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ELECTRICAL NERVE STIMULATION
FOR CONTROLLING PAIN ASSOCIATED
WITH ORTHODONTIC TOOTH
MOVEMENT

PETER M. ROTH, D.D.S., M.S.D.,*

and

WILLIAM JAMES THRASH, D.D.S., M.A.,**

Los Angeles, Calif., and San Antonio, Texas

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The Alpha-Stim 2000 used in this study uses microampere (μ A) current, not milliampere (mA) as reported herein.

Effect of transcutaneous electrical nerve stimulation for controlling pain associated with orthodontic tooth movement

Peter M. Roth, D.D.S., M.S.D.,* and William James Thrash, D.D.S., M.A.**

Los Angeles, Calif., and San Antonio, Texas

Transcutaneous electrical nerve stimulation (TENS) was assessed for its effect on periodontal pain associated with orthodontic separation. Forty-five adult subjects were randomly assigned to a TENS group, a placebo TENS group, and a control group. They were further subdivided into intraoral and extraoral electrode placement, and 1-, 2-, and 3-day treatment duration groups. In each patient orthodontic separators were placed mesial and distal to the upper first molars, bilaterally. Subjects were asked to rate their discomfort every 12 hours for 4 days with a 10 cm visual analogue scale. The results showed a significant decrease in reported pain for those subjects in the TENS group at the 24-, 36-, and 48-hour assessment periods as compared to either the placebo or control group. In the control group postseparation discomfort continued through the 60-hour assessment period. The present study suggests that TENS is an effective nonpharmacologic method of controlling postadjustment tooth pain. (*Am J ORTHOD DENTOFAC ORTHOP* 90: 132-138, 1986.)

Key words: Transcutaneous electrical nerve stimulation (TENS), pain, postseparation, nonpharmacologic, duration

Pain as a result of early tooth movement is one of the most cited negative side effects associated with orthodontic treatment. Although not quantitatively documented, it has been noted that this pain is usually experienced during or immediately following the adjustment of an orthodontic appliance and may last from 2 to 4 days.¹ The pain intensity ranges from a slight soreness when clenching to a constant, throbbing pain.

Attempts to control postadjustment orthodontic pain have encompassed many modalities. Appliances are designed using lighter wires that deliver less force to the teeth.² However, many patients continue to report discomfort. Pharmacologically, the drug of choice is aspirin or other forms of mild analgesics.³ These are not without side effects⁴ and are often ineffective. Although many noninvasive, nonpharmacologic pain control techniques have been proposed, none to date have been systematically assessed to control postadjustment tooth pain.

One such widely used noninvasive pain control technique is transcutaneous electrical nerve stimulation (TENS). A form of stimulation-produced analgesia, TENS is delivered via surface electrodes placed over the painful area or within the nerve innervating the painful area's distribution. Most TENS devices produce a direct current from a self-contained battery source, usually as an asymmetric, biphasic waveform with a positive rectangular wave component combined with a negative spike component. The current generated has a voltage range of 0 to 90 V (60 mA) and a frequency range of 0 to 100 Hz. The pulse width duration ranges from 10 to 200 μ sec.⁵

Applications of TENS in general pain control include chronic pain^{6,7} and postsurgical pain.⁸ The first dental application of TENS was for treatment of myofascial pain dysfunction (MPD).⁷ In that study 20 MPD patients were stimulated at just below sensation threshold for 3 minutes initially and subsequently for 30 minutes. Of these, 16 reported "excellent," 2 reported "good," 0 reported "fair," and 2 reported "poor" pain relief. It should be noted that no control groups were present in this investigation. Mumford (1976)⁹ assessed the effects of TENS of the pain threshold of electrically stimulated tooth pulp. The results demonstrated a higher pain perception threshold after the TENS application.

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*Clinical Instructor, Department of Orthodontics, University of California at Los Angeles.

**Assistant Professor, Department of Community Dentistry and Psychiatry, University of Texas Health Science Center.

As in the aforementioned study, there was no control for placebo effects. In a controlled experimental design, Hannson and Ekblom (1983)¹⁰ compared the effects of high frequency, low frequency, and placebo TENS therapy for patients attending an emergency outpatient dental clinic. The results showed a significant reduction in pain ratings in the two TENS groups as compared to the placebo group.

The purpose of the present investigation was three-fold: (1) to assess the effectiveness of TENS therapy as compared to placebo or no therapy control groups during the initial response to orthodontic tooth movement, (2) to assess the effects of location and duration of TENS therapy during orthodontic tooth movement, and (3) to document the time course of postadustment tooth pain.

MATERIAL AND METHODS

Design

The present study used a four-factor repeated measures experimental design. Factor one consisted of the random factor of treatment modality (T). The levels of this factor included TENS, placebo, and control modalities. Factor two was an additional random factor of treatment location (L). The two levels of factor two consisted of intraoral and extraoral locations. Factor three was a random factor of number of applications (R). The levels for this factor were 1, 2, and 3 days. The fourth factor was the repeated factor of measurement period (M). The levels for the measurement period factor were 12, 36, 48, 60, 72, 84, and 96 hours. The dependent measure consisted of the visual analogue scale (VAS).¹¹

Subjects

Forty-five adult volunteers were used in the study—27 men and 18 women. The mean age was 28 years and the range was 22 to 41 years. All subjects had a full compliment of teeth, excluding third molars, and interproximal contacts were present on the mesial and distal surfaces of the maxillary first molars. Subjects with known cardiac arrhythmias or those with demand pacemakers present were excluded. No special demographic characteristics were considered.

Subjects (N = 45) were randomly and equally assigned to the following treatment conditions: TENS intraoral, TENS extraoral, placebo intraoral, placebo extraoral, and control (n = 9 per group). With the exception of the control group, each of the experimental groups was further divided into a 1-, 2-, and 3-day treatment schedule. This was impossible with the control group because no treatment was provided.

Apparatus

An Alpha-Stim model 2000* was used to deliver the electrical current. Its intensity range of 25 to 500 mA has been reported as the most effective for managing head and neck pain.¹² Modality 'A' of the TENS unit produces a biphasic waveform with varying pulse widths in the millisecond range and intensities in the microampere range. The VAS used in the present study consists of a vertical 10 cm line anchored by the descriptors of "NO PAIN" at the bottom and "SEVERE PAIN" at the top. The VAS score was defined as that distance (in millimeters) from the bottom of the line to the point at which the subject marks his or her pain state. This scale has been found to be superior to other pain scales in its stimulus discrimination characteristics.^{11,13}

Procedures

Following the signing of institutionally approved consent forms, subjects in the treatment and placebo groups were informed that they would assess a pain reduction device that would deliver a mild electric current. Both groups were told that the intensity of the current was so small that the most they would feel was a very slight tingling, if anything at all. Control subjects were informed that they were participating in a study to assess the discomfort experienced during orthodontic treatment.

For all subjects Unitek S-1 elastic separators[†] were placed mesially and distally to both maxillary first molars. For those subjects in the external groups, sponge pad electrodes were placed bilaterally over the subjects' zygomatic arches (Fig. 1). The subjects were asked to hold the electrodes in place throughout the duration of the treatment. The TENS unit was set to deliver a current frequency of 0.5 Hz with an intensity of 500 mA. The duration of each session was 20 minutes. For the intraoral group current was applied directly to the teeth by placing one probe electrode on the crown of each tooth and the other electrode on the palatal mucosa adjacent to the tooth (Fig. 2). The TENS unit was set at a frequency of 0.5 Hz and at an intensity of 50 mA. The first and second molars and the second premolar on each side of the arch received 6 seconds of treatment current. The placebo subjects were exposed to identical treatment conditions with the exception that there was no current output from the TENS unit.

Following the separator placement, each subject was given eight VAS scoring slips and instructed to

*Electromedical Products, Hawthorne, Calif.

†Unitek Corporation, Monrovia, Calif.



Fig. 1. External sponge pad electrodes placed bilaterally over subject's zygomatic arches.

evaluate their pain every 12 hours by marking the spot on the line they believed to best represent the pain they were experiencing at the time. The VAS score is the distance from the bottom of the line to the point of the subject's mark, measured to the nearest millimeter. Subjects were also instructed to make each evaluation independently from the previous ones by not consulting the previous VAS ratings. Subjects in both the 2- and 3-day treatment groups returned 24 hours later to repeat the treatment procedure. Subjects in the 3-day treatment group returned for an additional treatment 24 hours later. The subjects in the control group received no treatment procedures. Because each repeated factor is nested within the same treatment condition, the presence of absence of any electrical feeling from the TENS unit will not confound the experimental design.

Analysis of data

A four-factor, repeated measures analysis of variance was used to assess the data. The four factors were treatment modality, number of applications, treatment location, and measurement period. The simple main effects test was performed for all sublevel analyses. Least significant difference was used for all multiple pairwise comparisons. An 0.05 level of significance was used for all data analyses.

RESULTS

The mean VAS scores for the different treatment groups at the various assessment periods are shown in Table I. These ranged from 1.77 to 23.33. It should be noted that when TENS was applied intraorally, an extremely large standard deviation of 23.70 was found. In addition, a large standard deviation was noted at the 12-hour assessment period.

The four-way repeated measures analysis of vari-



Fig. 2. Internal probe electrodes. One is placed on the crown of each tooth and the other on the palatal mucosa adjacent to the tooth.

ance revealed a significant interaction between treatment modality and measurement period [$F(7,14) = 6.75, P < 0.001$]. This means that there was a significant difference between the mean VAS scores for the treatment modality groups, but that this difference was dependent on the measurement period at which the assessment took place. It should be noted that the effects of treatment location and of applications were not significant.

Because a significant interaction period existed for treatment modality and measurement period, a test of simple main effects was performed to identify at which assessment periods the significant differences between treatment conditions existed. It was found that there was a significant difference between the treatment modalities at the 24-hour [$F(1,34) = 14.72, P < 0.001$], 36-hour [$F(1,34) = 7.94, P < 0.001$], and 48-hour [$F(1,34) = 10.45, P < 0.001$] conditions. In other words, those subjects receiving TENS reported significantly lower VAS scores than did subjects receiving placebo TENS at the 24-, 36-, and 48-hour treatment periods.

Because of the lack of effect of both the treatment location and number of applications, both the TENS and placebo treatment groups were collapsed across those factors for the purpose of comparison to the control group. This allowed the three groups to be directly compared using a two-factor ANOVA with factor one consisting of treatment modality and factor two measurement period. The results indicate that a sig-

Table I. Mean visual analogue scores as measured across time and treatment conditions

	Time (hours)							
	12	24	36	48	60	72	84	96
<i>Tens</i>								
Internal (n = 9)								
Mean	16.55	4.77	9.11	5.55	10.11	12.44	12.44	9.33
Standard deviation	23.70	6.96	13.00	9.30	16.18	17.64	17.64	15.28
External (n = 9)								
Mean	1.77	2.11	2.33	3.66	3.33	3.33	4.22	3.66
Standard deviation	2.16	2.80	3.55	3.77	4.55	4.58	6.32	5.67
Total (N = 18)								
Mean	14.16	3.44	5.72	4.61	6.72	7.88	8.33	6.50
<i>Placebo</i>								
Internal (n = 9)								
Mean	10.22	15.22	13.66	13.00	12.77	12.33	12.88	12.00
Standard deviation	10.19	15.86	9.26	11.98	12.89	13.85	13.85	14.93
External (n = 9)								
Mean	16.44	23.33	19.22	17.55	13.00	8.55	6.66	4.77
Standard deviation	14.83	17.38	15.63	12.58	10.88	8.17	5.87	4.26
Total (N = 18)								
Mean	13.33	19.27	16.44	15.27	12.89	10.44	9.77	8.38
<i>Control (N = 9)</i>								
Mean	17.88	14.55	22.22	16.44	18.00	9.88	9.22	5.44
Standard deviation	25.41	6.89	14.37	8.24	13.63	7.13	6.74	4.41

nificant interaction exists between the two factors [F(14,168) = 3.53, $P < 0.01$]. This indicates that the particular differences in effectiveness between the treatment modalities is dependent on the measurement period in which treatment was assessed.

To determine at which measurement periods a significant difference between treatment modalities existed, a simple main effects test was performed. It was found that a significant difference between the modalities existed at the 24-hour [F(2,42) = 8.75, $P < .001$], 36-hour [F(2,42) = 6.65, $P < .001$], and 48-hour [F(2,42) = 7.20, $P < .001$] measurement periods. The multiple pairwise comparisons revealed that at the 24-, 36-, and 48-hour assessment periods, those subjects receiving TENS reported significantly lower VAS scores than did those subjects in the placebo ($P < 0.05$) and control ($P < 0.05$) groups. It should be noted that there was no significant difference between the placebo and control groups at any time.

To determine the duration of postseparation tooth pain in untreated subjects, the control group was assessed using a least significant difference test at the 0.05 level. Based on the assumption of zero pre-separation tooth pain, an additional time period (T = 0) was added. This showed that at measurement periods 12, 24, 36, 48, and 60 hours, the VAS scores differed significantly from those at the pre-separation measurement period ($P < 0.05$). This indicates that reported

postseparation tooth pain appeared before 12 hours and disappeared between 60 and 72 hours.

DISCUSSION

A major contribution of the present study was the documentation of the time of onset and duration of the initial pain response associated with the orthodontic tooth movement. The time of onset was between zero and 12 hours (Fig. 3). This pain lasted through the 60-hour assessment period and disappeared between 60 and 72 hours. These findings are similar to the clinical observations reported by Burstone (1964)¹ and by Hoffman (1972).¹⁴

The TENS subjects reported significantly less pain than the placebo and control subjects at the 24-, 36-, and 48-hour measurement periods (Fig. 4). This finding is similar to Hymes (1974),⁸ who found that subjects receiving TENS therapy immediately after abdominal surgery reported less pain than controls and similar also to Mumford (1976),⁹ who found an increase in the pain threshold of human teeth after TENS application.

Pain levels for the placebo subjects were less than those of the control subjects; however, this difference was not significant. The failure of this study to show a significant placebo effect supports the findings of Kim (1984),¹⁵ and Hansson and Ekblom (1983),¹⁰ but is contrary to the findings of Bailey and associates (1984),¹⁶ who reported a strong placebo effect.

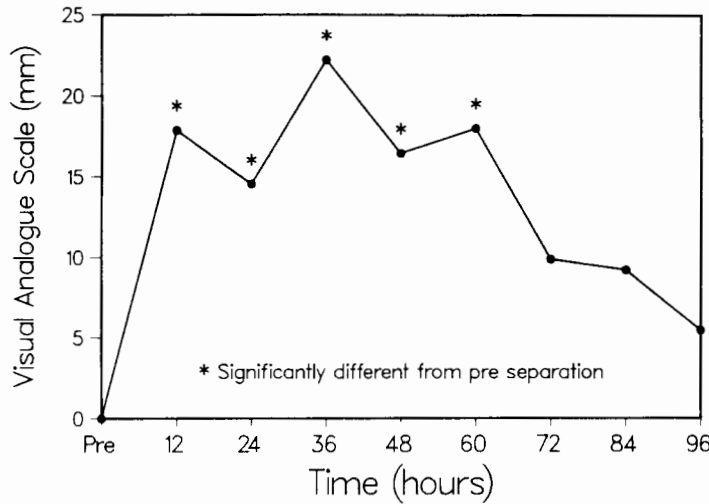


Fig. 3. Mean visual analogue pain ratings on the control group as measured across time. There was no treatment or implied treatment with this group, thus indicating the general duration of postseparation tooth pain. The asterisk (*) indicates those times that were significantly different from the pretreatment period ($P < 0.05$).

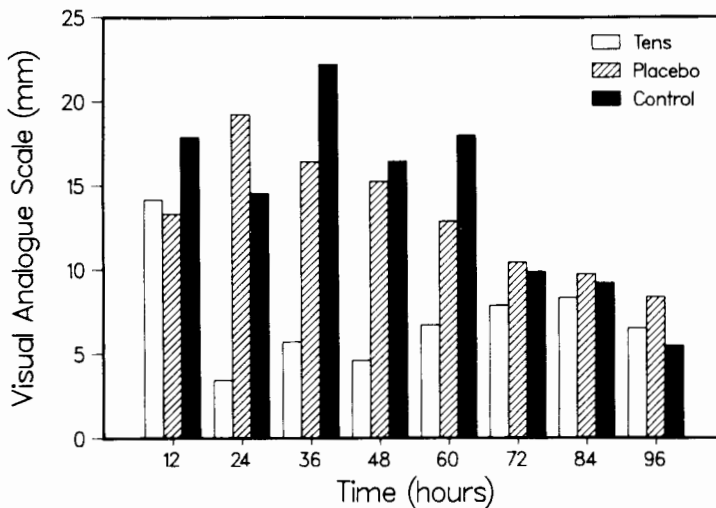


Fig. 4. Mean visual analogue pain ratings of the major treatment variables. The actual values and standard deviations are shown in Table I.

Many investigators believe that the parameters of the TENS current influence the mechanism by which the analgesia is produced. Stratton (1982)¹⁷ proposed that a high frequency/low intensity TENS application stimulates the A-delta and A-beta fibers, blocking the transmission of painful stimuli by the small unmyelinated C-fibers in the spinal cord; this is in accord with Melzack and Wall's gate control theory.¹⁸ The onset of analgesia in high frequency/low intensity TENS is less than 10 minutes, lasts for approximately 30 minutes, and is not blocked by administration of the narcotic

antagonist naloxone hydrochloride.¹⁹ In contrast, analgesia resulting from a low frequency/high intensity TENS application has been shown to have an onset of 15 to 30 minutes and a duration of several hours²⁰ and can be blocked by naloxone,²¹ which is consistent with the existence of an endorphin mediated mechanism.

It is interesting to note that there was no significant TENS effect found at the 12-hour assessment period. Based on the discussed mechanisms of action for TENS, one would expect that the TENS effect would be significant at 12 hours. Hughes and associates

(1984)²¹ found that plasma β -endorphin levels of subjects receiving TENS increased significantly within 30 minutes after TENS application. The gate control mechanism should elicit an almost immediate response.¹⁹ Therefore, the failure to find a significant TENS effect at the 12-hour assessment period was probably the result of the large variance in the time of pain onset (Table I), thus making it difficult to demonstrate a statistical difference at that particular time period.

It is also of interest to note that there was no significant effect of treatment schedule on reported pain levels as a single application of TENS was shown to be effective in reducing pain for more than 48 hours and was as effective as two or three TENS treatments. The prolonged analgesia effect of a single TENS application was also demonstrated by Melzack (1975)¹⁹ and Baur (1983).¹² It is difficult to explain this finding using the two TENS mechanisms previously described.

Several other mechanisms not previously discussed may help explain the prolonged analgesic effect. One such mechanism involves the concept of memory-like pain pathways. Livingston (1943)²² and Melzack (1973)²³ suggested that prolonged intense pain or even low-level abnormal inputs may produce a self-sustaining neural pathway that subserves memory-like processes related to pain. This mechanism implies that once a neural pain pathway has been established, future stimulation of that pathway can occur by lower level inputs. The concept of a memory-like mechanism in pain is supported by convincing experimental evidence obtained in both human subjects²⁵ and animals.²⁶ If a single application of TENS at the time of separator placement prevented the neural pathway from being established, then pain levels in these subjects, even several days postseparation, should be less than in those subjects in whom the pain pathways were allowed to be established. This could account for the prolonged analgesic effect observed.

In the present study the effect of electrode placement was not significant. However, this finding must be considered with caution. The mean VAS scores for TENS intraoral treatment are much higher than those obtained with the TENS extraoral treatment. The failure to demonstrate this effect statistically is probably a result of the high degree of variance in the TENS intraoral group. The relationship between variance (standard deviation²) and the difference in the mean values of the groups results in the possibility of being unable to demonstrate statistical significant differences. Additional subjects can be tested to reduce the amount of within-group variance and decrease the chance of making these types of errors. However, the relationships between variance and means do not lessen the validity of those

statistical differences that are observed. Thus, additional testing should be performed before any clinical recommendations on electrode placement are made.

The clinical application of the present findings is significant. Orthodontic patients could receive a TENS treatment immediately following any procedure that may cause discomfort. If subsequent investigations demonstrate similar results, the most efficient means of TENS application might be with intraoral electrodes for 6 seconds per tooth. If additional research demonstrates a shorter duration of extraoral TENS to be equally effective, then perhaps this might be even more convenient as the patients could hold the electrodes in place without assistance and home application would be feasible.

The potential benefits to the patients are many. White (1984)³ has suggested that poor oral hygiene and cooperation may result from pain caused by treatment and toothbrushing. Perhaps a reduction in the pain experienced would lead to better patient compliance. Many patients may avoid seeking orthodontic treatment because of the pain that is associated with it. The ability to offer more comfortable orthodontic treatment might enable the orthodontist to provide service for previously apprehensive patients. Finally, the use of TENS might result in a decrease in the amount of analgesics needed.

The present study demonstrated that TENS is effective in reducing the pain associated with orthodontic separations; however, much more study is needed in this field. Future studies should focus on determining what treatment parameters are most effective for treating this type of pain. Particular emphasis should be placed on learning how the analgesia experienced is affected by varying the duration and location of TENS application. The question of whether a shorter period of extraoral TENS application is as effective as the 20-minute application used in this study requires further investigation. Other investigations should determine if TENS is effective in reducing orthodontic pain in mandibular teeth and if TENS is effective in children.

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Reprint requests to.

Dr. Wm. James Thrash
Dept. of Community Dentistry
UTHSCSA-Dental School
7703 Floyd Curl Rd.
San Antonio, TX 78284