Effectiveness of Various Modes of Computerized Delivery of Local Anesthesia in Primary Maxillary Molars

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Abstract

Purpose: The purpose of this study was to compare the effectiveness of infiltration and intrasulcular injection, delivered by a computerized delivery system (CDS), to primary maxillary molars.

Methods: The study population consisted of 178 children (2-14 years old) who received local infiltration (buccal and palatal) or intrasulcular injection to primary maxillary molars with the use of a CDS. Behavior was managed using: (1) behavioral management techniques; (2) N_2O inhalation; or (3) sedation. Measured dependent variables included the: (1) child's subjective perception of well-being before and immediately after anesthesia (scale=0-100); (2) child's pain behavior during anesthesia, as measured by Children's Hospital of Eastern Ontario pain scale (CHEOPS; range=4-13); and (3) effectiveness of anesthesia during dental treatment.

Results: Low stress levels were shown for most children before and immediately after anesthesia (range=12-23). The CHEOPS rating for pain-distractive behavior associated with palatal and buccal infiltration and intrasulcular anesthesia by CDS was similar (6.0±1.9, 5.8±1.7, and 5.9±1.6, respectively). Children treated under sedation, compared to behavioral management techniques, showed higher CHEOPS scores (P=.004). The effectiveness of anesthesia using a CDS (infiltration and intrasulcular) had a downward trend, but was not significantly different for restoration (91%), pulpotomy and preformed crowns (79%), or extraction (74%; mean=86%). There was no significant difference between infiltration and intrasulcular effectiveness or for age, gender, or tooth location (primary maxillary first vs second molars).

Conclusions: CDS caused low levels of stress and pain reaction after palatal infiltration equal to that for buccal infiltration. All procedures achieved anesthesia effectiveness (86%), with no differences between primary maxillary first and second molars. (Pedaitr Dent 2006;28:29-38)

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Effective pain control in children during dental treatment is important to achieve comfort, cooperation, and compliance with dental care during adulthood.[1,2] Buccal infiltration (supraperiosteal injection) is the most routinely used procedure to anesthetize primary maxillary molars. It is easy to apply, generally nonpainful, and achieves effective anesthesia for dental treatment. It is insufficient, however, for placing a rubber dam, matrix, dental wedge, or preformed crown without pain or discomfort. Therefore, most treatments require a subsequent palatal injection together with the buccal infiltration, a procedure that is traumatic to many patients.

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Methods used to reduce pain during local anesthesia include: (1) application of topical anesthesia; (2) use of narrow needles; and (3) slow delivery of the injected solution.[3-5] Recently, a computerized system for slow delivery of local anesthetic was developed (Wand, Milestone Scientific, Inc, Deerfield, Ill). This computerized delivery system (CDS) has a microprocessor combined with an electronically controlled motor that enables delivery of a small volume of anesthetic solution under a controlled low pressure (even during injection to resilient tissues, such as the palate or periodontal ligament). The manufacturer suggests that administering injections with the system is potentially painless.[5]The cost of the basic unit is approximately $1,500; the disposable units necessary for individual injections (plastic tube, needle) are approximately $1.50 each.

CDS's effectiveness at reducing pain-related behavior during palatal infiltration has been evaluated, but with

conflicting results.[4-8] Allen et al[4] and Gibson et al[8] have shown that pain experienced during the computerized administration of a palatal injection was significantly lower, associated with less disruptive behavior, and required less restraint than the traditional, manual injection. In contrast, Asarch et al[6] have shown that infiltration and palatal anesthesia delivered by CDS or by the traditional method induced comparable pain-disruptive behavior. Nevertheless, most studies agree that there is no significant difference in the disruptive behavior of children when computerized administration is compared with the traditional buccal injection for maxillary molars.[6,8,9]

An insufficient anesthesia level can cause pain during operative treatment.[10] Factors that contribute to anesthesia difficulties in children include: (1) age[11,12]; (2) gender[3,12,13]; (3) symptoms[10,14-18]; (4) injection anxiety[10,19-22]; (5) initial dose of anesthetic solution administered[23,24]; (6) operative procedure performed[10,13]; (7) use of N_2O/oxygen inhalation or sedation[25]; and (8) the arch treated.[11,13,26] In addition, the deep location of the apex of the primary maxillary second molars beneath the zygomatic bone—which may be too dense and thick to allow adequate infiltration—can be associated with unsuccessful anesthesia in the buccal infiltration of primary maxillary molars.[27-29] Malamed[30] stated that the widely spread roots or palatal innervations of primary maxillary molars may be associated with anesthesia difficulty and, thus, may necessitate palatal anesthesia. Interestingly, although some textbooks in pediatric dentistry agree on the ineffectiveness of local infiltration in anesthetizing the primary maxillary second molar as compared to primary maxillary first molar,[27,28] there are no clinical studies that examine the extent of this issue.

The possible ineffectiveness of anesthesia of primary maxillary molars can usually be solved by anesthetizing the posterior alveolar nerve on the maxillary tuberosity.[27,28] This technique, however, has several disadvantages:

1. Since the mesio-buccal root of the primary maxillary second molar is not consistently innervated by just the posterior superior alveolar nerve, the maxillary block's effectiveness is limited.[27-31]
2. The prolonged duration of anesthesia after maxillary block increases the possibility of postoperative trauma, such as lip or cheek biting.
3. Hematoma can develop during anesthesia administration, due to penetration of the needle too far posteriorly into the pterygoid plexus of veins or as a result of perforation of the maxillary artery.
4. Anesthesia of the mandibular nerve can occur, since the mandibular division of the fifth cranial nerve is located lateral to the posterior superior alveolar nerves.[30]

Intraligamental injection administered by a high-pressure syringe was another approach used to solve problems of insufficient anesthesia.[32,33] Brännström et al,[34,35] however, have shown that anesthetic fluid injected under pressure can cause hypoplasia in the corresponding permanent dental bud. This technique also correlated with long postoperative pain (up to 7 days after injection) and a relatively short period of anesthesia for quadrant dentistry.[36-39]

Although the recently introduced intrasulcular anesthesia delivered by a low pressure delivery system (CDS) is delivered to the same area as the high pressure intraligamental injection, these 2 techniques differ. The CDS allows the operator to inject the anesthetic solution under low pressure (165 psi), which enables laminar diffusion into the attached gingiva and adjacent bone, and avoids damage to the adjacent tissue. In contrast, the intraligamental anesthesia—injected by a high pressure syringe—induces high pressure on the tissue (1,200 psi), causing: (1) ischemia; (2) transitional necrosis of the adjacent bone; (3) damage to the developing tooth buds; and (4) long postoperative pain.[34-38] While intraligamental injection causes more postoperative pain than an injection performed with a conventional syringe,[36-39] the prevalence of postoperative pain following CDS intrasulcular injection is similar to that of conventional injection.[43] Moreover, some researchers support the use of intrasulcular injection by CDS for primary teeth.[40,42,43] Notwithstanding, the possibility of damaging the underlying permanent tooth bud during CDS-IS requires further studies.

The purpose of the present study was to evaluate the recently introduced computerized delivery system (CDS) to administer local anesthesia to primary maxillary first and second molars in children with regard to the following parameters:

1. self-reported stress associated with administration of infiltration and intrasulcular injection;
2. child pain-related disruptive behavior during buccal and palatal infiltration and during intrasulcular administration;
3. effectiveness of anesthesia achieved in primary maxillary first and second molars; and
4. effectiveness of anesthesia regarding age, gender, and different behavioral management approaches, such as a nonpharmacological approach, N_2O, or sedation.

Methods

Study population

The study population consisted of 178 children (52% males), ages 2 to 14 years (mean=6.8±2.8 years), who attended 2 dental offices specializing in pediatric dentistry and who received dental treatment by 2 certified pediatric dentists (MA and SB). All children received local anesthesia to primary maxillary molars with the use of a computerized delivery system (CDS; Wand, Milestone Scientific, Inc, Deerfield, Ill).

During the study's first phase, 122 children were treated and anesthetized by local infiltration to the buccal mucosa and, subsequently, to the palatal mucosa (CDS-INF; mean age=6.7±2.6 years). During the second phase, 56 children were treated and anesthetized by injecting the solution into the intrasulcular region (CDS-IS; mean age=7.2±3.0 years).

The differences in the numbers between groups were due to results obtained by another study (carried out simultaneously) in which the CDS system was used to anesthetize primary mandibular molars.[43] The study proved that injecting the solution intrasulcular (CDS-IS) is a very efficient mode to achieve proper anesthesia. It was decided to use the CDS-IS in the maxillary region. Regarding age (P=.26), there were no differences between the children who received CDS-INF or CDS-IS.

Children were grouped according to age: (1) group 1 (2-4 years); (2) group 2 (5-8 years); and (3) group 3 (≥9 years). Children were also grouped according to behavior management approaches.

The computerized technology of local anesthesia administration was introduced to the parents who then gave their consent for their child's treatment plan. The Ethics Committee of Tel Aviv University, Tel-Aviv, Israel, approved the study.

Behavior management approaches

Proper behavioral cooperation from the children was achieved by:

1. behavior modification (BM; nonpharmacological) techniques only, such as:
   a. tell-show-do;
   b. desensitization;
   c. empathy;
   d. giving control by raising the left hand;
   e. retraining;
   f. behavior shaping;
   g. reframing; and
   h. distraction (BM);
2. inhalation of N_2O/oxygen (≤45% N_2O) in addition to BM; and
3. inhalation combined with sedation (intrarectal midazolam, 0.4 mg/kg, ≤7.5 mg[41]), where extra measures were necessary (SED).

The SED approach was used for uncooperative or very young children. The selection method for use of the behavior management technique only or in combination with N_2O, or sedation was not random, but based on the clinical experience of the treating dentist, as is usual in pediatric practice.

Computerized delivery system (CDS) for anesthesia administration

Each injection was preceded by an application of topical gel (Benzocaine 20%, Sultan Topex, Englewood, NJ) for 50 to 60 seconds on the corresponding buccal and palatal mucosa (for infiltration) or inside the sulcus (for intrasulcular injection) by placing a dental spatula dipped with topical anesthetic gel into the correspondent gingival sulcus. The CDS system, with a 30-gauge, extra-short needle—was used to administer the solution according to the manufacturer's recommendations.

Two modes of administration were used:

1. CDS-INF was administered in the buccal and palatal sites. Anesthetic solution was administered into the buccal corresponding alveolar mucosa and into the palatal corresponding alveolar mucosa.
2. CDS-IS was administered into the sulcus of the mesio-buccal root, disto-buccal root, and palatal root of the treated tooth. The needle was inserted parallel to the long tooth axis, and a drop of local anesthetic solution was immediately deposited before the needle entered the tissue. After 4 to 5 seconds, the needle was advanced apically and an additional volume of approximately 0.9 ml (18 mg) was administered to each root, as previously described.[42,43]

Lidocaine cartridges, 2% with 1:100,000 epinephrine (Octacain, Novocal Pharmaceutical of Canada, Cambridge, Ontario, Canada), were used for all procedures. The mean volume of injected solution was similar to the amount recommended for a routine infiltration rather than the amount used for intraligamental anesthesia injected by a high-pressure syringe.[40,42,43] This is because the local anesthetic solution diffuses mainly to the surrounding attached gingiva and bone (as witnessed by blanching of the attached gingival) when the low-pressure CDS is used.

The estimated volume of approximately 0.9 ml has also been determined as optimal in a former study.[43] Since leakage of the solution into the oral cavity often occurs, however, the actual injected volume is probably lower and should be studied further. Nevertheless, the amount of injected local anesthesia did not exceed 4.4 mg/kg body weight of the child.[44]

Rubber dam and rubber dam clamp were applied immediately after the local anesthetic solution was delivered and the operative treatment was initiated.

Data collection

Demographic data

A structured form was designed to collect all demographic and dental variables, including information about the:

1. patient's age;
2. gender;
3. approach of behavioral management used (behavior modification only, inhalation of N_2O, or sedation by intrarectal mediazolam);
4. tooth location; and
5. dental treatment procedure (composite or amalgam restoration, stainless steel crown, pulpotomy, or extraction).

Evaluation of child's subjective perception during administration of anesthesia

The child's subjective perception of well-being, before and immediately after administration of the anesthesia, was assessed using the self-report measure face picture scale (FPS). With the FPS, the child indicates 1 of 5 pictures (representing faces ranging from laughing to crying) that best represents his feeling at the moment (scores=0-100).[45,46] Children treated with only behavioral modification or in conjunction with N_2O were requested to respond to

this scale. Children who receive N_2O are often afraid but in control and could usually respond to this measure.[43] Although N_2O could affect their emotional status, it was still important to obtain the child's subjective impression of the new injection technique. Children under sedation were not able to complete this measure. Since the study was undertaken in a real dental clinical setting, it occasionally happened that the authors did not ask the child before the administration of anesthesia about their feelings. Therefore, there were some missing data.

Impartial evaluation of pain-reaction during administration of anesthesia

During anesthesia administration (buccal infiltration, palatal infiltration, or intrasulcular), children were observed by an impartial observer who did not participate in the treatment. Behavior was scored according to the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS),[47] which refers to several parameters (crying, facial display, verbal expression, torso, arm, and leg movements) and rated according to several possible behaviors. Total scores ranged from 4 to 13. A pilot study was conducted to validate the CHEOPS scale, in which the 2 participating pediatric dentists observed 15 patients and rated them separately. Each disagreement was discussed until full agreement was achieved. Afterward, each dentist familiarized the scale with the impartial observer in their private clinic and another 15 patients were observed, at which time complete agreement was achieved. These patients were not included in this study.

Usually, infiltration of the buccal mucosa has no effect on the palatal mucosa. Therefore, in CDS-INF, separate CHEOPS scores were obtained for buccal and palatal infiltration. In contrast, when intrasulcular anesthesia is applied at one of the proximal tooth sides, there is usually an apparent effect at the palatal side (evident as blanching of the palatal mucosa). Therefore, in CDS-IS only, one CHEOPS score was recorded for the entire procedure.

Because some changes occurred in the study outline as preliminary results emerged, separate CHEOPS scores for buccal and palatal injections were available for only 114 children,. Initially, the authors were not convinced about the effect of CDS on injection-associated pain. Therefore, the clinical procedure was to inject the anesthetic solution (with the use of CDS) both buccally and palatally and evaluate a child's behavior for the entire procedure as one. Once initial results emerged and the authors were convinced that the CDS system is effective at reducing injection-associated pain,[43] they decided to further compare the children's pain behavior when receiving buccal and palatal injections, separately.

Effectiveness of anesthesia

The effectiveness of the anesthesia (presence or absence of pain-disruptive behavior during treatment) was assessed by the clinician. Each single, even mild, sign of discomfort was rated as a positive presence of pain.[48] Anesthesia was rated as adequate only when the child was completely relaxed during treatment.

Statistical analysis

Interactions between CHEOPS scores, age, and behavior management approach were evaluated by 1-way analysis of variance (ANOVA). Association between CHEOPS scores, gender, and injection type were evaluated by *t* tests. Association between CHEOPS during buccal and palatal infiltration was evaluated using paired *t* tests. Interactions between CHEOPS scores during buccal and palatal injection, according to management approaches, were evaluated using ANOVA with repeated measures. The *t* test was used to evaluate the differences between FPS scores before and after anesthesia. The presence of possible associations between effectiveness and gender, age, behavioral management approach, dental procedure performed, and injection type was evaluated by Pearson's chi-square.

Results

Table 1 summarizes the distribution of patients according to age, behavior management approach, and local anesthesia type.

Dental procedures

Treatment was carried out on 52 first (29%) and 126 second (71%) primary maxillary molars. Procedures included 117 amalgam or composite restorations, 42 pulpotomies and preformed stainless steel crowns, and 19 extractions. Distribution of type of anesthesia in relation to operative treatment is shown in Table 2.

Pain associated with injection procedure Child's self-report (Table 3)

FPS scores before and immediately after administration of anesthesia were available for 32 children who received CDS-IS and 55 children who received CDS-INF. Generally, FPS scores were higher for both procedures (CDS-INF, CDS-IS) before injections (mean=18.1±31.1 and 22.6±27.6, respectively) than after (mean=13.0±23.2 and 12.0±16.3, respectively), with no significant differences between scores (P=.517 and *P*=.83, respectively) and no effect of gender, or injection technique (INF or IS). Children ≥9 years old gave significantly higher FPS scores before (*P*=.002) and after injection (P=.005) than children 5 to 8 years old.

CHEOPS scores (Tables 4 and 5)

To calculate the CHEOPS score for the entire CDS-INF procedure (buccal and palatal), the higher score for each variable during the CDS-INF procedure (buccal or palatal) was used. CHEOPS scores for all CDS-INF and CDS-IS procedures were available for 122 and 56 children, respectively. CHEOPS scores showed a low pain-related behavior during administration of anesthesia. There was no effect on age (*P*=.36) or gender (*P*=.12), but a significant effect of mode of anesthesia administration on CHEOPS scores was

Table 1. Distribution of Patients According to Age, Behavior Management Approach, and Anesthesia*

Anesthesia	Age (ys)	Behavior management approach: BM†	N_2O‡	SED§	Total
CDS-INF‖	2–4	2 (2%)	3 (3%)	26 (21%)	31 (25%)
	5–8	9 (7%)	34 (29%)	27 (22%)	70 (57%)
	≥9	12 (10%)	7 (6%)	2 (2%)	21 (17%)
Total		23 (19%)	44 (36%)	55 (45%)	122 (100%)
CDS-IS¶	2–4	1 (2%)	2 (4%)	12 (21%)	15 (27%)
	5–8	15 (27%)	7 (13%)	7 (13%)	29 (52%)
	≥9	8 (14%)	4 (7%)	0	12 (21%)
Total		24 (43%)	13 (23%)	19 (34%)	56 (100%)

*No. (%) of patients in each category.
†Behavior modification (nonpharmacological) techniques only.
‡Inhalation of N_2O/oxygen (≤45% N_2O) in addition to behavior modification.
§Inhalation of N_2O/oxygen combined with sedation (intrarectal midazolam).
‖Infiltration administered by a computerized delivery system.
¶Intrasulcular anesthesia administered by a computerized delivery system.

detected (P=.034). The behavior management approach was statistically correlated with pain-disruptive behavior during injection (P=.004). That is, children treated under sedation showed higher CHEOPS scores than children treated by behavioral management techniques.

Different CHEOPS scores for buccal and palatal CDS-INF were available for 114 patients, in which no significant differences were found (5.8±1.7 and 6.0±1.9, respectively; P=.24), although children tended to complain more about leakage of the bitter anesthetic solution during the palatal injection (P=.2).

Effectiveness of anesthesia (Table 6)

There were no significant differences between the 2 treating dentists concerning the effectiveness of anesthesia (P=.7). The overall effectiveness of CDS-IS and CDS-INF anesthesia in treating primary maxillary molars was 88% and 85%, respectively, with no effect for gender (P=.86) or the operative procedure (P=.095). The SED group showed a significantly lower anesthetic effectiveness than the BM group (P=.007). BM group children showed the highest effectiveness of CDS-IS and CDS-INF (100% and 96%, respectively), followed by the N_2O group (85% and 86%, respectively), and the SED group (74% and 80%, respectively). No correlation was found between age and the effectiveness of local anesthesia (P=.2).

There was no difference in anesthesia effectiveness between primary maxillary first and second molars (87% vs 86%, respectively; P=.926).

Discussion

The present study's purpose was to compare the effectiveness of infiltration and intrasulcular injection, delivered by a computerized delivery system, to primary maxillary molars. Although a standard randomization method was not used and 2 different pediatric dentists treated the children (with a possible operator bias for behavior), as much standardization as possible was used. The 2 treating dentists are faculty members from the Department of Pediatric Dentistry at Tel Aviv University who are involved in teaching behavioral management approaches to undergraduate dental students. Therefore, it is likely that their clinical judgment and treatment techniques are similar. Moreover, before initiating the study, an exact protocol was prepared that specified modes of injection administration, behavioral management, dental treatment, data collection, etc. The intention was not

Table 2. Effectiveness of Anesthesia Delivered by a Computerized Delivery System in Achieving Anaesthesia in Primary Maxillary First and Second Molars During Various Dental Procedures*

	Primary maxillary first molar: INF†	IS‡	Primary maxillary second molar: INF	IS	Mean effectiveness
Restoration	96% (21/22)	90% (9/10)	89% (57/64)	90% (19/21)	91% (106/117)
Pulpotomy and preformed crown	89% (8/9)	0/1	75% (15/20)	83% (10/12)	79% (33/42)
Extraction	33% (1/3)	86% (6/7)	50% (2/4)	100% (5/5)	74% 14/19
Total	88% (30/34)	83% (15/18)	84% (74/88)	90% (34/38)	86% (153/178)

*Percentage of effective anesthesia (number in parenthesis represents no. of teeth in each category).
†Infiltration administered by a computerized delivery system.
‡Intrasulcular anesthesia administered by a computerized delivery system.

Table 3. FPS* Scores According to Various Variables

	No.	FPS score before injection Mean (±SD)	FPS score after injection Mean (±SD)
Injection type			
CDS-IS†	32	22.6 (±27.6)	12.0 (±16.3)
CDS-INF‡ Buccal and palatal	55	18.1 (±31.1)	13.0 (±23.2)
t test		*P*=.517	*P*=.832
Gender			
Boys	40	17.6 (±28.8)	15.1 (±24.5)
Girls	47	22.1 (±30.6)	10.5 (±17.2)
t test		*P*=.497	*P*=.31
Age (ys)			
2–4	–	–	–
5–8	47	10.2 (±22.9)	7.1 (±15.8)
>9	34	33.2 (±32.5)	21.6 (±25.1)
t test		*P*=.002	*P*=.005
Behavior management approach			
BM§	41	28.2 (±29.9)	14.1 (±18.8)
N_2O‖	46	12.1 (±27.5)	11.2 (±22.6)
t test		*P*=.016	*P*=.524
CDS-INF			
BM	19	34.6 (±34.5)	16.5 (±22.8)
N_2O	36	9.6 (±25.8)	11.1 (±23.6)
t test		*P*=.007	*P*=.421
CDS-IS			
BM	22	23.5 (±26.0)	12.1 (±15.1)
N_2O	10	20.6 (±32.9)	19.8 (±6.2)
t test		*P*=.796	*P*=.951

*Face picture scale.
†Intrasulcular anesthesia administered by a computerized delivery system.
‡Infiltration administered by a computerized delivery system.
§Behavior modification (nonpharmacological) techniques only.
‖Inhalation of N_2O/oxygen oxygen (≤45% N_2O) in addition to behavior modification.

to change the patient's dental care, but to evaluate CDS' effectiveness in different clinical settings.

Generally, the stress levels reported by children before and immediately after anesthesia (as reflected by the FPS) were relatively low (approximately 12-23 on a scale of 0-100). Most children rated the injection experience as relatively nonstress provoking, which indicates that CDS anesthesia for primary maxillary molars was nonstressful with either CDS-INF or CDS-IS.

The pain associated with CDS injection, as evaluated by the pain-disruptive behavior during injection (CHEOPS), was also low (about 6 on a scale of 4-13 in both modes of injection). Scores regarding infiltration to the buccal and palatal mucosa were almost similar. The main difference was in the verbal complaint towards a bitter taste of the local anesthetic solution that leaked into the oral cavity during injection, mostly present during infiltration in the palatal area and during CDS-IS. This suggests that the palatal injection administered by CDS evokes low levels of pain, basically similar to the pain evoked by an infiltration to the buccal mucosa. This is an important improvement. The present findings agree with Allen et al[4] and Gibson et al,[8] who have shown that pain-disruptive behavior during CDS-INF to the palatal mucosa decreased significantly compared to the traditional syringe injection.

Interestingly, pain-disruptive behavior during injection and effectiveness of anesthesia were significantly correlated with behavior management approach. Children treated via SED showed significantly higher CHEOPS scores and lower anesthesia effectiveness scores compared to children treated with behavior modification techniques. This emphasizes the difficulty in interpreting pain-disruptive behavior in children who are in an advanced difficult to manage stage. In the present study, even a single, mild sign of discomfort, such as eye, hand, or body movements and sound was interpreted as pain. Obviously, children who are in an advanced difficult-to-manage stage are more prone to body movement and signs of discomfort—which, in the present study, were interpreted as ineffectiveness. Nevertheless, it is always preferred to mistakenly relate the disruptive behavior of a noncompliance child to a pain than to mistakenly relate a pain-related disruptive behavior to noncompliance.

Notwithstanding, an 86% overall effectiveness of all behavior management approaches (BM, N_2O, SED) and a 98% effectiveness in children receiving dental treatment by behavior management alone (BM) can be considered good. The high effectiveness of anesthesia may be related to routinely palatal anesthesia, which anesthetizes the palatal innervation in molars with widely spread roots.[30] Effectiveness of local anesthesia was not correlated with age, although younger children are usually treated under sedation. These results agree with Nakai et al,[10] who did not find an effect of

age on the effectiveness of local anesthesia. Furthermore, no interaction was found between effectiveness of anesthesia and gender, which is in accordance with Ram and Perez.[49]

CDS anesthesia was less effective in areas with pre-existing infection, which explains the downwards trend in anesthesia effectiveness for pulpotomy and extraction. This is in agreement with Nakai et al.[10] The relatively lower effectiveness of anesthesia in extractions, pulpal-therapies, and preformed crowns could be related to the fact that many of these teeth were symptomatic before treatment or associated with acute local inflammation, which could have reduced the efficacy of local anesthesia. Moreover, extractions and preformed crowns necessitate pressure on the tooth, which can be translated as pain and discomfort by the child patient.

According to several pediatric textbooks,[27,28] the effectiveness of local infiltration in the primary maxillary first molars is superior to that of the primary maxillary second molars. This is based on:

1. the anatomic findings of plexus formation of the middle and posterior superior alveolar nerves in the primary maxillary molars area; and
2. the maxillary bone thickness approaching 1 cm overlying the roots of primary maxillary second molars, which may interrupt adequate infiltration.[29]

Table 4. CHEOPS* Scores According to Gender, age, and Behavior Management Approach

Variables	n	CHEOPS scores Mean (±SD)	Statistical test†	*P* value
Gender				
Boys	92	6.5 (±2.1)	t test	T=1.53 *P*=.127
Girls	86	6.1 (±1.7)		
Age (ys)				
2–4	46	6.7 (±2.2)	1-way ANOVA	F =1.01 *P*=.366
5–8	99	6.2 (±1.8)		
≥9	33	6.2 (±1.9)		
Behavior management approach				
BM‡	47	**5.6 (±1.6)**	1-way ANOVA	F=5.712 *P*=.004
N_2O§	57	6.2 (±1.9)		
SED‖	74	**6.8 (±2.0)**		

*Children's Hospital of Eastern Ontario pain scale.
†Significant results marked by bold.
‡Behavior modification (nonpharmacological) techniques only.
§Inhalation of N_2O/oxygen (≤45% N_2O) in addition to behavior modification.

Table 5. CHEOPS* Scores According to Injection Type

Injection type	Variables	No.	CHEOPS scores Mean (±SD)	Statistical test†	*P* value
CDS-IS vs CDS-INF	CDS-INF‡ buccal and palatal	122	**6.5 (±2.1)**	t test	.034
	CDS-IS§	56	**5.9 (±1.6)**		
	Total	178	6.5 (±2.0)		
CDS-INF buccal vs palatal					
CDS-INF to buccal	BM‖	21	**5.2 (±1.3)**	ANOVA with repeated measures	.012
	N_2O¶	43	5.4 (±1.6)		
	SED#	50	**6.3 (±1.8)**		
	Total buccal	114	5.77 (±1.7)#		
CDS-INF to palatal	BM	21	**5.4 (±1.7)**	ANOVA with repeated measures	.08
	N_2O	43	5.7 (±1.7)		
	SED	50	**6.4 (±2.1)**		
	Total palatal	114	6.0 (±1.9)**	#Paired t test	.24

*Children's Hospital of Eastern Ontario pain scale.
†Significant results marked by bold.
‡Infiltration administered by a computerized delivery system.
§Intrasulcular anesthesia administered by a computerized delivery system.
‖Behavior modification (nonpharmacological) techniques only.
¶Inhalation of N_2O/oxygen (≤45% N_2O) in addition to behavior modification.
#Inhalation of N_2O/oxygen combined with sedation (intrarectal midazolam).
**Compared variables.

Table 6. Effectiveness of Anesthesia According to Several Variables

	Effectiveness*			
	Negative	Positive	Total	Pearson's chi-square; *P* value
Behavior management approach				
BM†	**1 (2%)**	**46 (98%)**	47 (100%)	9.79; .007
N_2O‡	8 (14%)	49 (86%)	57 (100%)	
SED§	**16 (22%)**	**58 (78%)**	74 (100%)	
Total	25 (14%)	153 (86%)	178 (100%)	
Gender				
Boys	13 (14%)	79 (86%)	92 (100%)	0.001; 1
Girls	12 (14%)	74 (86%)	86 (100%)	
Total	25 (14%)	153 (86%)	178 (100%)	
Age (ys)				
2-4	10 (22%)	36 (78%)	46 (100%)	3.17; .2
5-8	12 (12%)	86 (88%)	98 (100%)	
>9	3 (9%)	30 (91%)	33 (100%)	
Total	25 (14%)	152 (86%)	177 (100%)	
Tooth treated				
Primary maxillary first molar	7 (14%)	45 (87%)	52 (100%)	0.21; 1
Primary maxillary second molar	18 (14%)	108 (86%)	126 (100%)	
Total	25 (14%)	153 (86%)	178 (100%)	
Injection type				
CDS-INF‖	18 (15%)	104 (85%)	122 (100%)	0.162; .82
CDS-IS¶	7 (13%)	49 (88%)	56 (100%)	
Total	25 (14%)	153 (86%)	178 (100%)	
Dental treatment type				
Restoration	11 (9%)	106 (91%)	117 (100%)	6.36; .095
Pulpotomy	4 (21%)	15 (79%)	19 (100%)	
Extraction	5 (26%)	14 (74%)	19 (100%)	
Preformed crown	5 (22%)	18 (78%)	23 (100%)	
Total	25 (14%)	153 (86%)	178 (100%)	

*Significant results marked in bold.
†Behavior modification (nonpharmacological) techniques only.
‡Inhalation of N_2O/oxygen (≤45% N_2O) in addition to behavior modification.
§Inhalation of N_2O/oxygen combined with sedation (intrarectal midazolam).
‖Infiltration administered by a computerized delivery system.
¶Intrasulcular anesthesia administered by a computerized delivery system.

In the present study, all primary maxillary molars received buccal infiltration (or intrasulcular anesthesia to buccal roots) and palatal anesthesia. This enabled a high anesthesia effectiveness (86%) and a similar effectiveness for both primary maxillary first and second molars (*P*=.926). This supports the contention of Malamed[30] that primary maxillary molars can have palatal innervations or divergent roots, which can benefit from palatal anesthesia. This further emphasizes the need for controlled clinical research.

CDS-IS and CDS-INF have similar effectiveness when it comes to: (1) child subjective perception of well-being (FPS); (2) pain behavior during injection (CHEOPS); and (3) effectiveness of anesthesia. Nevertheless, CDS-IS anesthesia has several minor disadvantages that should be considered:

1. bitter taste during injection caused by leakage of the solution into the oral cavity and, in some cases, resulting in negative behavior;

2. inability to calculate the precise amount of injected local anesthetic solution due to solution leakage into the oral cavity, which is extremely important, especially in very young children who need sedation and several dental treatments;
3. longer injection time; and
4. high costs caused by the relatively high price of disposable units (plastic tubule) necessary for the injection.

Conclusions

Based on this study's results, the following conclusions can be made:

1. A mean of 86% anesthesia effectiveness was achieved for all procedures with the use of a computerized delivery system (CDS).
2. CDS caused low levels of stress and pain-disruptive behavior reaction after palatal infiltration that was equal to that for buccal infiltration.
3. Infiltration and intrasulcular administration of anesthesia with the use of CDS show a comparable effectiveness rate in achieving anesthesia in primary maxillary first and second molars.
4. There was no significant difference between CDS-INF and CDS-IS in the effectiveness of anesthesia.
5. Age and gender had no effect on anesthesia effect or pain perception.

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