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Original article

Pain parameters for buffered and non-buffered anesthetic injections in children undergoing dental procedures

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ABSTRACT

Background: *Dental procedures, such as injections, usually cause pain and make children uncomfortable and uncooperative. One approach for reducing pain is the use of buffered anesthetics.* ***Purpose:*** *The research objective was to assess the pain parameters between buffered and non-buffered anesthetic injections, based on oxygen saturation, pulse rate, and the self-reporting of pain by the children.* ***Methods:*** *The research method was quasi-experimental, with purposive sampling of 19 children. Pain parameters, based on oxygen saturation and pulse rate, were measured using a pulse oximeter. The self-reporting of pain used the Wong–Baker FACES® pain rating scale. Statistical analysis used a t-test and Mann–Whitney test with $P < 0.01$ taken as statistically significant.* ***Results:*** *The results showed a significant difference in oxygen saturation before and after the injection of buffered and non-buffered anesthetics ($P = 0.0002$). Delivering the buffered anesthetics were reported to be less painful than non-buffered anesthetics. The oxygen saturation and pulse rate were inversely proportional to the self-reporting of pain in children. Statistical analysis showed no significant difference between oxygen saturation ($P = 0.5$) and pulse rate ($P = 0.4886$) in those receiving buffered and non-buffered anesthetics. However, there was a significant difference in the self-reporting of pain between the two groups ($P = 0.00000262$).* ***Conclusion:*** *Pain parameters could be measured physiologically and psychologically. This research concludes that physiologically, there was no difference in pain parameters, based on oxygen saturation and children's pulse rate. Psychologically, there was a difference in the self-reporting of pain; 14 children reported that delivering the buffered anesthetic was painless.*

Keywords: *Pain parameters; oxygen saturation; pulse rate; self-report; buffered anesthetics; non-buffered anesthetics*
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INTRODUCTION

Children show unique variations in maturity, personality, temperament, and emotions according to their vulnerability and ability to cope with dental treatment situations. Therefore, pediatric dental care remains a challenge. The largest percentage of children brought by parents for a first dental visit was between 6–9 years of age.[1,2] Herawati's[3] study on children aged 7–11 years at Cimahi Elementary School, West Java, showed that the prevalence of premature loss of primary teeth was 36.4%. These children have speech and cognitive abilities, so they can report what they feel, marked by an increase in the acceptance of responsibility for oral hygiene, even though parental involvement is still needed. Dental care procedures often make children uncomfortable and uncooperative because tooth preparation, rubber dam placement, pulp treatment, injection, and tooth extraction can cause pain.[4]

Pain is a complex and unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage.[5] Painful stimulation can cause physiological and psychological reactions to protect the body from tissue damage. Patients can generally self-report pain experiences, except for toddlers and children with special needs. Behavioral problems and a refusal to attend dental treatment, such as preparation and injection, suggest that children are afraid, especially about feeling discomfort and pain.[6] Pain control during dental care procedures is essential in pediatric dentistry[7,8] and primarily involves the use of local anesthesia.[7] The fear

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and pain of injecting local anesthetics can impact a child psychologically during the visit and influence attitudes in subsequent sessions.[9,10]

Local anesthetics commonly used in pediatric dentistry are amide-type agents, e.g., 2% lidocaine with 1: 100,000 epinephrine. This agent is used because it rarely causes allergies and has excellent potential at low concentrations. Local anesthesia causes pain when pricking the mucosa with a needle when administering local anesthetics and a burning sensation from the acidity of the anesthetics that causes local irritation.[11] Injection into dense tissue, such as the palate, is considered one of the most painful injections. This injection requires pressures of up to 660 psi. A computer-controlled local anesthetic delivery (CCLAD) system, the Wand (Milestone Scientific, 1998), was developed to minimize pain sensations. Pediatric dentistry literature also reports other efforts to reduce pain using anesthetic solution patches, chemically modifying anesthetic agents, buffering anesthetics, or warming anesthetics.[11]

Research by Malamed,[11] Guo,[12] Chopra,[13] and Phero,[14] analyzed various attempts to administer local anesthetics more conveniently. Buffering the anesthetic agent is recommended by adding a sodium bicarbonate ($NaHCO_3$) base solution to the local anesthetic so that the pH is nearly neutral.[7] Malamed[10] stated that using lidocaine with epinephrine, buffered to a physiological pH immediately before injection, significantly accelerated the onset of action and increased injection comfort. Khatri[7] reported that buffered lidocaine could reduce pain during the injection of inferior alveolar nerve blocks in children aged 5–10 years. Based on these reports, this study aims to assess pain parameters between buffered and non-buffered anesthetic injections, based on oxygen saturation, pulse rate, and the self-reporting of pain in children.

MATERIALS AND METHODS

Ethics clearance was obtained from the Research Ethics Committee of the Faculty of Medicine, Universitas Padjadjaran No. 194/UN6.KEP/EC/2020. This study used a quasi-experimental study design. The study population was children who came to the Polyclinic of Pediatric Dentistry, Dental and Oral Hospital of Universitas Padjadjaran from January to March 2020. Nineteen children were selected by purposive sampling. The inclusion criteria were children aged 6–9 years who had primary molars on both sides of the maxilla (left and right), with mobility grades 0, 1, and 2 for extraction procedures, and whose parents gave informed consent. Frank's behavioral scale requirements were level three (positive) or four (very positive). The exclusion criteria were children allergic to local anesthetic solutions and with a history of special needs and systemic diseases.

The study was conducted on three visits, and the interval between visits was one week. The tell–show–do method was used to explain the procedure during each visit before carrying it out. A dental anesthesiologist administered the injection using an anterior, middle superior alveolar technique immediately after mixing the anesthetic solution using a CCLAD system, i.e., the Wand® (Milestone Scientific, Livingston, NJ, USA) (Figure 1).

At the first visit, the right side was injected using a buffered anesthetic, followed by the right primary first molar extraction. A buffered anesthetic solution was prepared by mixing a basic solution of 8.4% $NaHCO_3$ with 2% lidocaine + 1:100,000 epinephrine using the Onpharma® Onset mixing pen.[15] A week later, a right-sided post-extraction control was performed, and the procedure was continued for the left side using a non-buffered anesthetic followed by extraction of the left primary first molar. The third visit was made one week later for a left-sided post-extraction control.

Pain at the time of injection (using buffered and non-buffered anesthetics) was assessed by oxygen saturation and pulse rate using a handheld pulse oximeter (GE Healthcare Company, USA) and self-report of pain using the Wong–Baker FACES® pain rating scale (Wong–Baker FACES Foundation, Oklahoma City, OK, USA). Differences in pain parameters based on oxygen saturation and pulse rate were analyzed using paired and unpaired t-tests. Differences in pain parameters, based on self-reported pain, were analyzed using the Mann–Whitney test.

RESULTS

Table 1 shows the results of the paired t-tests for oxygen saturation. The p-value is 0.0002, indicating a significant difference in oxygen saturation ($P < 0.001$) before and after

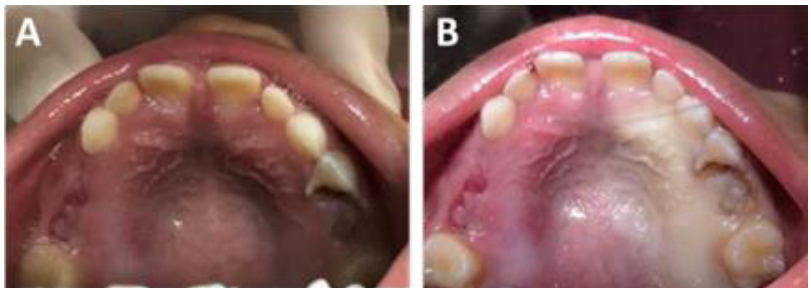

Figure 1. A. Before injection. B. After injection.

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each treatment. However, the oxygen saturation results using the unpaired t-test in Table 2 showed a *P*-value = 0.5, indicating no significant difference in oxygen saturation ($P > 0.01$) between buffered and non-buffered anesthetic injections.

Table 3 shows the results of the paired t-tests for pulse rates. The results of the pulse rates using buffered anesthetic have a *P-value* = 0.00000832, while for the non-buffered anesthetic, the *P-value* was 0.0000438, indicating a highly significant difference ($P < 0.001$) in pulse rate before and after buffered and non-buffered anesthetic injections. The results for the pulse rates using the unpaired t-test (Table 4) showed a *P-value* of 0.4886 ($P < 0.001$), indicating no significant difference in pulse rate between buffered and non-buffered anesthetic injections.

Table 5 shows the self-report results based on the Wong–Baker FACES® pain rating scale. With buffered anesthetics, 74% had a pain value of 0, whereas 26% had a pain value of 2. For non-buffered anesthetic, 5% had a pain value of 2, whereas 47% had a pain value of 4. The Mann–Whitney test (Table 6) showed a *P-value* of 0.00000262, indicating a highly significant difference in self-reported pain between buffered and non-buffered anesthetics ($P < 0.001$).

Table 1. The difference in oxygen saturation before and after injection of buffered and non-buffered anesthetics using the paired t-test

Treatment	n	Oxygen saturation ± SD		t-count	*P-value*
		Before	After		
Buffered	19	97.53 ± 1.61	97.89 ± 1.37	4.44	0.0002 **)
Non-buffered	19	98.00 ± 1.00	98.37 ± 0.96	4.44	0.0002 **)

Note: n = sample; SD = standard deviation; A *P-value* < 0.001 was considered statistically significant

Table 2. The difference in oxygen saturation between buffered and non-buffered anesthetics using the unpaired t-test

Treatment	n	Mean (difference) oxygen saturation ± SD	t-count	*P-value*
Buffered	19	0.68 ± 0.67	0	0.5
Non-buffered	19	0.68 ± 0.67		

Note: n = sample; SD = standard deviation; A *P-value* < 0.001 was considered statistically significant

Table 3. The difference in pulse rate before and after injection of buffered and non-buffered anesthetics using the paired t-test

Treatment	n	Pulse rate ± SD		t-count	*P-value*
		Before	After		
Buffered	19	92.42 ± 15.29	100.16 ± 12.47	5.81	8.32E-06 **)
Non-buffered	19	94.26 ± 9.73	103.16 ± 13.11	5.03	4.38E-05 **)

Note: n = sample; SD = standard deviation; A *P-value* < 0.001 was considered statistically significant

Table 4. The difference in pulse rate between buffered and non-buffered anesthetics using the unpaired t-test

Variable	n	Mean (difference) pulse rate ± SD	t-count	*P-value*
Buffered	19	10.68 ± 8.01	0.03	0.4886
Non-buffered	19	10.16 ± 8.81		

Note: n = sample; SD = standard deviation; A *P-value* < 0.001 was considered statistically significant

Table 5. Self-report of pain on the Wong–Baker FACES® pain rating scale for buffered and non-buffered anesthetics

Pain level	Buffered		Non-buffered	
	n	%	n	%
0	14	74	1	5
2	5	26	9	47
4	0	0	9	47
6	0	0	0	0
8	0	0	0	0
10	0	0	0	0
Total	19	100	19	100

Note: n = sample

Table 6. The difference in self-reported pain results between buffered and non-buffered anesthetics using the Mann–Whitney test

Variable	n	Mean	Sum of Ranks	SD	Z	*P-value*
Buffered	19	11.8	224.5	± 32.06	- 4.55	2.62E-06 **)
Non-buffered	19	27.2	516.5			

Note: n = sample; SD = standard deviation; Z = corrected for ties; A *P-value* < 0.001 was considered statistically significant

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DISCUSSION

Table 1 shows no change in oxygen saturation in seven children who received buffered anesthetics and nine who received non-buffered anesthetics. The remaining children had slight changes in oxygen saturation during the administration of local anesthetics, though in the normal range, which according to the World Health Organization (WHO), [16] must be 95–100%. Rayen et al.[17] reported that the oxygen saturation value did not change during dental treatment. The use of local anesthetic agents in dental care can result in changes in physiological responses.[18] Table 2 shows that oxygen saturation variations were the same with buffered and non-buffered anesthetics. Saatchi et al.[19,20] reported a similar result, i.e., no significant difference for the inferior alveolar nerve block using buffered and non-buffered anesthetics.

Table 3 shows that pain parameters based on pulse rate varied significantly before and after injection using buffered and non-buffered anesthetics. Most children showed an increase in pulse rate after the injection. Two children experienced a decrease in pulse rate while administering both buffered and non-buffered anesthetic injections. According to the WHO, the normal pulse rate for children aged 6–9 years is 60–140 beats per minute. Yagesh Kumar et al.[21] reported a smaller increase in pulse rate, pain, and disruptive behavior when using CCLAD compared to conventional syringes. Rayen et al.[17] reported a rise in the pulse rate of children in all dental care procedures.

Table 4 shows no significant difference in pulse rate between buffered and non-buffered anesthetics. Buffered and non-buffered anesthetics increased the pulse rate but within the normal range. This study is inconsistent with studies in adults by Senthoor et al.,[22] which showed a significant decrease in pulse rate using buffered anesthetic injection after previously having been given an injection using non-buffered anesthetics.

In this study, buffered anesthetics did not cause significant physiological changes. Malek et al.[23] stated that monitoring pain by observing changes in vital signs was not recommended. Monitoring oxygen saturation and pulse rate in pediatric dental care is recommended to prevent cardiovascular accidents. Cowen et al.[24] states that an objective method of pain assessment is to observe changes in the autonomic nervous system, such as pulse rate, blood pressure, sweating, and pupillary responses. A pulse oximeter monitors pulse rate and oxygen saturation while administering local anesthetics.

Table 5 shows that most children reported pain values of 0, i.e., no pain during the injection of buffered anesthetics. The self-reported results are consistent with those of Malamed,[11] Guoet al.,[12] Chopraet al.,[13] and Pheroet al.,[14] who reported that buffered anesthetics could reduce pain during anesthetic administration. Table 6 shows a difference in the value of pain parameters, based on self-reports using the Wong–Baker FACES® scale. Fourteen children reported buffered anesthetics as less painful than non-buffered anesthetics. One child said there was no pain with both buffered and non-buffered anesthetics. The Wong–Baker FACES® facial pain rating scale used in this study complies with the American Academy of Pediatric Dentistry guidelines on pain assessment. Ethnic, cultural, and language factors can influence the expression of pain and its assessment.[5] The experience of pain can shape children's perception of pain in the future. Self-reported pain assessment is the gold standard for pain assessment.[25]

This study's results agree with those found by Afsal et al.[7] who studied healthy children aged 5–10 years using the Wong–Baker pain rating scale. It showed a significant difference in the injection of 2% buffered lidocaine compared to 2% non-buffered lidocaine and 4% articaine. Gupta et al.,[26] and Kashyap et al.[27] also found that buffering anesthetics could reduce pain during injection. Malamed[10] noted that a lower anesthetic pH tended to produce a burning sensation at the injection site and a slightly slower onset of action.

Lidocaine cartridges have an acidic pH due to the addition of hydrochloric acid (HCl) to extend their shelf life.[28,29] Adding a buffer solution can increase the pH of the anesthetic solution from about 3.5–5.5 to 6.5–7.3.[30] When added to local anesthetics, there is a reaction between $NaHCO_3$ and HCl, which produces water and carbon dioxide (CO_2).[8] Davoudi et al.[8] reported that CO_2 provided an independent anesthetic effect that increased the anesthetic action sevenfold. Buffered lidocaine uses 0.5 mmol/ ml $NaHCO_3$ in a ratio of 9:1, which is the most common method for reducing pain when administering local anesthetics.[30]

Goodchild and Donaslon,[31] in Compendium Continuing Education in Dentistry (2019), examined three buffered anesthetic ratios of 9:1, 19:1, and 18:1. An anesthetic buffer ratio of 9:1 produces an average pH of 6.97 ± 0.06, while anesthetic buffer ratios of 19:1 and 18:1 produce a slightly lower pH of 6.77 ± 0.12 and 6.82 ± 0,05, respectively. This study used a 19:1 buffered anesthetic ratio according to the instructions for the Onpharma® Onset[15] mixing pen. The Chemistry Laboratory of Universitas Padjadjaran measured the anesthetic pH in this study. The pH of the non-buffered and buffered anesthetics were 4.16 and 6.82, respectively. Although adding $NaHCO_3$ shortens the shelf life of the anesthetic, the solution can still be used at room temperature without reducing the effects of lidocaine.[30]

The researchers ensured uniformity in administering injections via the quasi-experimental, non-randomized sampling method. However, the samples did not all have the same probability, which is a limitation of this study. Researchers also did not provide a specific time to calculate the onset and duration of the action of anesthesia. Certain patients in the study sample required additional intra-ligament injections.[32]

This study concluded that there was no difference in pain parameters, based on oxygen saturation and pulse rate, between injections using buffered and non-

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buffered anesthetics. However, there were differences in pain parameters according to self-reported feedback. Pain parameters can be measured physiologically and psychologically. Physiologically, there was no difference in the oxygen saturation and pulse rate between buffered and non-buffered anesthetics. Psychologically, based on self-reported feedback, 14 children in this study reported that a buffered anesthetic was painless.

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