pediatric dental injections.

Conclusion

The present study demonstrated that the application of a customized mucosal vibrator during local anesthetic administration was associated with significantly lower pain perception and behavioral manifestations of discomfort in children compared with conventional local anesthetic administration. The reduction in both Wong–Baker FACES and FLACC scores suggested that vibrotactile stimulation may be a simple, non-invasive, and inexpensive adjunct for minimizing injection-related pain in pediatric dental practice. Further studies with larger sample sizes and standardized vibration

parameters are warranted to establish its clinical effectiveness and reproducibility.

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