Local Anesthesia
Feature Article

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Abstract

Thirty patients received maxillary infiltration and mandibular inferior alveolar nerve block injections with both a traditional syringe and a computerized system, the Wand. Patients noted their preference for either system and rated their injection pain and postoperative discomfort on a ten-point scale for each type of injection. Mean injection discomfort ratings with the Wand were lower than with the syringe but were not statistically significant. Reduced postoperative discomfort using the Wand for the inferior alveolar nerve block was significant. Both of the dentists in the study and those patients who stated a preference favored the Wand system.

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Pain perception and utility: A comparison of the syringe and computerized local injection techniques

Acceptance of dental treatment was facilitated by the hypodermic syringe and the introduction of procaine and, subsequently, of lidocaine amide as anesthetic agents in the early 20th century.[1] Despite advances in anesthetic devices, agents, and techniques, complete control of pain and anxiety associated with injections is not possible. Studies report that 20–23% of the population is highly anxious about dental treatment.[2] Many patients recall painful treatment associated with an injection and regard the needle/syringe with fear.[3] These individuals may delay or avoid dental treatment or endure treatment with great distress. Physical and psychological stress related to the injection also may complicate therapy. Studies of medical emergencies occurring during dental treatment indicate that 55% are due to psychogenic stress or excessive anesthetic uptake by the cardiovascular system within five minutes of the injection.[4]

Many measures to alleviate discomfort associated with an injection have been tried. Premedication with sedative-hypnotic/relaxation drugs (for example, nitrous oxide, barbiturates, and tranquilizers) is well-documented.[5] A number of newly introduced anesthetic devices indicate professional interest and a receptive market. Recent devices include a transcutaneous electronic nerve stimulation (EDA, 3M Dental, St. Paul, MN; 800/364-3577), a needleless injection system (MadaJet XL, Mada, Inc., Carlstadt, NJ; 800/526-6370), an intraosseous injection system (Stabident, Fairfax Dental Inc., Miami, FL; 800/233-2305), and a cutaneous delivery bioadhesive patch (DentiPatch, Noven Pharmaceuticals, Miami, FL; 888/55-NOVEN).[6]

Nevertheless, the traditional syringe still is the primary means of administering local anesthesia and, therefore, is the focus of attention. Research has shown that some variations, such as usage of minimal gauge needles and prewarmed cartridges, are not effective in reducing discomfort.[7,8]

Malamed states that a burning/painful sensation during an injection comes primarily from administering the anesthetic too rapidly or with too much force.[9] The recommended time to administer 1.8 cc of solution to prevent tissue damage or serious reaction is a minimum of 60 seconds. However, a recent survey reports an average injection time of only 20 seconds.[9]

Injection pressures also vary widely because of the wide variance in soft tissue elasticity. Palatal injections may require pressures as high as 660 psi, so digital control of a syringe may be difficult, erratic, and uncomfortable.[10] A recently introduced computerized anesthetic delivery device, the Wand (Milestone Scientific, Deerfield, IL; 800/862-1125) (Fig. 1), is advertised to address several problems related to injections by delivering a constant flow rate regardless of tissue density.

This clinical study compared patient discomfort using both a syringe and the Wand delivery system for two common injections, a maxillary infiltration injection and

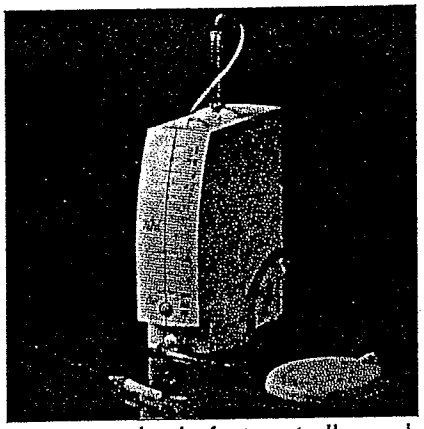

Fig. 1. Wand unit, foot controller, and handpiece.

mandibular inferior alveolar nerve block injection. Subjective responses regarding apprehension, postinjection soreness, and preference of delivery systems were recorded.

Materials and methods

Thirty patients were selected from applicants responding to a solicitation for participation. The criteria for patient selection were good health status; not pregnant nor likely to become so during the study period; and schedules permitting two clinical appointments and a follow-up survey. Patients ranged in age from 23–54 with a median age of 35; 26 of the 30 subjects were female. At the first appointment, patients received a printed explanation of the study, Institutional Review Board-approved consent forms, and medical/dental history forms. The dentist reviewed with patients their medical history and informed them that they would receive two injections of each type on one side of the mouth at each of two separate sessions. Patients also were given a brief explanation of the Wand, including the audible signals used by the device.

Patients were randomly assigned to one of the two dentists for all four injections. For the first session, a table was used to randomly select the side of the mouth, left or right, to be anesthetized and the type of injection, syringe or Wand, to be used for the maxillary and mandibular site. Each patient received one injection with the syringe and one injection with the Wand at each appointment. The selected maxillary lateral incisor was anesthetized with a supraperiosteal infiltration injection (maxillary infiltration). The other injection, on the same side, was an inferior alveolar nerve block (mandibular block). Needle gauge, anesthetic type, and basic technique were the same for both injections.

At the second visit, injections were performed on the opposite side of the mouth. Injection device and location were reversed from the first session so that each patient ultimately received maxillary infiltration and mandibular block injections with both the syringe and the Wand. Since no dental treatment was performed, any anxiety was assumed to be due solely to the injections. The two dentists administering the injections provided a subjective evaluation of the patients' preinjection anxiety and level of comfort during the injection. They also rated the ease of use of each device and their respective preference for delivery type.

Prior to the injection, vitality of the maxillary lateral and mandibular canine was tested by applying a refrigerant spray (Frigi-Dent, Ellman International, Inc., Hewlett, NY; 800/835-5355) with a cotton-tipped applicator to register a timed response to the stimulus. A topical anesthetic (Hurricaine, Beutlich Pharmaceuticals LP, Waukegan, IL; 800/238-8542) was applied for approximately 30 seconds prior to each injection.

A 30 gauge needle and 3% mepivicaine (Carbocaine) without vasoconstrictor were used for all injections. Approximately 0.9 mL of anesthetic was used for maxillary infiltration and 0.9–1.4 mL for the mandibular block. Timers were used to register both onset time and confirmed time of pulpal anesthesia. Probing was used to confirm soft tissue anesthesia. When soft tissue anesthesia was noted, refrigerant was applied to the tooth every minute until pulpal anesthesia was confirmed. In the few instances when inadequate anesthesia required re-injection, the process was re-timed.

Immediately following each injection, the assistant recorded the patient's discomfort using a linear verbal response scale (VRS) from 0 (no discomfort) to 10 (severest discomfort conceivable). Immediately after the appointment, the dentist marked a similar 0–10 scale

Table 1. Summary of responses and data elicited from dentists and patients.

- Patient's discomfort during administration with the syringe and with the Wand (after each injection).
- Patient's perception of postappointment discomfort/soreness with the syringe and with the Wand.
- Patient's assessment of apprehension prior to the first injection with the syringe and with the Wand (recorded at the second appointment).
- Patient's assessment of apprehension prior to the second injection with the syringe and with the Wand (via telephone interview 24 hours or more after second appointment).
- Patient's preference for future injection (via telephone interview).
- Operator's perception of patient's apprehension prior to the syringe and prior to the Wand (after each appointment).
- Operator's perception of patient's discomfort during administration with the syringe and with the Wand (after each appointment).
- Operator's perception of ease of use for syringe vs. Wand (after each appointment).
- Operator's perception of profoundness of anesthesia for the syringe and for the Wand (after each appointment).
- Time after injection to soft tissue anesthesia and to pulpal anesthesia for the syringe and for the Wand.

for both syringe and Wand injections to record his perception of the patient's preinjection apprehension and discomfort during the injection. Responses and data elicited from patient and dentist, recorded for analysis, are summarized in Table 1.

A statistical analysis of the consistency of responses to the injections repeated at successive appointments was made, as was a comparison of the responses to the syringe and the Wand system. Comparisons were made separately for the maxillary infiltration and mandibular block injections by the paired t-test. The 5% significance level was used in the test. The statistical computation was performed with the use of SAS Institute software (Cary, NC; 919/677-8000).

Results

Several categories of inquiry, such as onset time and profoundness of anesthesia, did not show any differences between the two devices. Other differences reflect the anatomical variations between a maxillary infiltration and a mandibular block. Detailed statistical comparisons of the dentists' perceptions of patient apprehension and discomfort versus the patients' ranking of apprehension and discomfort were not made because the patients' rankings were solicited in the presence of the dentists.

Data were collected and analyzed for the patients' apprehension, perception of discomfort, postoperative soreness for each visit for each delivery device, and for maxillary infiltration and mandibular block injections. Discomfort levels are classified into four groupings: None (0); minimal (1-2); moderate (3-5); and severe (6-10). The dentists also rated the devices for ease of use and profoundness of anesthesia.

Consistency of responses

Patients' perception of discomfort during and after injection was recorded as a 0-10 score. Strong agreement of responses to injections in successive appointments was identified when a patient's scores from one appointment to the next differed by a value of 2 or less. Table 2 shows the number of consistent responses between appointments for discomfort during injection and postoperative discomfort. McNemar's Chi-square test is applied to compare the consistency of the responses. Differences in percentage between the syringe and the Wand for injection discomfort are not statistically significant ($p = 0.182$) but they are significant for postoperative discomfort ($p = 0.045$), with more consistent responses with Wand injections.

The postoperative discomfort for mandibular block favoring the Wand was significant, as shown in Table 3; the average postoperative discomfort scores of mandibular block injections were 2.17 for the syringe and 1.00 for the Wand.

Clinicians "ease of use" ratings

For the first injections given with the Wand, the clinicians were learning the technique, so "no difference" was reported frequently. Following the "learning curve," both clinicians routinely selected "Better with Wand." The operator's perception of "ease of use" for each pair of injections was recorded in three categories: Syringe better than Wand, Wand better than syringe, and no difference. The clinician's "ease of use" ratings for 60 injections (two for each patient) were 1 for syringe, 45 for Wand, and 14 no difference.

Patient's preference for future injections

Approximately two-thirds of the patients expressed a preference for a particular device for future injections (Table 4). Within this group, the Wand was favored by a two-to-one ratio. The other patients stated no preference.

Discussion

The manufacturer especially recommends the Wand for dense, nonresilient tissues (for example, palatal mucosa and the periodontal ligament space) because palatal injections with a syringe are relatively uncomfortable. A previous study by Hochmann et al showed a significant preference for the Wand in palatal injections.[11] They blindfolded dentist volunteers, who received palatal injections by both systems. Using a 5-point scale, the Wand system reduced the discomfort level 2-3x compared to the syringe. Another randomized, crossover, half-mouth treatment comparison, using both superior and inferior alveolar block injections, reported 80% reduction in pain with the Wand system.[12]

The supraperiosteal infiltration and the inferior alveolar nerve block injections are the most frequently utilized injections for dental therapy. Improved patient comfort during these routine injections would be of broad application, so the maxillary infiltration and mandibular block injections were selected for study.

Patient response

Preexisting conditioned anxiety about dental injections likely would affect patients' ratings of discomfort. In fact, two patients in this study registered discomfort responses of 8 and 9 at both appointments.

Krochak and Friedman asked patients to record a five-step level of anxiety for sequential stages of a dental visit: making an appointment, anesthetic injection, and finally an "inadequate numbness" requiring a second injection.[13] Patients then received a Wand injection before treatment and rescored the same questions postoperatively. The authors concluded that lower anxiety scores after exposure to the Wand demonstrated successful desensitization. In this study, patients were not screened for preexisting anxiety.

Even though this study attempted to minimize collateral anxiety, the mean injection discomfort rankings were 3.12 for the syringe and 2.42 for the Wand. Patients

Table 2. Consistency of patient responses.

	Syringe Cases (percentage)	Wand Cases (percentage)	McNemar's Chi-square	p
Perception of discomfort during injection	19 (63.324)	24 (80.0)	1.778	0.1824
Perception of postoperative discomfort	20 (66.727)	27 (90.0)	4.000	0.0455

Table 3. Patients' postoperative perception of discomfort.

	Position	Syringe mean	Wand	difference mean	SD	P value* (2 tails)
During injection	Maxillary	3.10	2.17	0.93	3.13	0.1131
	Mandibular	3.13	2.67	0.47	2.75	0.3605
After injection	Maxillary	0.90	0.90	0.00	2.08	1.0000
	Mandibular	2.17	1.00	1.17	2.76	0.0276

*P value determined by paired t-test.

Table 4. Patients' preference for future injections.

Preference stated	Syringe	Wand	None	Total
None			9	9
Minimal	0	3		3
Moderate	3	5		8
Strong	3	7		10
Total	6	15	9	30

rated 13 (10.8%) of the 120 injections on the VRS scale from 6–9 (categorized as "severe" discomfort) despite the fact that both dentists were experienced, diligent, and patient in administering the injections. Seven of these 13 injections were maxillary infiltrations and six involved a mandibular block.

Milgrom reported that more than 20% of patients have high dental fears and that women were almost twice as likely as men to be affected.[14] Other studies of experimentally induced pain report women have a lower threshold for pain and rate the stimulus higher than do men.[15] The discomfort ratings of this study, with a high percentage of female subjects (87%), are probably higher than for a gender-balanced population.

Clinical appointments proceeded without undue incident. Seven of the 60 mandibular block injections required re-administration of anesthetic. Malamed postulates a success rate for the inferior alveolar block at about 80%, equivalent in this study to 12 missed mandibular blocks.[9] Surprisingly, two maxillary infiltration injections required re-injection of anesthetic. There was no correlation between the need to re-inject and the device used.

Injection discomfort

Other studies have compared discomfort rankings for Wand and syringe injections. A randomized, crossover, half-mouth treatment comparison for scaling and root planing therapy using both superior and inferior alveolar injections concluded the Wand to be significantly less painful than conventional injections.[16] Using a 10-point scale with 57 patients between the ages of 5 and 13 receiving inferior alveolar blocks, Asarch reported slightly higher but statistically equivalent mean pain recordings for the Wand.[17] No differences in pain or anxiety were reported in another study using buccal infiltration injections, although monitored heart rates took longer to return to baseline with the computerized device.[18]

In this study, the Kappa statistical protocol verified that patient assessments between the first and second appointments were in enough agreement to allow a paired t-test to compare mean rankings of the Wand and the syringe. In order to compare one system to the other, category percentages for the combined sessions (Tables 5 and 6) and reported means and *P* values (Table 5) are presented. For discomfort with injection (Table 3), the mean discomfort ratings for the Wand were lower than for the syringe but the difference was not significant. However, an examination of the mean discomfort rankings (Table 7) indicates a tendency of the Wand to produce less injection discomfort.

The different injection sites were analyzed separately to determine if one system was tolerated better for a respective site (maxillary vs. mandibular) and type of injection (infiltration vs. block). There was no significant difference for discomfort/pain between systems by specific location or type of injection.

Postoperative discomfort

It was expected that the mean postoperative discomfort for the mandibular block injection would be greater than for the maxillary injection because it requires protracted jaw opening; penetration through more dense and nerve filled tissues; and, frequently, needle repositioning. However, a significant difference ($p < 0.05$) in decreased postoperative discomfort between the two systems for maxillary and mandibular sites was found only for the mandibular block using the Wand (Table 3).

The explanation for this difference between systems is not certain. A possible explanation is the

Table 5. Patients' perception of discomfort during injection: Syringe vs. Wand.

Syringe	Visits 1 & 2 combined		Wand	Visits 1 & 2 combined	
	n	%		*n*	%
None (0)	6	10.0	None (0)	9	15.0
Minimal (1–2)	19	31.7	Minimal (1–2)	27	45.0
Moderate (3–5)	27	45.0	Moderate (3–5)	19	31.7
Severe (6–10)	8	13.3	Severe (6–10)	5	58.3

Discomfort level reported using a 10-point verbal scale, with 0 indicating no discomfort and 10 indicating worst discomfort.

Table 6. Patients' perception of postoperative discomfort: Syringe vs. Wand.

Syringe	Visits 1 & 2 combined		Wand	Visits 1 & 2 combined	
	n	%		*n*	%
None (0)	34	56.7	None (0)	40	66.6
Minimal (1–2)	7	11.7	Minimal (1–2)	12	20.0
Moderate (3–5)	15	25.0	Moderate (3–5)	5	8.3
Severe (6–10)	4	6.6	Severe (6–10)	3	5.0

Table 7. Patient injection discomfort percentage by category.

Category	Syringe	Wand
No pain (0)	10.0	15.0
Minimal pain (1–2)	31.7	45.0
Moderate pain (3–5)	45.0	31.7
Severe pain (6–10)	13.3	8.3

Wand's slower delivery rate compared to that frequently observed for the syringe. Although the mandibular syringe injection times were not recorded, both dentists administered the anesthetic slowly, so injection times for both systems were roughly equivalent.

Protocol limitations

Although numerous methodologies exist to assess pain, it is accepted that pain is extremely difficult to quantify. It is problematic to offer statistical analyses of a patient population using subjective data on a point scale unique to each individual. Numbers cannot really be quantified (a "4" is not necessarily equivalent to twice the discomfort of a "2", and a "2" for one patient may be equivalent to a "5" for the next). Nevertheless, medians and means of the arrays compare relative results for the same patients in the same experimental conditions.

As discussed earlier, past experiences could have influenced patients' ratings. First appointment injection experience, good or bad, may have influenced second visit ratings of injections, or postoperative discomfort and knowledge of the study's objective could bias patient judgment of injection discomfort. The results showed relative decrease in anxiety associated with the second Wand injection. However, it is not possible from this study to know whether any difference in anxiety is due to differences in pain perception or simply resolution of anxiety associated with a new experience. Although statistics were recorded for each visit, the study was not designed to isolate and analyze possible confounding factors between visits.

Operators' evaluation of the Wand

The dentists in this study generally preferred the Wand system, as have others evaluating it.[19] Of 11 dentists treating 72 patients with both Wand and syringe, 40% reported equivalent success with the Wand and 40% reported better anesthetic success.[20] Another study reported onset time of lip tingling to be approximately 30 seconds earlier when using the Wand for inferior alveolar blocks.[21]

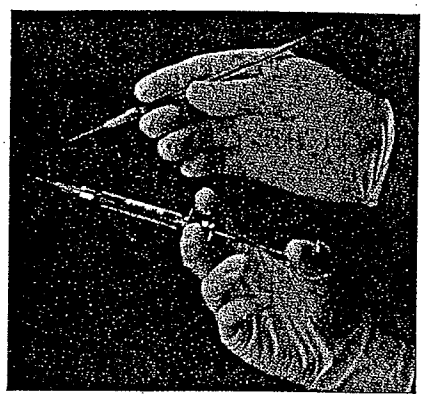

Fig. 2. Wand handpiece (top) and traditional syringe.

In this study, the dentists and assistant confirmed some advantages advertised by the manufacturer of the device. Its use eliminates sterilization maintenance of a syringe. The handpiece allows a precise pen grasp which is easier to manipulate and which does not make metallic contact with the teeth and tissues when positioning for an injection (Fig. 2). The improved tactile feedback, visibility, and automated aspiration allow concentration on needle positioning and patient interaction. The system delivers a controlled pressure and volume, minimizing tissue distension, eliminating the need for heavy finger pressure, and preventing too-rapid injection. Such control of pressure and positioning with the syringe is difficult. The manufacturer claims a significant advantage to the handpiece design in facilitating targeting of a foramen.

The pen-grasp permits needle rotation as it penetrates the tissue to minimize needle deflection resulting from tissue resistance. This rotation technique used for the Wand to administer the

mandibular block was the primary difference in the insertion technique between the two systems. It might be a factor in the slight comfort rating difference during injections and the significantly lower postoperative discomfort rating noted for the Wand.

A recent *in vitro* simulation using tissue-like substrates confirms increased targeting accuracy with a bi-directional needle rotation.[22] However, a clinical study comparing traditional with guided inferior alveolar injections indicated that needle deflection was not a factor in the success of the inferior alveolar nerve block injection.[23]

Although the operators judged the Wand easier to use, the model used had a significant disadvantage. A prolonged aspiration cycle (approximately 14 seconds) before anesthetic administration could commence was undesirable. The delay was caused by the minimal diameter and extended length of the handpiece and tubing connecting the needle to the anesthetic cartridge on the base unit. A redesigned model (the Wand Plus) now has an aspiration time of approximately 5 seconds. The original model also can be reprogrammed easily to have this 5-second aspiration time. While still more prolonged than the momentary reversal of pressure on the thumb ring of a syringe, it no longer is a significant problem.

The plastic handpiece has been redesigned to permit visual confirmation of any blood during aspiration. The cartridge is not directly visible to the dentist, so a check of indicator lights on the unit is needed on the older models to determine the volume of drug delivered. The redesigned unit adds an audible indicator for dispensed volume of anesthetic. A series of repetitive beeps denotes the aspiration cycle while a slow or rapid beeping tone confirms the selected speed of anesthetic delivery. These beeps may alarm the patient unless he or she is forewarned. Since the computer is designed to interpret any cessation or pressure change on the foot switch as intent to aspirate, it automatically reinitiates that cycle unless the function is deactivated on the unit. Some practice is needed to ensure efficient use of the pedal and aspiration cycle.

Conclusion

The percentage of injections ranked as severely uncomfortable (10.8% rated a 6 or above on a 10-point scale) was higher than anticipated considering the dentists' experience and the protocol designed to minimize patient anxiety.

Mean injection discomfort ratings with the Wand were lower than with the syringe but were not significantly so. More patients rated the Wand as completely and/or minimally uncomfortable compared to the syringe injection. Even among patients indicating severe discomfort or pain, a lower percentage gave this rating for injections received via the Wand.

Postoperative discomfort for mandibular block injections was significantly less using the Wand system than with the syringe. There were no differences in postoperative discomfort for the maxillary infiltration injection.

Approximately two-thirds of the patients expressed a preference for a particular system for future injections. Of this group, the Wand was favored by a two-to-one ratio. The remaining patients stated no preference.

With experience, the dentists increasingly preferred the Wand system to the syringe system. The long aspiration cycle with the model used in the study was a disadvantage but the redesigned aspiration cycle should reduce this problem considerably.

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References

1. Ring ME. Dentistry, an illustrated history. New York: Harry N. Abrams, Inc.;1993.

2. Locker D, Shapiro D, Liddell A. Who is dentally anxious? Concordance between measures of dental anxiety. Community Dent Oral Epidemiol 1996; 24:346-350.

3. Rao A, Sequeire PS, Peter S. Characteristics of dental fear amongst dental and medical students. Indian J Dent Res 1997;8:111-114.

4. Matsuura H. Analysis of systemic complications and deaths during dental treatment in Japan. Anesth Prog 1989;36:223-225.

5. Holroyd SV, Wynn RL, Requa-Clark B, eds. Clinical pharmacology in dental practice, ed. 4. St Louis: C.V. Mosby;1988.

6. Estafan DJ. Invasive and noninvasive dental analgesia techniques. Gen Dent 1998;46:600-603.

7. Hamburg HL. Preliminary study of patient reaction to needle gauge. N Y State Dent J 1972;38:425-426.

8. Rogers KB, Fielding AF, Markiewicz SW. The effect of warming local anesthetic solutions prior to injection. Gen Dent 1989;37:496-499.

9. Malamed SF. Handbook of local anesthesia, ed. 4. St. Louis: C.V. Mosby; 1997.