Original Article

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Efficacy of sucrose application in minimizing pain perception related to dental injection in children aged 3 to 9 years: a randomized control trial

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Background: Dental fear and anxiety are significant challenges in managing behavior in children. Oral administration of sucrose or sweet-tasting solutions has shown effectiveness in reducing procedural pain in infants and neonates. This study aimed to investigate whether pre-application of sucrose solution had an effect on minimizing pain perception during injection and to assess the potential impact of the child's age and sweet preference.
Methods: A randomized control clinical trial was conducted on 60 children aged 3–9 years requiring buccal infiltration injections. Following parental consent, demographic data of the children were recorded. Sweet preferences was assessed using a modified forced-choice test. Children were equally and randomly allocated into study (sucrose) and control groups using a lottery method. Sucrose solution or distilled water, respectively, was applied to the lateral surface of the tongue for 2 min. Topical anesthetic was applied at the site of injection, followed by local anesthesia administration. The children rinsed their mouths thrice with water immediately after anesthetic injection. A video was recorded during injection which was then scored by three blinded examiners on the Sound Eye Motor (SEM) scale. The children also self-evaluated using Wong-Baker Faces Pain Rating Scale (WBFPS).
Results: The mean SEM scores and WBFPS scores were analyzed using the Kruskall–Wallis test. The mean SEM score in the study group was 1.37 ± 0.61, compared to 3.17 ± 0.87 in the control group, showing a statistically significant difference ($P < 0.001$). Mean pain scores assessed by WBFPS in the study group were 0.60 ± 1.4, while in the control group, they were 6.27 ± 2.33, also showing a statistically significant difference ($P < 0.001$). Children with a sweet preference demonstrated a subjective reduction in pain perception.
Conclusion: Application of sucrose before dental injections in children helps to minimize pain upon injection across all age groups.

Keywords: Analgesia; Anesthesia; Dental; Pediatric Dentistry; Sucrose; Topical Anesthetics.

INTRODUCTION

Literature evidence indicates that fear of dental injections among individuals undergoing dental treatment is a major cause of anxiety [1]. This anxiety and fear of pain can deter patients, particularly children, from seeking necessary dental care. In addition to effective pain management addressing these anxieties is crucial, as even short-term pain can have long-lasting psychological effects on the child [2].

Over the years, dentists have diligently pursued methods to minimize pain during injections and to make the injection procedure as comfortable as possible, especially for children. These methods include the use

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of topical local anesthetic sprays or gels, pre-cooling of the injection site [3], warming of local anesthesia (LA) solution [4], buffering of LA solutions [5], vibrations [6], distractions [7], and pre-treatment with lasers [8].

Historically, studies on the use of sweet substances for pain management date back to 632 AD, where Prophet Mohammed advocated giving infants a well-chewed date to reduce pain [9]. Thorek, in 1938, mentioned that anesthesia might not always be necessary in infants, as a sugar-water-soaked sponge could suffice to calm the baby [10]. However, randomized control trials evaluating the use of sucrose in infants were published only after the late 1980s. Over time, studies have evaluated the efficacy of sweet tasting solution in minimizing pain during immunization, catheterization, venepuncture, and cold pressor test in neonates and infants [11,12]. A Cochrane review by Harrisson et al. has confirmed the efficacy of sucrose in procedural pain management in infants and neonates [13].

The exact mechanism of action remains unclear, but it has been postulated that sugar or sucrose induces a hedonic response and the release of endogenous opioids, which in turn exert an analgesic effect and increase the latency to report pain.

There is limited research evaluating the analgesic effect of sweet substances in preschoolers and older children. In dentistry, studies have been conducted using sucrose [14] honey solutions [15], and xylitol [16,17], reporting a statistically significant reduction in pain perception on injection.

Against this background, the present study aimed to determine if the prior application of sucrose solution affects minimizing pain perception on dental injection in children. The study also evaluated the impact of age and sweet preference on pain perception.

METHODS

1. Study design

A randomized controlled, single-blind clinical trial was conducted to compare the efficacy of sucrose application in reducing the pain perception related to dental injection across children aged 3–9 years.

The study was conducted in the Department of Pediatric and Preventive Dentistry. The Institutional Research and Ethical Board of the University approved all aspects of this research. (IREB/2021/PEDO/09). The study was registered with National Clinical Trial Registry (CTRI no: CTRI/2022/06/043150).

The sample size was determined by two sample mean tests (one-sided). The study parameters were Alpha = 0.05 and Power = 0.80. The minimum estimated sample size was found to be n = 32 (16 per group).

The study procedure was explained to the parents, from whom informed consent was obtained. Children between the ages of 3 and 9 years who reported to the department were assessed for eligibility. Inclusion criteria comprised children requiring buccal infiltration injections for treatment, with no prior history of dental injections, a Frankl's Rating score of 3 or 4, and ASA criteria 1 and 2. Exclusion criteria included children with systemic illnesses and/or with special health care needs, diabetes, presence of abscess, swelling, or fistula at the injection site, and a Frankl's rating 1 or 2. A total of 70 children were initially assessed for eligibility. Children who fulfilled the inclusion criteria were selected. Radiographs and prophylaxis were conducted for the selected children on their first dental visit. The 60 selected children were divided into two groups: Group 1 (study - sucrose) and Group 2 (control - distilled water). Each group was further divided into two subgroups (n = 15 in each subgroup) based on age: subgroup 1(3 – 5 years) and subgroup 2 (6 – 9 years).

Demographic details of patients including name, age, and sex were recorded. The patient's sweet preference was determined through a modified forced-choice test, as described by O'Connor and Kasari in 2000 [18], which was further modified by Pepino and Manella in 2006 to assess the sweet taste preference in children [19]. The children were shown pictures of five pairs of commonly consumed local sweet (chocolate, ice-cream, biscuits,

cake, and ladoo) and savory food items (wafers, chakli, dhokla, samosa, and dosa) and were asked to point out their preferred option. Additionally, the children were asked to identify their favorite food and the food they consistently requested their parents to buy. If a child chose the sweet type of food three times and answered the questions with a sweet food as the answer, they were considered to have a sweet preference.

The selected children were randomly allocated to the two groups by a dental assistant using a lottery method. Only the assistant was aware of the group assignments. On the day of the procedure, the assistant handed an envelope to the operator containing either sucrose or distilled water in a syringe without a needle. Both the child and the operating dentist were blinded to the contents of the envelope.

2. Procedure

A 30% fresh sucrose solution was prepared daily by mixing 30 g of pharmacy grade sucrose powder in 100 ml of drinking water. Two milliliters of this solution was taken in a syringe without a needle and applied on the lateral surface of the child's tongue repeatedly over 2 min. Following this, topical anesthetic gel (Septodont Lignospan-O − 5% lidocaine) was applied at the site of injection on the dried mucosa for 1 min. The buccal infiltration injection was then administered using an aspirating metal syringe (Septodont) and a 30-gauge short needle (Septodont-Septoject). An anesthetic cartridge (Septodont Lignospan Special) containing 2% lignocaine with 1:80,000 adrenaline was used. The needle was concealed from the child, who was informed about the "magic medicine" that would make their tooth sleep. With the lip lifted and pulled taut, the syringe was positioned parallel to the long axis of the targeted tooth, and the needle was inserted into the mucobuccal fold over the designated tooth. The injection was administered at a rate of 1 ml per minute. In the sucrose group, the injection was administered within 5 min of the application of sweet solution. Conversely, in the control group, 2 ml of distilled water was applied on the lateral surface of the child's tongue, followed by topical anesthetic and buccal infiltration injection. Throughout the injection procedure, a video was recorded using a smartphone mounted on a tripod stand placed 6 ft away from the area of operation, to ensure that the child's entire body was visible. Post the injection, each child was instructed to rinse their mouths thrice with mineral water to remove any residual sweet solution and topical anesthetic. After rinsing, the children self-evaluated their pain levels using the Wong-Baker Faces Pain Rating Scale (WBFPS) by indicating the figure corresponding to their pain level on a scale of 0 − 10. The recorded video was then sent to three examiners via email. The examiners were trained in the scoring system, and inter-examiner reliability was assessed (kappa value 0.86). They observed the child's sound, eye, and motor movements during the injection and assigned an appropriate score on the Sound Eye Motor (SEM) scale, ranging from 1 − 4, indicating comfort to severe discomfort. The required endodontic procedure was carried out after the anesthetic injection.

3. Statistical analysis

All the data from this study was analyzed using SPSS software version 23 (IBM, Armonk, NY, USA). The SEM scores and the WBFPS scores of the two groups were analyzed by Kruskal–Wallis test and the post hoc Tukey analysis. ANCOVA test was applied to assess the effect of sweet preference on pain perception.

RESULTS

Demographic data including age, sex distribution, and sweet preference were analyzed. No statistically significant difference was found between the two groups, indicating that all parameters were matched at baseline (Table 1 and Table 2).

When considering the WBFPS scores in the study and control groups (Table 3), a statistically significant difference in the pain score across all groups was observed ($P < 0.001$). These results suggest a variation

Table 1. Distribution of study participants according to mean age

	Study group		Control group		Comparative statistics	Significance
	n	mean ± SD	n	mean ± SD		
Sub group 1 (Age group 3-5 years)	15	4.53 ± 0.743	15	4.27 ± 0.799	t = 0.947	P = 0.352
Sub group 2 (Age group 6-9 years)	15	7.33 ± 1.11	15	7.33 ± 1.17	t = 0.00	P = 1
Age group 3-9 years	30	5.93 ± 1.70	30	5.80 ± 1.84	t = 0.291	P = 0.77

n, number; SD, standard deviation.

Table 2. Distribution of study participants according to Gender for age group 3-9 years

	Study group		Control group		Comparative statistics	Significance
	Age: 3-5-years					
	n	%	n	%		
Male	11	73	9	60	χ^2=0.6	P = 0.43
Female	4	27	6	40		
				Age : 6-9-years		
Male	9	60	5	33.4	χ^2=2.1	P = 0.143
Female	6	40	10	66.6		
				Age : 3-9-years		
Male	20	66.6	14	46.7	χ^2=2.44	P = 0.118
Female	10	33.4	16	53.3		

n, number.

Table 3. Comparing the values of Wong-Baker Faces Pain Scale between the two study groups according to all age groups

	(Mean ± SD)	Severity index	Mean rank	Post hoc significance	Kruskal Wallis test
Study group 3-5 years	0.53 ± 1.18	Study group 3-5 years	16.10	1.00	P < 0.01*
		Study group 6-9 years	16.63	0.931	
		Control 3-5 years	46.20	< 0.01*	
		Control 6-9 years	43.07	< 0.01*	
Study group 6-9 years	0.67 ± 1.63	Study group 3-5 years	16.10	0.931	
		Study group 6-9 years	16.63	1.00	
		Control 3-5 years	46.20	< 0.01*	
		Control 6-9 years	43.07	< 0.01*	
Control 3-5 years	6.67 ± 2.22	Study group 3-5 years	16.10	< 0.01*	
		Study group 6-9 years	16.63	< 0.01*	
		Control 3-5 years	46.20	1.00	
		Control 6-9 years	43.07	0.69	
Control 6-9 years	5.87 ± 2.44	Study group 3-5 years	16.10	0.69	
		Study group 6-9 years	16.63	< 0.01*	
		Control 3-5 years	46.20	< 0.01*	
		Control 6-9 years	43.07	1.00	

*P < 0.05 - Statistically significant. SD, standard deviation.

in the reduction of pain during dental injection across all age groups with the application of sucrose solution.

Similarly, there was a statistically significant difference in the SEM score across all groups (P < 0.001). The results of this table indicate that there was a difference in the reduction of pain on dental injection across all age groups on the application of sucrose solution (Table 4).

Table 5 presents the ANCOVA for sweet preference across study and control groups categorized by age for the WBFPS and SEM scales. A statistically significant difference was observed in sweet preference and WBFPS score (P = 0.014). However, when the ANCOVA test was applied for the above-mentioned scores, no statistically significant difference was found in the sweet preference

Table 4. Comparing the values of Sound, Eye, and Body movement (SEM) scores between the two study groups according to all age groups

	(Mean ± SD)	Severity index	Mean rank	Post hoc significance	Kruskal Wallis test
Study group 3-5 years	1.33 ± 0.61	Study group 3-5 years	17.00	1.00	P < 0.01*
		Study group 6-9 years	18.17	0.849	
		Control 3-5 years	42.83	< 0.01*	
		Control 6-9 years	44.00	< 0.01*	
Study group 6-9 years	1.4 ± 0.63	Study group 3-5 years	17.00	0.849	
		Study group 6-9 years	18.17	1.00	
		Control 3-5 years	42.83	< 0.01*	
		Control 6-9 years	44.00	< 0.01*	
Control 3-5 years	3.13 ± 0.99	Study group 3-5 years	17.00	< 0.01*	
		Study group 6-9 years	18.17	< 0.01*	
		Control 3-5 years	42.83	1.00	
		Control 6-9 years	44.00	0.849	
Control 6-9 years	3.2 ± 0.77	Study group 3-5 years	17.00	0.849	
		Study group 6-9 years	18.17	< 0.01*	
		Control 3-5 years	42.83	< 0.01*	
		Control 6-9 years	44.00	1.00	

*P < 0.05 - Statistically significant. SD, standard deviation.

Table 5. Analysis of Co-variance for sweet preference across Study and Control groups according to age groups

For Wong Baker Scale			
Levene's Test of Equality of Error Variances			
F	df1	df2	Significance
1.055	3	56	0.376
Tests of Between-Subjects Effects			
Source	Mean Square	F	Significance
Corrected Model	76.087	24.106	< 0.001*
Intercept	129.473	41.021	< 0.001*
Group	51.785	16.407	< 0.001*
Sweet Preference	14.940	4.733	0.034*
Group * Sweet Preference	12.224	3.873	0.014*
For SEM scale			
Levene's Test of Equality of Error Variances			
F	df1	df2	Significance
2.875	3	56	0.044*
Tests of Between-Subjects Effects			
Source	Mean Square	F	Significance
Corrected Model	7.447	13.080	< 0.001*
Intercept	31.587	55.480	< 0.001*
Group	4.884	8.578	< 0.001*
Sweet Preference	0.374	0.656	0.422
Group * Sweet Preference	1.146	2.013	0.123

*P < 0.05 - Statistically significant. N, number; SD, standard deviation.

and SEM score (P = 0.123).

DISCUSSION

This study assessed the efficacy of sucrose application in minimizing pain perception related to dental injection across different age groups (3 – 9 years) in children. Additionally, the impact of sweet preference on pain perception was also evaluated. Heightened sweet preferences are observed during childhood, with a gradual decline during late adolescence and early adulthood [20]. An age-related decline in the hedonic value of sweet-tasting food has been suggested for the same [21].

A thorough literature search revealed only 2 studies that suggested sucrose-induced analgesia in children above 7 years of age [14,21]. Hence, for this study, an age range of 3 – 9 years was selected, further subdivided into two groups: 3 – 6 years and 6 – 9 years, to examine the potential influence of age on the perception of analgesia.

Since the mode of action is primarily a hedonic response to ingestion of sweet-tasting substance, it is hypothesized that children who do not prefer sweets may respond differently. Previous research indicated that children with a preference for sweets demonstrated increased latency to report pain during cold pressor test [19]. To test this hypothesis, the children's sweet preference was recorded before the start of the study using a forced-choice test. This test was further modified to include five pairs of locally available sweet and savory items. Children selecting three or more sweet foods were categorized as having a sweet preference.

Sucrose was selected for this study as it is the sweetest of all-natural sugars and is easily available. A 30% sucrose solution concentration was selected based on literature suggesting that sucrose concentrations between 20 - 30% reduce composite and multidimensional behavioral pain scores, as well as individual behavioral and physiological pain scores. Sucrose solution was applied rather than ingested as it is the sweet taste that induces analgesia rather than the sugar itself. Research indicates that the effectiveness of sucrose is at a maximum between 3 and 5 minutes of application and peaks at 2 min, an interval considered to coincide with the endogenous opioid release [22]. Ghadheri et al. (2020) [14] asked the subjects to hold 10 ml of sucrose solution in their mouth for 2 minutes before injection. In this study, sucrose solution was applied on the lateral surface of the tongue with a syringe without a needle as per AAP guidelines [11]. This was done over a period of 2 minutes and the injection was given within 5 minutes of application. This method of application over the lateral surface of the tongue was chosen as we had a young age group and it would have been challenging for the children to hold sucrose water in their mouths for an extended period.

Assessment of pain was done by both subjective and objective methods. In the subjective assessment, the WBFPS was used. Utilizing facial expression scales is simple, and the majority of them exhibit satisfactory to exceptional psychometric characteristics [23]. The WBFPS was selected, due to the young age group of children involved, who found it easier to indicate the image that best depicted their pain level. Generally, children prefer this type of assessment instrument when given a choice. Bieri et al. found that this assessment method could be properly used in children younger than 9 years of age [24]. The objective assessment of pain was performed using the SEM scale. Three independent examiners rated the pain scores based on the child's behavior while receiving the injection as recorded on video.

The primary mechanism underlying the analgesic effects of sweet solution is still under postulation, but numerous studies suggest that it may be attributed to the hedonic response to sucrose or to a sweet taste, which causes an increase in the release of endogenous opioids. Sweet palatable solutions enhance morphine-induced analgesia [25-28]. Research has indicated that when sweet solutions are orally consumed and stimulate one's sweet receptors, it can trigger the release of endogenous opioids [29]. Sucrose is said to reduce pain sensation when administered orally and not via gastric gavage [30]. Following the consumption of sweet substances, an increase in endogenous β-endorphin activity was observed in both rat brains and human plasma [30-32]. Besides the endogenous opioid system, other neurotransmitters and receptors are likely involved. A study conducted by Irusta et al. found that nicotinic cholinergic receptors play a significant role in the analgesic effects induced by sweet substances. The study also found that the administration of atropine, a cholinergic antagonist, reduced sucrose-induced analgesia [33] Currently, available evidence suggests that the process of reducing pain sensations may occur through both opioid and non-opioid pathways.

In this study, the age and gender were not statistically

significant at baseline, showing they were equally matched. A notable strength of this study is the inclusion of a wide age range. Regarding the sweet preference, there was no statistically significant difference between the study and control group, though it was noted that a majority of children in both groups preferred sweets.

Intergroup group comparison revealed a statistically significant difference in Wong-Baker pain scores, with scores being lower in the study group than in the control group ($P < 0.001$), which denoted a reduction in pain on dental injection after prior application of sucrose solution. Similarly, when considering the SEM scores, pain scores in study group were lower than those in the control group. This difference was statistically significant ($P < 0.05$), which also proves that the sweet solution reduces the pain on injection. These results were similar to those of Ghadheri et al. [14]. However, they contradict the studies done by Poulsen et al. and Slater et al. who reported that sucrose was not efficient in reducing pain in children [12,34]. It is suggested that sucrose may not directly reduce nociceptive activity in the central sensory circuits and may not be an effective analgesic drug [34].

According to the results of the present study, there was a notable decrease in pain perception with prior application of sucrose solution in 3 to 9 year old children during dental injections. These results were in accordance with previous studies carried out in infants and neonates [35,36]. These results were also in similar to the previous studies conducted in older children [14,21]. However, they contradict prior reports by Thyr et al. (2007), Slater et al. (2010) who reported that positive hedonic effect of sweet tasting substances decreases with growth and thus evokes less pleasure and analgesia [34,37].

In a previous study by Davangere Padmanabh et al. (2024), cryoanesthesia was reported to be superior to sweet solution analgesia. Cryoanesthesia works by cooling the injection site to prevent the local neuronal transmission of painful stimuli, which may explain its effectiveness. Additionally, their study noted that xylitol solution was more effective than the control group [17]. In a previous pilot study conducted by us in 2023, using xylitol in 5–7-year-old children, xylitol solution was found to be equally effective as sucrose solution in minimizing pain perception [16].

In the current study, when the sweet preference and the perception of analgesia were evaluated, a statistically significant difference in the sweet preference and the reduction of pain scores on subjective assessment (WBFPS) was observed. This implies that the children who preferred sweets reported lower pain scores. However, there was no statistically significant difference seen in the objective scale (SEM scale), further reinforcing hedonic response of sweet solutions. The limitations of the present study was that pulse rate and cortisol levels were not considered as objective assessment parameters and this could be incorporated in further research.

In conclusion, the present study demonstrates that prior application of 30% sucrose solution on the tongue minimizes the perception of pain during dental injection in 3–9-year-old children, as evidenced by the Wong-Baker and SEM scale. Sweet solution analgesia was achieved in 3–9-year-old children, indicating that age did not affect perception. While the child's sweet preference had a statistically significant difference when using the subjective Wong-Baker Faces Pain Rating Scale, it did not have a statistically significant difference when using the objective SEM scale.

Thus, 30% sucrose solution can be used as an adjunct to topical anesthetic to minimize the perception of pain during dental injection.

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