

The effectiveness of electronic dental anesthesia in children

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Abstract

This study compared the effectiveness of traditional local anesthesia with a Transcutaneous Electrical Nerve Stimulation unit that controls pain via electronic dental anesthesia for restorative dental procedures in 6- to 12-year-old children. The sample included 27 children who had two antimere teeth that required restorations of similar size (preventive resin restorations). In each case, the cavity preparation extended into dentin. One of the teeth was treated with conventional local anesthesia and the other with EDA. Selecting which tooth and which method to complete first was done randomly. Both restorations were done at the same appointment. Throughout the procedure, the child was asked to assess the level of discomfort using the Eland Color Scale, which allowed the children to draw on their past painful experiences to judge the level of pain they perceived. The patients demonstrated no overall significant difference in pain perception between the two modalities of treatment, regarding dentin sensitivity and rubber dam clamp placement. When asked which method they preferred after the study, 78% of the patients chose EDA over local anesthesia. (Pediatr Dent 15: 191-96, 1993)

Introduction

Transcutaneous Electronic Nerve Stimulation (TENS), which provides electronic dental anesthesia (EDA), has been used to help control pain in adults in recent years.

Electrical anesthesia was used only by a small number of providers until 1967. A rebirth was prompted by results of a study by Wall and Sweet¹ on the gate control theory of pain transmission, resulting in a more scientific approach. In the same year, Shealy² introduced TENS to help control chronic pain. In recent years, modifications have been made to make TENS useful in the dental setting. Malamed et al.³ use the term electronic dental anesthesia or EDA when referring to the applications of TENS to dentistry. Therefore, throughout the literature the two terms, EDA and TENS, are used interchangeably.

According to Allgood,⁴ "TENS is the direct stimulation of the nerves by short-duration, small amplitude electric pulses." TENS units are grouped into three categories. High-frequency (25–150 Hz) is the mode used most frequently to manage chronic TMJ pain and acute postoperative pain, and to provide EDA. Low frequency (2–10 Hz) is used when high-frequency TENS becomes ineffective because of accommodation during treatment of chronic pain. Ultralow-frequency (0.5–2 Hz) is again useful for treating chronic TMJ pain and measuring accurate vertical dimension of rest. A balanced, biphasic wave form with a zero net DC component should be used for dental purposes; otherwise adverse skin reactions can result.

Several interrelated theories for the mechanism of pain control exist for EDA, including the gate control,⁵ endorphin release,^{6,7} and serotonin release.⁸ The gate control theory was the first theory to explain the mechanism for EDA.⁵ There are two types of nerve fibers that carry pain

impulses to the brain: A-delta (small-diameter, myelinated) and C (unmyelinated). A-beta fibers are large-diameter, myelinated afferent nerve fibers responsible for the tactile sensations of pressure and touch. It is theorized that in the dorsal horn of the spinal cord a "gate" allows transmission of the A-delta and C fibers to pass through to the higher levels of the brain. The large A-beta fibers, when activated by pressure or touch, travel faster than the A-delta and C fibers carrying pain and close the "gate" so the pain is not perceived.

Another explanation offered for the effectiveness of TENS is that it stimulates the release of endorphins, which attach to opiate receptors and block the transmission of noxious stimulation. Endorphins are natural morphine-like substances the body can release when stimulated. Adams⁶ found that the analgesic effects of TENS could be reversed by injection of the narcotic antagonist, naloxone-hydrochloride. A more recent study by Abram, Reynolds, and Cusich⁷ revealed that naloxone could only partially reverse the effects, thereby suggesting that factors other than endorphin release also help to block pain.

Hochman,⁸ reported a third theory to explain the mechanism of pain control. He found an increased blood serotonin level to be associated with an increase in pain tolerance. Serotonin is a neurotransmitter produced in areas of the central nervous system as a result of the metabolism of the amino acid L-tryptophan. Patients who are tryptophan-deficient seem to have higher levels of pain, as well as a history of sleep disorders. These studies also indicated that patients who exhibit only marginal analgesia using TENS subsequently experience more favorable results when given 2000–3000 mg of L-tryptophan daily for

three days prior to the use of TENS.

Several other less popular theories have been offered as explanations for the effects of TENS analgesia. Among these are the importance of dopamine, norepinephrine, and electrocoagulation of the odontoblasts in the dentinal tubules adjacent to the site of enamel/dentin preparation.⁹ The exact mechanism remains unknown and may be a combination of one or more theories.

The anesthetic effect of TENS was evaluated during 600 dental procedures, including subgingival scaling, endodontic treatment, and dental restorations. Pain control was evaluated relative to procedure type, the patient's level of relaxation, sensitivity to pain, and the patient's skepticism about the success of pain reduction during the procedure. More than 76% of the patients reported by Hochman⁸ had at least 90% success with the use of TENS as dental anesthesia.

Bishop¹⁰ conducted a double-blind study of 50 patients undergoing TENS for restorative procedures, periodontal scaling, endodontic therapy, myofascial pain disorder therapy, and extractions. The TENS experimental group had a success rate of 92.8% with the restorative procedures, whereas the placebo group responded favorably in only 15% of the restorative procedures. Quarnstrom and Milgrom¹¹ combined nitrous oxide/oxygen with TENS for an 84% success rating. The TENS group, without the nitrous oxide/oxygen, had success in 55% of the adult patients. A study by Malamed and coworkers³ revealed an overall success rating of 89% with TENS in treatment of Class I, II, III, IV, and V carious lesions. Generally, the success rating decreased slightly as the lesion depth increased and was dependent on the patient's ability to grasp the concept of controlling the TENS unit to provide adequate pain relief. The youngest patient evaluated was 11 years old.

According to Quarnstrom,¹² the young child with a primary or mixed dentition does not need to control the TENS unit to benefit. He subjectively reported a high success rate in patients 12 years of age and younger.

One of two published studies that evaluated the use of EDA in children was conducted by Abdulhameed et al.¹³ They evaluated the effects of peripheral electrical stimulation to determine tooth pain thresholds and oral soft tissue comfort in 30 children, 8–14 years old. A visual analog scale (VAS) was used to measure the comfort level by each subject and the investigator. A 33% increase in tooth pain threshold was reported, but the reliability of the VAS with children was questionable since they had trouble applying it on a consistent basis.

Harvey and coworkers¹⁴ evaluated the pain perceptions of 20 children from 8 to 14 years old during Class I amalgam preparations on permanent mandibular first molars. They demonstrated a statistically significant decrease in pain perception for EDA, compared to the control group. The control group was treated with an inactive EDA unit to allow the study to be double blinded.

Children are often unable to effectively describe pain.

According to Hammond and Full,¹⁵ a child's expression of pain may be affected by factors such as age, developmental stage, verbal competency, body language, and emotional maturity. McGrath and coworkers¹⁶ recommended simple, self-reporting measures for children older than six years of age, including a VAS.

Spirito and Stark¹⁷ reported that one major criticism of self-reporting measures in young children is their lack of cognitive ability and language skills to evaluate themselves using common self-reporting measurement techniques.

Several authors have recommended self-reporting scales including the VAS for assessing pain in children.^{18–20} According to Stewart's judgment,²¹ the most reliable measurement of pain was the patient's subjective assessment of pain, when compared to an objective interpretation of a person's behavior. Stewart used the Stewart Pain Color Scale to evaluate and measure pain in adults.

Stewart's color scale was later modified by Eland²² for use with children between four and 10 years of age. Hammond and Full¹⁵ used the Eland Color Scale to evaluate nitrous oxide analgesia and children's perception of pain. They concluded the Eland Color Scale was effective in measuring pain in children.

Methods and materials

Subjects

All participants in this investigation were patients at the University of Iowa Pediatric Dental Clinic and met the following criteria and conditions:

1. Healthy, cooperative, and between six and 12 years of age
2. Not color blind²³
3. Two primary/permanent posterior antimere molars with lesions of similar size, requiring a preventive resin restoration that extended into dentin on the occlusal surface; each tooth free of restorations, vital, nonmobile, free from trauma, and objectively and subjectively asymptomatic; primary second molars when included for treatment, exhibiting no radiographic root resorption
4. Parents consented to the procedure.

Participants were randomly divided into two groups. Group 1 had the first restoration with a local anesthetic and the second with EDA. Group 2 received treatment in reverse order. Placing the children into groups was completed by random assignment. Both preventive resin restorations were completed at the same visit.

The analgesic effectiveness of EDA, using the Spectrum Max-SD[®] (Medical Designs, Westerville, OH) and the local anesthetic Xylocaine[®] (Astra, Westborough, MA)—2% lidocaine with 1:100,000 epinephrine—were evaluated with the Eland Color Scale. Before using the color scale, each child was interviewed about events that had hurt in the past. Then they were asked the following questions: "Of all the things that have ever hurt you, what hurt you the most?", "What hurt a little less than the answer you just gave?", and "What was something that

only hurt a little." Their responses were used to administer the color scale.

The protocol, first developed by Eland²² and later modified by Hammond and Full,¹⁵ was conducted in the following manner:

1. Present eight felt squares in a row in the exact same order to every child (yellow, orange, red, green, blue, purple, brown, black) across the top of a white felt board.
2. Ask the child "Of these colors, which is like _____?" (the event identified by the child as hurting the most)
3. Place the color square in the middle of the felt board away from the other colors; represents severe pain—numerical value of 3
4. Ask the child "Which color is like _____?" (the event identified by the child that hurt, but less than the most painful event)
5. Place the color square below the square chosen to represent severe pain; represents moderate pain—numerical value of 2
6. Ask the child "Which color is like _____?" (the event identified by the child as hurting just a little)
7. Place the color square below the colors representing severe and moderate pain; represents mild pain—numerical value of 1
8. Ask the child "Which color is like not hurting at all?"
9. Place the color square at the bottom of the color squares; represents no pain—numerical value of 0.

Treatment

All subjects received either EDA or local anesthesia for the restorative procedures. The EDA was achieved by drying the buccal mucosa bilaterally in the arch where treatment was being performed to allow for placement of the disposable electrode pads, which self-adhere to the tissue. The pads used were Dentrede 37® (The Electrode Store, Yucca Valley, CA) (Fig 1). The Spectrum Max-SD

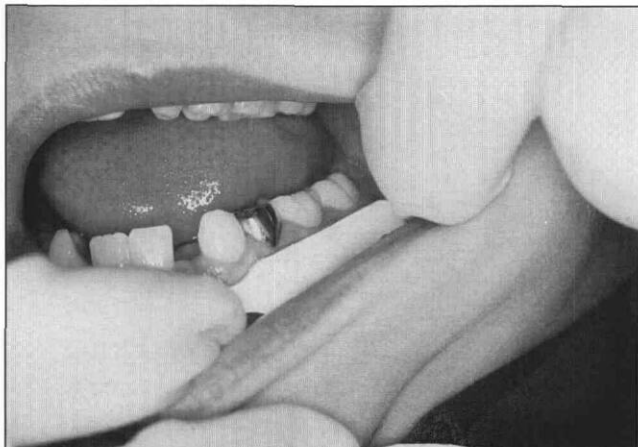


Fig 1. Placement of an electrode pad on the left side of the mandibular arch.

was set to a pulse rate of 110 Hz and a normal mode pulse width of 225 microseconds. The waveform of the Spectrum Max-SD is an asymmetrical, rectangular, biphasic pulse with a net zero D.C. component.

The investigator (Et) controlled the level of EDA by slowly increasing the amplitude until the orbicularis oris muscle began twitching for the maxillary arch and the lower lip began twitching for the mandibular arch. If at any time the children felt discomfort while the investigator was increasing the EDA, they were to raise a hand and the amplitude was decreased. The amplitude then was decreased until the twitching stopped and was maintained throughout the procedure. This technique was used at the suggestion of Dr. Quarnstrom¹² who has treated a number of patients with the Spectrum Max-SD in his office. For all 27 patients, the amplitude level ranged from 7 to 12 mA. The patient was allowed 5 min to adjust to the sensation of the EDA at the amplitude level.

When local anesthetic was used, there was also a 5-min delay prior to treatment to allow for adequate effect. For the maxillary arch, an infiltration injection was used. Local anesthesia also was given for soft tissue comfort on the lingual during rubber dam clamp placement. Long buccal, inferior alveolar and lingual nerve blocks were used in the mandibular arch. If, after the 5-min wait for the effects of the local anesthetic, appropriate soft tissue signs indicating effective anesthesia did not develop, then the injection was repeated. However, the injection did not need to be repeated in any case. All procedures were completed with rubber dam isolation.

Pain perception evaluation

The Eland Color Scale was used before, during, and after the restoration procedures to assess the child's perception of pain.

Treatment was initiated by placing a rubber dam to eliminate salivary contamination. After placing the dam (step 1), the child was asked to point to one of the four colors previously chosen to represent the level of discomfort he or she was experiencing. Then the child was asked to point to a color with the high-speed hand piece running near, but not in contact with the tooth (step 2). After penetrating the enamel (step 3), the child was also asked to point to the color representing the level of discomfort. Once the dentin was penetrated and the caries was completely removed (step 4), the child was again asked to pick the color that represented the level of discomfort. The tooth then was restored with composite resin and sealed with a clear resin sealant. After final inspection of the restoration, the rubber dam was removed. The child selected the last color 5 min postoperatively (step 5). The child's five color selections were recorded, corresponding to the identified pain levels (Table 1).

Statistical analysis of data

The values recorded for each step of the restorations completed with EDA and local anesthesia were analyzed via chi-square analysis to determine any statistically sig-

Table 1. Definitions of the pain perception scores

| Score | Definition |
|-------|---|
| 3 | An event identified by the child as hurting the most |
| 2 | An event identified by the child as a hurt but less than the most painful event |
| 1 | An event identified by the child as hurting a little |
| 0 | No pain |

nificant differences in responses between the two techniques at a level of $P < 0.05$. This nonparametric method was used because of the subjective numerical data collected in the study.

Results

The treatment scores for the EDA and local anesthesia are in Table 2.

Rubber dam clamp placement and dentin sensitivity were used to compare pain control effectiveness. The mean scores of the rubber dam clamp placement (step 1) were 1.48 ± 0.94 for EDA and 1.18 ± 0.88 for local anesthesia, with a difference of 0.30. The mean scores for dentin sensitivity (step 4) were 1.04 ± 0.85 for EDA and 0.85 ± 0.95 for local anesthesia, with a difference of 0.19. There was no statistical difference between the two methods of pain control, regarding rubber dam clamp placement and dentin sensitivity at a confidence level of $P < 0.05$ (Fig 2).

Step 2 was to run the high-speed handpiece adjacent to the tooth, which revealed a 0.37 ± 0.88 mean for EDA and a 0.15 ± 0.46 mean for local anesthesia. The difference was again not statistically significant at a level of $P < 0.05$. Step 3 involved touching the high-speed to the enamel; EDA had a mean of 0.26 ± 0.74 and local anesthesia had a mean of 0.22 ± 0.91 , which again was not statistically significant at $P < 0.05$. Step 5, at the completion of the restoration, had a mean of 0.26 ± 0.62 for EDA and a mean for local anesthesia of 0.22 ± 0.51 . These three steps were used to evaluate the ability of the children to use the Eland Color Scale to convey pain effectively. The relatively low scores for these

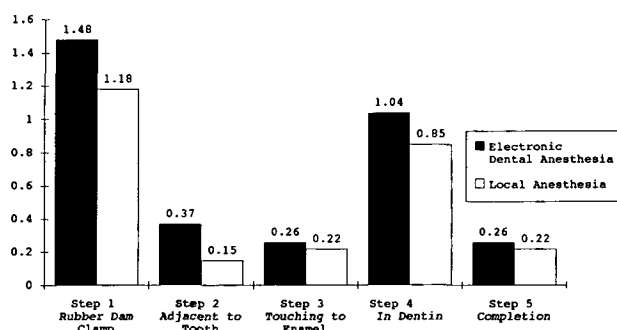


Fig 2. Mean score of all five steps of the restoration, for EDA.

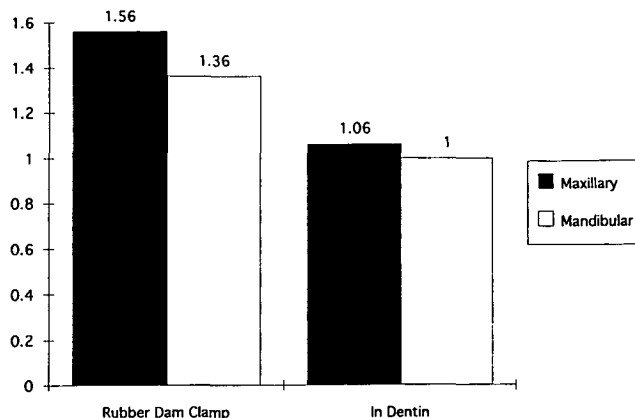


Fig 3. Differences in scores for EDA between the maxillary and mandibular arches.

three steps, which should have been painless, indicate that the Eland Color Scale appears to have been effective (Fig 3).

EDA also was used to identify differences in pain control between the 16 subjects who had the maxillary arch treated and the 11 subjects who had the mandibular arch treated (Fig 4). Upon placing the rubber dam clamp, a mean score of 1.56 ± 0.96 was reported for the maxillary arch and 1.36 ± 1.01 for the mandibular arch, which is not significantly different at $P < 0.05$. For dentin sensitivity, the mean score for the maxillary arch was 1.06 ± 0.83 and for the mandibular arch 1.00 ± 0.85 ; again there was no significant difference present at $P < 0.05$. Primary teeth

Table 2. Scores for electronic dental anesthesia (EDA) local anesthesia (LA)

| Procedure | EDA/LA 0 | EDA/LA 1 | EDA/LA 2 | EDA/LA 3 | EDA Mean SD | LA Mean SD | $P < 0.05$ |
|-----------|-------------|-------------|-------------|-------------|----------------|---------------|------------|
| RD | 3/5 | 13/15 | 6/4 | 5/3 | 1.48 ± 0.94 | 1.18 ± 0.88 | NS |
| HAT | 22/24 | 2/2 | 1/1 | 1/0 | 0.37 0.88 | 0.15 0.46 | NS |
| HE | 20/23 | 5/2 | 1/2 | 1/0 | 0.26 0.74 | 0.22 0.93 | NS |
| DS | 7/12 | 14/9 | 4/4 | 2/2 | 1.04 0.85 | 0.85 0.95 | NS |
| C | 24/22 | 2/4 | 0/1 | 1/0 | 0.26 ± 0.62 | 0.22 ± 0.51 | NS |

RD — rubber dam clamp placement, HAT — highspeed handpiece adjacent to tooth, HE — highspeed handpiece on the enamel, DS — dentin sensitivity, C — completion, NS — not significant.

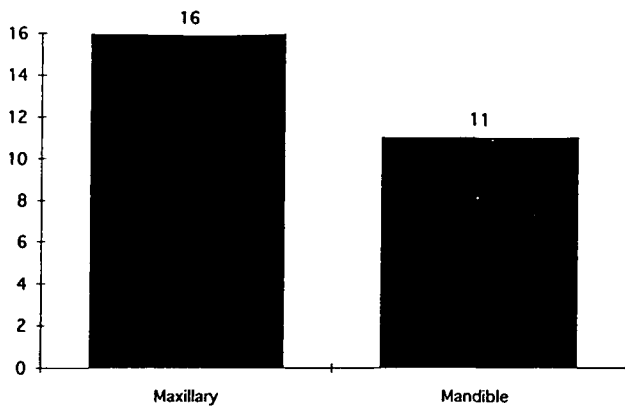


Fig 4. Arches treated in the study.

were treated in six of the 27 subjects (Fig 5).

There was also no significant difference between children who received EDA first versus those who received local anesthesia first.

After completing the restorations, each child was asked which method they preferred; 78% (22 of the 27 patients) preferred EDA over local anesthesia.

Discussion

This study was completed to compare the effectiveness of EDA to that of local anesthesia for controlling pain in children. Each patient had one tooth treated with EDA and the antimere tooth treated with local anesthesia at the same appointment, which enabled the children to serve as their own controls.

Random selection determined which tooth and in what sequence the teeth would receive EDA for each patient. Every attempt was made to keep from biasing the subjects against local anesthesia. For example, it was never referred to as a "shot" or "the needle." We explained that one tooth would be done with "electronic dental anesthesia" and the other with "sleepy water" that may feel like a "little pinch." Then the child was pinched slightly on the hand to demonstrate the sensation. The EDA was explained as a sensation "like when your foot falls asleep, but it will be in your mouth."

One patient being treated with the EDA, began crying upon placement of the rubber dam clamp and required use of local anesthesia. The scores for all of the steps that were unable to be completed with the EDA were assigned the score of 3, which increased the scores for EDA.

Preventive resin restorations were selected for this study because the procedure is minimally invasive and could serve as a baseline to evaluate whether more extensive procedures should be evaluated. By definition, a preventive resin restoration does not necessarily extend into dentin and therefore may be a painless procedure. However, to assess pain perception, all preparations in this study extended into dentin.

The six subjects who had primary teeth treated in the study indicated a mean discomfort level of 2.40 ± 0.89

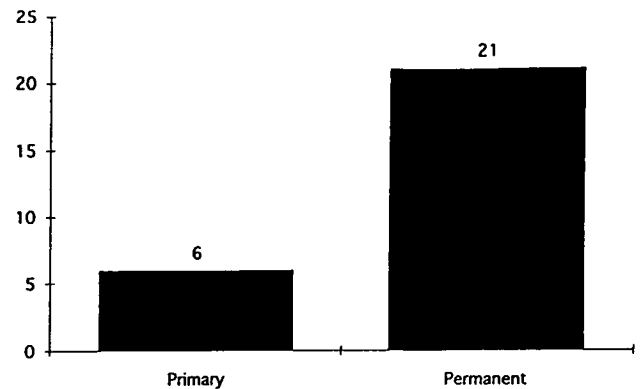


Fig 5. Number of permanent and primary teeth treated.

during the placement of the rubber dam clamp in the EDA group and 1.17 ± 0.75 in the local anesthesia group. Their mean age was 6.5 years. Even though random selection was used to decide which method would be completed first, mere chance dictated that EDA was used first in all six cases. This increased the EDA group's score. The subjects may have become more comfortable as the procedure progressed or the young age of the children may have influenced the results. This can only be speculated because of the small number of patients treated in the primary dentition.

Step 1, the rubber dam clamp placement, and step 4, response of dentin sensitivity, were used to evaluate pain control, as previously stated, with no significant differences. The Eland Color Scale was the only method used to evaluate discomfort levels of the children, allowing them to draw from their own past painful experiences to convey their level of discomfort. The colors were reviewed before each restoration to ensure the child was familiar with the meanings of the four colors. Therefore the child's initial color selection was retested and verified twice during the course of the appointment. Validity for this method was tested by evaluating the response to the running of the high-speed drill adjacent to the tooth and also on enamel, two steps that should cause no discomfort. More than 80% of the patients reported no pain for both steps. For the patients who reported some discomfort during those two steps, no significant differences existed between EDA and local anesthesia.

Ideally, the EDA and local anesthesia groups should have been compared to a no-anesthesia group. This was not possible, since only two antimere teeth are present for each patient. It would also be difficult to get a human subjects committee to approve a no-anesthesia group.

Some may question the effectiveness of the Eland Color Scale due to children's inability to accurately rate their level of pain. We attempted to control the possibility that the children might under- or overestimate the level of pain. For example, if children tended to overestimate the pain level for one method, then they would most likely overestimate the pain level for the other method. Since

each child evaluated both methods, the differences between the scores were more important than the actual scores themselves. The high standard deviations for many of the steps may result from children's varying pain thresholds.

Some may also argue that a molar with an open apex may respond differently than a molar with a closed apex, but we used antimere teeth on the same patient to avoid this issue.

The results of this study provide evidence that EDA can control pain as effectively as local anesthesia for relatively shallow lesions into dentin. A few lesions, however, were deep enough to cause the operator (Et) some concern about the possibility of pulpal involvement. This should provide a baseline for future studies examining EDA during more extensive dental restorations in children.

Conclusion

From the results of the study, the following conclusions can be made: 1) No significant differences were found between EDA and local anesthesia, regarding effectiveness in controlling pain perception in this study, and 2) Seventy-eight per cent of the subjects preferred EDA, versus 22% who preferred local anesthesia.

The authors thank Mr. Tim Cooke at The Electrode Store in Yucca Valley, CA for donating the Spectrum Max-SD® used in the study.

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1. Wall PD, Sweet WH: Temporary abolition of pain in man. *Science* 155:108-9, 1967.
2. Shealy CN, Mortimer JT, Reswick JB: Electrical inhibition of pain by stimulation of the dorsal columns: preliminary clinical reports. *Anesth Analg* 46:489-91, 1967.
3. Malamed SF, Quinn CL, Torgersen RT, Thompson W: Electronic

- dental anesthesia for restorative dentistry. *Anesth Prog* 36:195-98, 1989.
4. Allgood JP: Transcutaneous electrical neural stimulation (TENS) in dental practice. *Compend Contin Educ Dent* 7:640-44, 1986.
5. Melzack R, Wall PD: Pain mechanisms: a new theory. *Science* 150:971-79, 1965.
6. Adams JE: Naloxone reversal of analgesia produced by brain stimulation in the human. *Pain* 2:161-66, 1976.
7. Abram SE, Reynolds AC, Cusick JF: Failure of naloxone to reverse analgesia from transcutaneous electrical stimulation in patients with chronic pain. *Anesth Analg* 60:81-84, 1981.
8. Hochman R: Neurotransmitter modulator (TENS) for control of dental operative pain. *J Am Dent Assoc* 116:208-12, 1988.
9. Black RR: Use of transcutaneous electrical nerve stimulation in dentistry. *J Am Dent Assoc* 113:649-52, 1986.
10. Bishop TS: High-frequency neural modulation in dentistry. *J Am Dent Assoc* 112:176-77, 1986.
11. Quarnstrom FC, Milgrom P: Clinical experience with TENS and TENS combined with nitrous oxide-oxygen: report of 371 patients. *Anesth Prog* 36:66-9, 1989.
12. Quarnstrom FC: Personal communication. 1991.
13. Abdulhameed SM, Feigal RJ, Rudney JD, Kajander KC: Effect of peripheral electrical stimulation on measures of tooth pain threshold and oral soft tissue comfort in children. *Anesth Prog* 36:52-7, 1989.
14. Harvey M, Henteleff H, Zullo T, Elliott M: Transcutaneous electrical nerve stimulation for pain management during cavity preparations. *J Dent Res* 71(Abstr 159):125, 1992.
15. Hammond NI, Full CA: Nitrous oxide analgesia and children's perception of pain. *Pediatr Dent* 6:238-42, 1984.
16. McGrath PJ, Beyer J, Cleeland C, Eland J, McGrath PA, Portenoy R: Report of the subcommittee on assessment and methodologic issues in the management of pain in childhood cancer. *Pediatrics* 86:814-17, 1990.
17. Spirito A, Stark JS: Childhood pain: assessment and significance of self-report. *Behav Med Abst* 8:1-4, 1987.
18. Carpenter PJ: New method for measuring young children's self-report of fear and pain. *J Pain Symptom Manage* 5:233-40, 1990.
19. Erickson CJ: Pain measurement in children: problems and directions. *J Dev Behav Pediatr* 11:135-37, 1990.
20. Lavigne JV, Schulein MJ, Hahn YS: Psychological aspects of painful medical conditions in children. I. Developmental aspects and assessment. *Pain* 27:133-46, 1986.
21. Stewart ML: Measurement of clinical pain, in *Pain: A Source Book for Nurses and Other Health Professionals*. Jacox AK ED. Boston: Little, Brown and Co., 1977, pp 107-37.
22. Eland JM: Minimizing pain associated with prekindergarten intramuscular injections. Unpublished PhD Thesis, University of Iowa, 1980.
23. American Optical Corporation: Pseudo-isochromatic plates.