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Computerized anesthesia delivery system vs. traditional syringe: comparing pain and pain-related behavior in children

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The aim of this study was to compare the behavioral reaction of children who receive local anesthesia with a traditional syringe with the behavioral reaction of children who receive local anesthesia with a computerized device (Wand) and to differentiate between the reactions of highly anxious children with those displaying low anxiety. One hundred and twenty-five children aged 4–11 yr were randomly allocated to receive local anesthesia with the Wand or a traditional injection. Parents completed the Dental Subscale of the Children's Fear Survey Schedule (CFSS-DS). Two independent observers scored videotapes of the anesthesia in 15-s intervals. The occurrence of muscle tension, crying, verbal protest, movement, and resistance was registered and a score was given on the Venham distress scale. The mean injection time with the Wand was four times as long as with the traditional syringe. During the first 15 s of the injection, low-anxious children receiving local anesthesia with the Wand displayed less muscle tension, less verbal protest and less movement than children receiving local anesthesia with the traditional syringe. Within the high-anxious group no differences were found. It was concluded that low-anxious children seem to benefit from the use of the Wand instead of the traditional syringe in receiving local anesthesia.

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Pain is a complex multidimensional phenomenon (1). Many contextual, psychological, and physiological factors may moderate the relation between the pain stimulus and the pain response. In children, the level of maturation of physical, cognitive, and emotional systems are also of influence (2, 3). In addition, the characteristics of the painful stimulus, such as intensity, duration and location, seem to directly influence the relation between pain stimulus and response.

Dental visits are often associated with pain, particularly when an injection is expected. An injection can also provoke anxiety, particularly in children. Research shows that $\approx$14% of 4–11-yr-old Dutch children are dentally anxious, and the strongest fears are associated with injections (4, 5). While patients' fears may be acquired through vicarious experiences and threatening information, direct experience is the most common source of dental fear (6). This occurs despite many dentists having developed the skill of delivering almost painless injections, although a totally painless injection is impossible to achieve in all circumstances. As a consequence, there is a constant search for ways to avoid the invasive and often painful nature of the injection, and to find more comfortable and pleasant means of producing local anesthesia before starting the dental procedure. One of the systems developed to address the shortcomings of traditional dental syringes is the Wand system (7). The Wand device is a computer-automated injection system that provides a precise injection flow-rate, regardless of tissue resistance. The system maintains a constant positive pressure on the flow of the anesthetic solution. It is claimed that when advanced slowly, the drops of solution anesthetize the tissue ahead of the needle, thereby yielding a virtually painless needle insertion (7).

A few studies have been conducted (Table 1) using the Wand in children. Some of these studies found a reduction in disruptive behavior as a result of the use of the Wand system (8–11). Other studies did not find a reduction of pain when using the Wand in comparison with the traditional injection (12, 13). However, in at least one study (12), the Wand system was not used in accordance with the instructions of the manufacturers (14). Furthermore, it was found that children tended to react positively to both injection systems, possibly because the traditional injection was also administered at a slow speed (13).

The divergent results could be a consequence of the large age span used in some studies as this causes difficulty in choosing instruments that are valid for the total age group. Moreover, the behavioral pain response of the children can be difficult to assess in older children because their behavior is influenced by self- or social

Table 1

Studies with children and the Wand in dentistry

Author	*n*	Age (yr)	Design*		Injection†	Pain behavior	Pain self-report	Result
Asarch *et al.* (12)	57	5–13	1	Topical anesthetic (30–45 s)	a,b,c	Body movement, crying, restraints, dentist interference.	VAS	No difference
Gibson *et al.* (8)	62	5–13	1	Topical anesthetic (60 s)	b,c and d,e	Body movement, crying, restraints, temporary halt to treatment.	VAS	Fewer disruptive behaviours. First 15 s (palatal). No difference (buccal). No difference in the pain rating at all.
Allen *et al.* (9)	40	2–5	1	78% male. Topical anesthetic (30 s)	b,c and d,e	Body movement, crying, restraints, temporary halt to treatment.	None	Fewer disruptive behaviors with the Wand and less restraint.
Ram *et al.* (10)	98	2–4	1	Hydroxyzine and nitrous oxide	c and f	Facial display, arm/leg movements, torso movements and crying.	None	Fewer children reacted negatively to the Wand, no signs of discomfort after treatment.
Ram *et al.* (13)	55 47	3–5 6–10	1, 2	Topical anesthetic gel	g, h	Facial display, arm/leg movements, torso movements and crying.	None	No difference in pain behavior.
Palm *et al.* (11)	33	7–18	3	Topical anesthetic (60 s)	h	Crying, moving the head or other disruptive behaviors.	VAS	None of the children reacted with any disruptive behaviors. Pain ratings were higher after the traditional injection than after the Wand.

*1. Randomized controlled trial. 2. Random crossover design. 3. Split-mouth design.
†a, inferior alveolar block; b, palatal; c, buccal; d, palatal approach to anterior and middle superior alveolar nerves; e, anterior superior alveolar nerve; f, periodontal ligament injection; g, maxillary infiltration; h, mandibular block.
VAS, visual analogue scale.

control (15). It is reasonable to expect a change in the pain response by changing aspects of the painful stimulus. The use of the Wand includes changing the duration, intensity, and location of the pain stimulus.

The purpose of the present study was to compare the pain response of children who received local anesthesia with a traditional syringe injection and a computerized device (Wand), and to study the possible influence of several child characteristics – gender, age, and level of dental anxiety – on the pain response.

Material and methods

Participants

Following a power calculation (power 0.80, α □ 0.05, medium effect size on the Venham distress scale) (16), a sample size of 63 subjects per injection method was found to be necessary. Therefore, this study was conducted among 125 children (57 girls) aged 4–11 yr [mean age 6.2 yr; standard deviation (SD) 1.6]. Children were selected as a convenience sample of patients treated by two pediatric dentists in a specialist clinic. The reasons why the children were referred to the specialist dentist were heterogeneous. Most of the group was referred because of behavior management problems. Other reasons included extensive caries, young age, or their usual dentists being uncomfortable treating children. The selection criteria included: need for treatment requiring local anesthesia; age between 4 and 11 yr; fluent in Dutch; and no suspected or known developmental delay. All children who visited the specialist clinic in a period of 4 months were included in the randomization process. In this study, only children recently referred were included ($n = 130$), which also explains the difference in group size (see Table 2). Five children had to be excluded afterwards: two because they were too old; one because of technical difficulties with the video recorder; and two because the dentist did not adhere to the randomization protocol.

Table 2

Basic characteristics of the study population

	Injection method	
	Traditional ($n = 58$)	Wand ($n = 67$)
Age (yr)	6.0 (4–10.5)	6.4 (4–11.0)
Gender (girls)	31 (53%)	26 (39%)
Mean score CFSS-DS (min.–max.)	30.7 (16–49)	32.7 (15–57)
Local anesthesia in past 6 months	20 (37%)	23 (38%)

CFSS-DS, Dental Subscale of the Children's Fear Survey Schedule; max., maximum; min., minimum.

Ethical approval was obtained from the University Ethics Committee and the Interuniversity Dentistry Research School (IOT) at the Academic Center of Dentistry, Amsterdam. Written parental consent was obtained by the researchers before every individual treatment. The authors have no connection with the manufacturers of the Wand.

Methods

All treatments were videotaped and analyzed by two independent observers – a psychologist and a third year dental student. Both observers were extensively trained using video recordings of patients who were not included in the study.

Each child was randomly assigned to either the Wand or the traditional injection condition, based on a randomization list generated by SPSS (SPSS, 11.0; Chicago, IL, USA). The randomization was checked for age, gender, dental anxiety, and previous experience with local anesthesia. To avoid possible preference of the dentists, they were required to decide on the tooth to be treated before the anesthetic condition was told. As all children had been referred only recently, the dentist could easily explain the anesthesia procedure similarly for both techniques, and the dentists announced local anesthesia as a special child injection. Wand injections for maxillary teeth used one of two insertion sites – the anterior middle superior alveolar (AMSA, $n = 9$) or the palatal anterior superior alveolar (PASA, $n = 28$) – and in the lower jaw the periodontal ligament (PDL, $n = 25$) was used. Traditional anesthesia was performed after topical anesthetic had been placed in the area of the injection site for 60 s. For maxillary teeth, buccal ($n = 27$) and palatal ($n = 5$) injection sites were used, whereas in the mandible only the mandibular block ($n = 26$) anesthesia was given.

Measurements

Pain-related behavior: Five different pain-related behaviors were recorded as being present or absent during each 15-s interval of the injection phase: 1, body movement (movement of more than 15 cm of an extremity or turning of the body); 2, muscle tension, clear tension in the hands (white knuckles), or tension of the body; 3, crying or screaming; 4, verbal protest; and 5, bodily resistance, when it was needed to hold the child.

Distress: Because the behavioral response of children in dentistry is often a mixture of anxiety and pain, and because these two concepts are difficult to separate (17), it was decided to also assess distress behavior. Distress behavior can be defined as an occurrence of emotions felt or behavior displayed, during (dental) treatment, which is caused by factors like pain, fear, anxiety, and anticipatory or situational stress. The distress behavior was measured using Venham's (modified) clinical rating of anxiety and co-operative behavior. The scale consists of 6 points: 1, relaxed; 2, uneasy; 3, tense; 4, reluctant; 5, resistant; and 6, out of contact or untreatable. The scale has an established reliability and validity (18, 19).

Self-reported pain: The pain experience of the child was measured using a modified version of the visual analog scale (VAS). The scale resembled a thermometer and consisted of 11 points on a scale of 0 (no pain) to 10 (worst pain possible). Six faces, expressing different levels of pain/distress, were presented parallel to the scale so that young children could point out the face matching their own level of pain/distress (20).

Dental anxiety: To assess the level of dental anxiety, the parent was asked to complete the Dental Subscale of the Children's Fear Survey Schedule (CFSS-DS) on behalf of their child. As younger children are unable to complete the CFSS-DS on their own, and to enable comparisons between different age groups, it was decided to use the parent's version of the CFSS-DS. The CFSS-DS has been extensively validated and consists of 15 items, related to various aspects of dental treatment (e.g. 'how afraid is your child of the noise of the dentist drilling or having somebody examine their mouth'). Each item is scored on a 5-point scale, from 1 (not afraid at all) to 5 (very afraid). Total scores thus range from 15 to 75. Previous research has indicated scores below 32 as non-clinical. Children scoring in the 'non-clinical range' are generally not or only a little fearful, and are expected not to cause problems during treatment. Of the Dutch child population, 14% suffers from some degree of dental fear, as evidenced by CFSS-DS scores of > 32 (5).

Procedure

Each treatment session was videotaped from the moment the child entered the treatment room until the end of the local anesthesia. The period from entering the room until the start of the local anesthesia (when the needle touched the mouth) was designated the anticipation phase. The period from the start until the end of the local anesthesia (the needle leaving the mouth) was divided into 15-s intervals. For each interval, the observers coded the occurrence of the five pain-related behaviors and gave an overall distress score on the Venham scale. After the dental injection, when the child was calm (e.g. after a sip of water), the dentist presented the modified VAS to the child and read aloud the standardized instructions. Then, the child was asked to point out his or her level of pain on the scale. While the child was being treated, the parents filled out the CFSS-DS. As part of the routine in the dental clinic, parents were not present during treatment.

Observer's evaluation

A reliability exercise was performed using 20 cases from a training video. Results showed good agreement between two observers (intraclass correlations: 0.87 for Venham scale and 0.93 for pain-related behaviors). The videotapes from the study were evaluated by both observers independently and, in the event of disagreement, a final rating was reached by joint decision.

Data analysis

Distress scores on the Venham rating scale for the anticipation phase, and for the first and the second interval, were analyzed using a multivariate general linear model (GLM) (no covariates). Self-reported pain (VAS) was compared across the two groups using the *t*-test for independent samples. The different pain-related behaviors were compared across the two groups using the Pearson χ^2-test. Only the first 30 s could be compared because after 45 s the number of subjects anesthetized using the traditional system was too small for analysis.

Results

First, no difference was found between the two experimental groups regarding age, gender, mean level of dental anxiety, and children's experience with local anesthesia injections (Table 2). Furthermore, no differences were found between the two dentists on the variables mentioned above.

The Wand injection was found to take an average of 152.5 s (SD = 40.6), whereas the traditional injection took an average of 33.9 s (SD = 20.0). No differences were found relating to the distress response and the

self-reported pain of the children between the different injection techniques for the Wand (the AMSA, PASA or PDL), or for the traditional injection techniques (buccal, palatal or mandibular). Therefore, the injection site is not included as a variable in the statistical analysis.

Pain-related behavior

During the anticipation phase, no significant differences were found within the pain-related behaviors for the Wand and the traditional injection, although the pain-related behaviors tended to occur less often before an injection using the Wand. During the first 15-s interval of the injection, children in the Wand group showed less body movement, muscle tension, and verbal protest than children in the traditional-injection group. During the second 15-s interval of the injection, children injected using the Wand still showed less muscle tension and less verbal protest (Table 3).

Distress

Less distress was displayed during the first two intervals of the injection phase when injected using the Wand than when injected in the traditional way although this difference did not reach significance (multivariate GLM, $F(3,105) = 1.29$, $P = 0.283$; first 15-s interval, mean 1.09 vs. 1.48; second 15-s interval, mean 1.09 vs. 1.52) (Table 4).

Self-reported pain

No difference was found for the self-reported pain of the children. The mean pain score was 4.40 (SD = 3.22) for the Wand injection and 3.76 (SD = 3.57) for the children injected with the traditional method.

Dental anxiety

The mean dental anxiety score for the combined sample was 31.8 (SD = 9.6). When the group was divided into low-anxious ($n = 50$) (scores < 32) and high-anxious ($n = 49$) children, the mean anxiety scores were 24.5 (SD = 4.9) and 40.3 (SD = 6.1), respectively. Significant differences were found between the low- and high-anxious groups regarding the pain-related behaviors. It was found that highly anxious children were significantly more likely to cry than low-anxious children during anticipation and the first two intervals of the injection (anticipation: 26% vs. 5%, $P = 0.002$; first 15-s interval: 49% vs. 31%, $P = 0.047$; second 15-s interval: 59% vs. 22%, $P = 0.001$). Furthermore, it was found that highly anxious children more frequently have muscle tension during anticipation (69% vs. 41%, $P = 0.003$), and protest verbally during the first 15 s of the injection, than low-anxious children (29% vs. 14%, $P = 0.041$). Differences were also found regarding the Venham distress scores, as highly anxious children showed more distress during the anticipation phase and during the first two 15-s intervals of the injection (multivariate GLM: $F(3,95) = 3.39$, $P = 0.021$) (Table 5).

Low-anxious children reacted more positively to the Wand than to the traditional injection. During the anticipation phase, low-anxious children displayed body movement less frequently when injected with the Wand (29% vs. 3%, $P = 0.007$). During the first interval of the injection they displayed muscle tension (93% vs. 65%, $P = 0.009$), body movement (32% vs. 10%, $P = 0.032$) and verbal protest (29% vs. 0%, $P = 0.001$) less often,

Table 3

Frequency of pain-related behaviors during the anticipation phase, and the first and second injection interval

	n	Muscle tension	Cry/ scream	Verbal protest	Body movement	Resistance
Anticipation						
Traditional	58	62	19	10	24	9
Wand	67	49	13	8	12	5
First interval						
Traditional	58	91**	50	26*	35**	14
Wand	67	72**	33	12*	13**	8
Second interval						
Traditional	42†	93*	45	12*	17	14
Wand	67	73*	37	2*	18	8

The results are expressed in per cent.
*Significant difference between the two groups, χ^2-test, $P < 0.05$.
**Significant difference between the two groups, χ^2-test, $P < 0.01$.
†Sixteen traditional injections finished during the second 15-s interval and are therefore not included in the analysis.

Table 4

Mean Venham distress scores for the Wand and the traditional injection

	Injection method	
Injection phase	Traditional* ($n = 42$)	Wand ($n = 67$)
Anticipation	1.12 (0.78–1.46)	0.81 (0.54–1.08)
First 15-s interval	1.48 (1.13–1.83)	1.09 (0.81–1.37)
Second 15-s interval	1.52 (1.18–1.87)	1.09 (0.82–1.37)

The results are expressed as mean value (95% confidence interval).
*Sixteen traditional injections finished during the second 15-s interval and are therefore not included in the analysis.

Table 5

Mean distress score on the Venham scale for low- and highly-anxious children

	Dental anxiety		
Injection phase	Low ($n = 50$)	High ($n = 49$)	*P*-value
Anticipation	0.66 (0.36–0.96)	1.10 (0.80–1.40)	0.043
First 15-s interval	0.90 (0.60–1.21)	1.59 (1.28–1.90)	0.002
Second 15-s interval	0.94 (0.64–1.24)	1.61 (1.31–1.92)	0.002

The results are expressed as mean value (95% confidence interval).

and in the second interval they displayed muscle tension (95% vs. 65%, $P = 0.015$) and verbal protest (21% vs. 0%, $P = 0.008$) less often when injected with the Wand (Table 6). The children in the Wand group also had a lower Venham distress score in the anticipation phase and during the first two intervals (anticipation phase, mean 0.45 vs. 1.00; first interval, mean 0.65 vs. 1.32; second interval, mean 0.68 vs. 1.37) (Table 7). However, multivariate analysis showed that this difference was not statistically significant (multivariate GLM: $F(3,46) = 2.13$, $P = 0.110$).

When the reaction of highly anxious children to the Wand injection and the traditional injection was compared, no significant differences were found on the pain-related behaviors or the Venham distress scores.

Gender

Girls were less likely to display muscle tension in the first two intervals when injected with the Wand in comparison with the traditional injection (first interval: 65% vs. 94%, $P = 0.007$; second interval: 69% vs. 97%, $P = 0.017$). Boys showed verbal protest (10% vs. 30%; $P = 0.035$) and body movement (12% vs. 37%; $P = 0.016$) less frequently in the first interval and also less verbal protest in the second interval (0% vs. 16%; $P = 0.009$) when injected with the Wand.

Discussion

The pain response of children receiving a local anesthesia injection with the Wand in comparison with the traditional method was more positive during the first 30 s, as they showed less body movement, less muscle tension, and less verbal protest. Girls were found to show less muscle tension in response to a Wand injection, and boys showed less verbal protest and less body movement. In particular, low-anxious children seem to benefit from an injection with the Wand system in comparison to an injection with the traditional syringe, as demonstrated by less pain-related behavior (such as muscle tension, body movement and verbal protest).

Highly anxious children did not seem to benefit from the use of the Wand. Their reactions to both injection systems were similar, probably because of a ceiling effect. It is generally found that anxious children have higher distress scores in response to an injection than low-anxious children, and they also display more crying, muscle tension, and verbal protest. This group of children is already highly sensitive and distressed when entering the treatment room and it seems that the pain-related behavior is not influenced by the type of injection method. In a study by Ram & Peretz (13) a trend was found for children who reacted negatively to one technique to react in the same way to the other. Further study seems necessary, as the relationship of the anxiety level with the anticipation to aversive stimuli is only partially explained. It seems that the Wand primarily influences the response of low-anxious children as they experience the negative stimulus (injection) more consciously. The highly anxious children have been overstimulated much earlier in the process by situational factors and therefore they may not be able to experience the process in full consciousness. In order to positively change the anxiety threshold of these highly anxious children during the anticipatory part of the treatment, more treatment sessions are probably needed. It is possible that the use of the Wand system in sequential visits may have a positive effect for highly anxious children, as the longer injection time of the Wand system permits habituation.

No difference was found in self-reported pain of the children between the two conditions. One reason for this might be that the recording of self-reported pain in young children is not always reliable. In some 4–5-yr-old children the cognitive level is not yet sufficiently developed to understand the pain scale used in this study. However, analyzing only the self-reported pain of the older children did not change the results. Furthermore, although time was taken to calm the child during the study, it is possible that some children are still aroused from the injection at the moment the question is asked

Table 6

Frequency of pain-related behaviors during the anticipation phase, and the first and second injection interval, among low-anxious children

	n	Muscle tension	Cry/ scream	Verbal protest	Body movement	Resistance
Anticipation						
Traditional	28	50	11	7	29**	4
Wand	31	32	0	0	3**	0
First interval						
Traditional	28	93**	39	29**	32*	7
Wand	31	65**	23	0**	10*	7
Second interval						
Traditional	19†	95*	26	21**	11	5
Wand	31	65*	19	0**	13	3

*Significant difference between the two groups, χ^2-test, $P < 0.05$.
**Significant difference between the two groups, χ^2-test, $P < 0.01$.
†Nine traditional injections finished during the second 15-s interval and are therefore not included in the analysis.

Table 7

Mean Venham distress scores for the Wand and traditional injection for low-anxious children

	Injection method	
Injection phase	Traditional* ($n = 19$)	Wand ($n = 31$)
Anticipation	1.00 (0.61–1.39)	0.45 (0.15–0.75)
First 15-s interval	1.32 (0.87–1.76)	0.65 (0.30–1.00)
Second 15-s interval	1.37 (0.91–1.83)	0.68 (0.32–1.04)

The results are expressed as mean value (95% confidence interval).
*Nine traditional injections finished during the second 15-s interval and are therefore not included in the analysis.

and therefore are too upset to be capable of rating their pain, thus influencing the self-reported pain result.

Interesting differences were found in the behavioral reaction of boys and girls. It appears that the Wand system reduces internalizing behavior (such as muscle tension) in girls and externalizing behavior (such as verbal protest and body movement) in boys. Reducing externalizing behavior during treatment is of great importance because it often leads to behavior-management problems, thereby complicating the treatment of these children. Behavior-management problems are the most important reasons why children are referred to the specialized pediatric dentist. A study by TEN BERGE *et al.* (21) indicated that children referred to a special dental care center not only suffer from high dental fear but also have problems in several other behavioral and emotional areas. These problems appear to be heterogeneous; they were found in several specific problem areas, both external and internal (21).

The injection time of the Wand was much longer than that of the traditional method. Even so, time is saved because no additional time is needed for the setting of the local anesthesia. However, children who are already reacting negatively to the injection are thus longer in distress with the Wand system. On the other hand, the longer injection time of the Wand system may facilitate fear habituation, whereas a shorter duration may actually sensitize an already mildly anxious patient by not allowing sufficient time for habituation. As a result of its longer injection time, the Wand creates an opportunity for the dentist to teach a child to cope with the injection, which may change the child's behavior during a future local anesthesia injection. Further research is needed to test this hypothesis.

In this study, the injection method of the dentists, when using the traditional syringe, was left unchanged. However, injecting more slowly could have led to a different reaction of the children during the injection. It was also decided not to use a topical anesthesia when injecting with the Wand. Again, the reaction of the children could have been different when a topical anaesthetic was used. Furthermore, the results concerning the pain-related behaviors should be interpreted with caution. Taken all together, the Wand injection causes less pain-related behavior. However, not all children seem to benefit equally from the use of the Wand system. It seems that low-anxious children have the most positive reaction, which makes the Wand a useful system in normal practice.

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