EFFECTS OF LOW LEVEL LASER THERAPY ON ORTHODONTIC PAIN

A Thesis

by

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ABSTRACT

Purpose: To determine the effectiveness of low level laser therapy applied extra orally on the reduction of orthodontic pain. **Materials and Methods:** Sixty dental students were voluntarily recruited for this randomized, double-blinded, placebo-controlled, prospective clinical trial. To simulate orthodontic pain, all subjects had four separators placed mesially and distally to either the right or left maxillary and mandibular first molars. Subjects were randomly allocated to one of three different groups: experimental, placebo, and control. Subjects in the experimental group received devices that emitted low level laser therapy while subjects in the placebo group received identical devices that had the output of low level laser therapy dismantled internally. Subjects in each group filled out questionnaires at seven separate time intervals regarding their pain and quality of life changes from the orthodontic separators.

Results: When measured at rest, pain increased rapidly over the first 6 hours and then began to decrease after 48 hours. When measured while chewing, pain increased rapidly over the first 24 hours and then began to decrease after 72 hours. There were no significant differences between the experimental, placebo, and control groups for pain both at rest and while chewing at any of the time points. There were also no significant differences between the three groups for changes in eating habits and consumption of analgesic drugs. **Conclusion:** Extra oral application of low level laser therapy is not an effective way to decrease orthodontic pain.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

The vast majority of people who have had orthodontic treatment or are acquainted with others who have undergone orthodontic treatment know that pain is a common sensation experienced by patients. Research has shown that approximately 95% of all patients experience pain due to their orthodontic treatment. [1, 2] Oliver et al. conducted a survey to assess attitudes towards active orthodontic treatment.[3] Anonymous questionnaires were distributed to patients at or near the end of orthodontic treatment at two dental schools in the UK. Approximately 40% of the patients reported that pain was the worst aspect of wearing orthodontic appliances. Almost 30% of the sample also reported that pain was their primary reason for wanting to stop treatment. In a more recent survey, O'Connor assessed patients' perceptions before, during, and after orthodontic treatment.[4] He distributed anonymous questionnaires to 146 consecutive patients being treated in a single orthodontic practice. The results indicated that pain was ranked as the number one dislike during orthodontic treatment and the fourth greatest fear and apprehension that orthodontic patients had prior to their treatment.

Despite the high prevalence of pain associated with orthodontics and its importance to patients undergoing treatment, this topic has not been well studied. Many different methods of pain control have been used by orthodontic patients including analgesics, transcutaneous electrical nerve stimulation, and chewing on different objects such as Thera-Bite Wafers and Aspergum. Previous studies have shown that low level

laser therapy may significantly decrease orthodontic pain.[5-10] However, the vast majority of these previous studies had major design flaws because the operators were not blinded to the actual laser and placebo groups. Due to the subjective nature of pain, a patient's perception of the amount of pain they are experiencing can be influenced by the operator's thoughts or actions.[11] Therefore, stronger studies with total operator and subject blinding are necessary in order to reach more definitive conclusions. The purpose of the present study was to evaluate the effects of low level laser therapy on orthodontic pain using increased internal validity.

The following review will begin by discussing the basic definition of pain and common ways that have been used to measure pain. Different aspects of orthodontic pain including classification, effects, sources, and mechanisms will be covered next. For comparative purposes, the various methods to prevent or resolve orthodontic pain will be reviewed. Lastly, low level laser therapy and the previous studies using this modality of pain control in the field of orthodontics will be explored.

DEFINITION OF PAIN

Pain is a complex topic, which explains why there are numerous ways to define this sensation. According to the International Association for the Study of Pain, pain can be defined as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage."[12] Unquestionably, pain is a negative sensation in a part or parts of the body. However, a characteristic of pain is that it is always unpleasant, which contributes to it being an emotional experience. Therefore, this aspect must be included in the definition.

MEASUREMENT OF PAIN

The sensation of pain is a very complex, subjective experience. Therefore, the determination of a patient's pain cannot be objectively assessed and must be measured indirectly. There have been many ways that pain research has attempted to collect reliable and reproducible measurements. For adults and adolescents, the three most commonly used instruments for evaluating pain intensity are the Visual Analog Scale (VAS), Verbal Rating Scale (VRS), and Numerical Rating Scale (NRS).[13]

Most of the orthodontic pain studies use the Visual Analog Scale to measure patient's pain levels. The scale represents a line (usually 100 mm long) that has two end point anchors, which indicate the extremes, such as "no pain" and "worst pain imaginable". The patient is instructed to mark a location along the line which they believe best represents their current pain level. The Visual Analog scale holds two distinct advantages in measuring pain. First, it allows the patient to choose the exact intensity of their pain. Another advantage is that it provides the patients with the maximum opportunity for expressing their unique personal response style.[14]

The Verbal Rating Scale (VRS) is comprised of a series of adjectives used to describe various levels of pain intensity. Two adjectives such as "no pain" and "extremely intense pain" are used to mark the lowest and highest pain possibilities, respectively, along with other descriptive choices such as weak, mild, moderate, and strong pain to create a gradual list between the two extremes. Patients are then instructed to select the adjective from the list that they believe best represents the pain they experience.[13] However, the VRS has significant flaws in terms of reliability. It has

been shown that there are oftentimes differences in the interpretation and ordering of the pain descriptors between patients depending on different factors, such as age and degree of apprehension. In addition, this scale assumes that there are equal intervals between the different pain descriptors, which in reality is rarely the case.[15]

Rosier et al. studied the reproducibility of pain measurement and pain perception using both the Visual Analog Scale and the Verbal Descriptor Scale.[16] In order to calibrate the patients' pain thresholds, each patient was asked to recall the worst physical pain of their life and rate its intensity and unpleasantness at the beginning of each session. Based on comparisons between the two scales, pain intensity ratings collected with the VAS had significantly smaller session-to-session variation than the VDS. In addition, the visual analog scale was significantly more sensitive to small differences in perceived pain intensity and pain unpleasantness. Also, it was noted that the VAS did not portray some of the ordering effects that were present with the VDS.

Lastly, the Numerical Rating Scale is also used to evaluate pain, although it is not commonly used in orthodontics for studying pain perception. With this scale, the patients simply rate their pain from 0, representing no pain, to 10 or 100, representing the worst possible pain.[13] A limitation of this scale is that patients do not have the ability to choose the exact intensity of their pain and are forced to choose a number which they believe best represents it.

TYPES OF PAIN

Pain can be classified into three distinct types including nociceptive pain, inflammatory pain, and neuropathic pain.[17] Nociceptive pain can is considered a

physiological protective system which is necessary for detecting and minimizing contact with different dangerous or noxious stimuli. This type of pain can be felt from touching objects that are too sharp, cold, or hot. Inflammatory pain is caused by the activation of the immune system by tissue injury or infection. This pain discourages physical contact or movement of an injured body part which helps with its healing by reducing further risk of damage and promoting recovery. Lastly, neuropathic pain can result from abnormal functioning of the nervous system often due to damage or disease of the system. It is often characterized by continuous or intermittent; electrical, shooting, or burning sensations.

Another way to differentiate types of pain is by duration. Chronic pain can be defined as pain that lasts for longer than 3 to 6 months from the onset of injury. Alternatively, chronic pain has been defined as pain that persists longer than the "normal healing" time of an injury. On the other hand, acute pain is of shorter duration, typically less than 30 days. Generally, acute pain decreases as healing continues and ultimately reaches a definite endpoint.[18]

Orthodontic pain would be considered to be acute because of its short duration after a force is applied to the teeth. It would also be classified as an inflammatory pain based on the physical stimuli of orthodontic forces initiating an inflammatory response.[19]

CLASSIFICATION OF ORTHODONTIC PAIN BASED ON FORCE AND TIME

Burstone proposed a well-defined system to classify orthodontic pain based on the force application relationship and on the time of onset.[20] Based on the patient's response to the amount of force applied, pain can be broken down into three separate

categories: first, second, and third degree. Pain is considered to be first degree when the patient isn't aware of the pain unless the teeth are manipulated by an orthodontist. An example of this type of pain would be from using instruments such as a band pusher or force gauge on the teeth. Second degree pain occurs when the patient is clenching their teeth or performing heavy biting. It usually will occur within the first week of placing or adjusting an appliance and the patient is still able to chew a normal diet consisting of foods of varying degrees of hardness. Third degree pain often occurs spontaneously, and is severe enough to alter a patient's normal diet. An example of third degree pain would be during the first few days of having separators placed interproximally.

When categorizing pain based on the time of onset, Burstone divided pain into either immediate or delayed. Immediate pain is pain that can be felt at the exact time of placement of heavy forces on a tooth. It is related to the initial compression of the periodontal ligament by a heavy force. On the contrary, delayed pain occurs from forces that can range from light to heavy, and represents hyperalgesia of the periodontal membrane. Delayed pain often changes with time amongst the three degree mentioned above. For example, delayed pain can start as third degree pain and then become first or second degree pain with increasing time.[20]

EFFECTS OF ORTHODONTIC PAIN

The movement of teeth in the field of orthodontics is almost always accompanied by some degree of pain. This pain can have many negative effects on the orthodontic patient. Perhaps one of the most important effects caused by pain is decreased patient compliance. The amount of pain and discomfort experienced during orthodontic

treatment can predict acceptance of orthodontic appliances and cooperation with treatment.[21] It has also been suggested that pain during treatment and the patient's individual pain thresholds are closely related to their inability to cooperate during treatment and perform adequate oral hygiene.[22]

Besides decreasing patient compliance with many aspects of treatment, orthodontic pain can significantly affect patients activities of daily living. It has been found that the pain caused by orthodontics can significantly influence the need for analgesic consumption.[23] In addition, orthodontic pain has been shown to cause a significant change in food habits, from normal diets to ones comprised of softer foods.[24]

SOURCES OF ORTHODONTIC PAIN

The existing literature shows that all orthodontic procedures that precipitate any form of tooth movement are capable of causing pain in the majority of patients. These include, but are not limited to, archwire placement and activation, different fixed and removable appliances, and the placement of separators.[24-28]

Fernandes et al. studied the pain experienced after placement of both conventional nickel-titanium and superelastic nickel-titanium archwires.[25] The results of this randomized clinical trial showed that the discomfort level increased continuously every hour after the insertion of either type of wire. The pain level reached a peak on the first night, remained high on the second day, and decreased to baseline levels after 7 days. Stewart et al. examined patients' experiences with both fixed and removable orthodontic appliances.[26] Their questionnaires showed that both types of appliances cause pain in the majority of patients and that most problems relating to pain and

discomfort were resolved within 4-7 days. When compared with each other, the pain caused by fixed appliances was generally more severe than the pain caused by the removable appliances.

The placement of separators is a common procedure used in orthodontics to fit and cement molar bands for palatal expanders, head gears, or full fixed appliances to name a few. A study conducted by Ngan et al. demonstrated that the placement of separators caused a significant difference in the amount of pain experienced both 4 and 24 hours after placement as compared to controls.[28] At the 4 hour time point, the pain measured for the categories of chewing, biting, and fitting of back teeth together were each approximately 40% on the VAS discomfort scale. At the third evaluation time point of 7 days, the pain had returned to a non-significant level. These pain intensity levels measured at the 4 and 24 hour intervals were comparable to the pain caused by the placement of the first orthodontic archwire. Bondemark et al. also studied the pain caused by the placement of orthodontic separators. They concluded that significant pain of moderate intensity occurs during the separation period. In addition, the pain gradually increased after insertion until it peaked on day 2 (VAS mean ≈ 45%). On the third day, the pain was reported to begin to subside and by the fifth day the pain was almost completely resolved.[24] A similar study on the experience of orthodontic pain caused by elastic separators was performed by Bergius et al. In this study, the patients reported the highest intensity of pain the day after placement of separators (VAS mean = 43.7%). When evaluated at day 7 of the experiment, 42% of these patients reported still experiencing some degree of pain.[27]

MECHANISM OF ORTHODONTIC PAIN

Inflammation is a biologic response by a host to tissue injury. There are many different causes of tissue injuries that can initiate an inflammatory response, including microbial invasion, chemical stimuli, and physical stimuli. Acute inflammation is characterized by having varying degrees of five cardinal signs: pain, redness, swelling, heat, and loss of function. The movement of teeth orthodontically causes changes in blood flow in both the surrounding periodontal ligament and dental pulp, creating areas of ischemia, edema, and an inflammatory reaction.[19] This is turn, causes the release of many biochemical mediators which cause the pain experienced by orthodontic patients. The increased biochemical mediators include substance P, histamine, encephalin, dopamine, serotonin, glycine, glutamate, gamma-amino butyric acid, prostaglandins, leukotrienes, and cytokines produce a powerful hyperalgesia.[14, 29] The hyperalgesia is induced in the nociceptors due to their sensitization from these inflammatory mediators.

Orthodontic forces create areas of both compression and tension within the periodontal ligament. Pressure causes the fluids in the PDL to flow from their existing equilibrium to altered states due to the distortion of the periodontal ligament matrix and the cells within. This alteration leads to the peripheral nerve fibers in the periodontal ligament to create the sensation of pain through the release of neurotransmitters.[29]

During the process of neurogenic inflammation, the orthodontic tooth movement causes the stimulation of afferent nerve fibers to release neuropeptides such as substance P and calcitonin gene-related peptide which creates a painful response.[19] After the application of orthodontic force, the concentration of substance P has been shown to

greatly increase in the dental and periodontal tissues. This increase of substance P concentration occurred rapidly in the dental pulp, (after approximately 3 hours), and later (around 24 hours) in the periodontal ligament.[30] In addition, nerve fibers and blood vessels in the periodontal ligament show increased calcitonin gene-related peptide immunoreactivity during orthodontic tooth movement. This increased immunoreaction reaches its greatest density and intensity 3 days after force activation.[31]

The release of substance P and calcitonin gene-related peptide from the afferent nerve fibers creates a biochemical cascade which affects many types of cells in the periodontal ligament. Upon release, substance P modifies the secretion of various pro-inflammatory cytokines from monocytes. These pro-inflammatory cytokines include IL-1B, IL-6, and TNF-a.[30] Substance P and CGRP cause the release of histamine, leukotrienes, and prostaglandins from mast cells. In addition, these neuropeptides influence macrophages to release prostaglandins and various pro-inflammatory cytokines, which all contribute to the patient feeling a painful response. [19]

PAIN CONTROL METHODS

There are many different ways that patients undergoing orthodontic treatment attempt to decrease the pain they experience. The use of analgesics, such as nonsteroidal anti-inflammatory drugs (NSAIDs), is the most common way to decrease orthodontic pain.[13] These analgesics are known to be a successful method of orthodontic pain control. NSAIDs have been referred to as the gold standard for reducing this type of pain.[32] NSAIDs are able to successfully control pain by inhibiting the cyclooxygenase

enzyme which synthesizes prostaglandins from arachadonic acid. This ultimately causes a reduced concentration of prostaglandins which are important pain mediators.[33]

Patel et al. studied the effects of three different analgesics (ibuprofen, naproxen sodium, and acetaminophen) on orthodontic pain.[34] The three analgesics, along with a placebo, were administered 1 hour before, and 3 and 7 hours after separator placement. The results showed that administering ibuprofen at these three time intervals significantly reduced pain, approximately 50% compared with the placebo, during the first day. However, the analgesic effects diminished when the pain was measured 24 hours after separator placement.

Although analgesics such as NSAIDs have been shown to decrease the pain caused by orthodontics, their use entails some significant concerns. One of the major concerns pertains to NSAIDs interference with the inflammation cascade corresponding to the process of moving teeth. Chumbley et al. showed a significant decrease in tooth movement (approximately 50%) for the subjects given indomethacin during orthodontic therapy.[35] As a result, a decrease in the rate of tooth movement would invariably increase orthodontic treatment time, a negative consequence for both the patient and orthodontist. In addition, analgesics contain many potential adverse side effects and are also contraindicated for patients who are allergic to them.[36]

Besides pharmacologic agents, other modalities to decrease orthodontic pain have been suggested. In one study, transcutaneous electrical nerve stimulation, also known as TENS, has been shown to produce a significant decrease (approximately 66%) in orthodontic pain for subjects assessed 24, 36, and 48 hours after orthodontic

separation.[37] It has been suggested that chewing on hard objects after orthodontic adjustments diminishes orthodontic pain by accelerating blood flow around the compressed periodontal ligaments.[38] The majority of the patients who bit onto Thera-Bite wafers reported that they were effective in reducing pain. However, the majority of the patients who found these wafers ineffective also reported to have increased discomfort after chewing on them.[39] White studied the effects of having patients chew two pieces of Aspergum, (i.e. chewing gum containing aspirin), for 20 to 30 minutes immediately following archwire changes. He found that approximately 63% of the patients reported experiencing less discomfort than usual after chewing the gum.[22] More recently, low level laser therapy has been used to decrease orthodontic pain. However, the results of these studies have been controversial.

LOW LEVEL LASER THERAPY

Low level laser therapy (LLLT) has been used for decades in the field of dentistry for various purposes. LLLT is defined as treatment that uses lasers that have low enough energy outputs so that the temperature of the tissue being treated does not rise above normal body temperature (36.5° C). The effects are biostimulatory in nature.[36]

The precise mechanism of the biostimulation produced by LLLT is believed to be attributed to the respiratory chain enzymes, or cytochromes, within mitochondria or endogenous porphyrins in the cell that act as the energy absorbing chromophores.[40] Respiratory chain enzymes form high energy phosphate bonds in ATP that are used to drive cell metabolism. The absorption of light has the capability of increasing cell

metabolism, from decreased to normal levels. The increase in ATP availability, which drives the sodium-potassium pump of neuronal membranes, helps to maintain its negative resting potential and provide membrane stabilization for neurons.[41] An in vivo study using LLLT in the oral cavity showed a decrease in the firing frequency of nociceptors. The decrease in firing exhibited a maximal threshold effect.[42]

In addition to exhibiting neuronal effects, low level laser therapy is thought to decrease inflammation by inhibiting the production of inflammatory factors and pain-related neurotransmitters. An animal study evaluating the effects of LLLT demonstrated significant inhibition of the total number of leukocytes and myeloperoxidase activity, along with a reduction of polymorphonuclear cells at the site of inflammation. In addition, LLLT significantly inhibited the production of PGE2.[43] Another study involving human gingival fibroblasts demonstrated a reduction of PGE2 levels and the inhibition of COX-2 after LLLT.[44]

PREVIOUS LLLT STUDIES

There have been several studies evaluating the ability of low level laser therapy to reduce orthodontic pain. In a study conducted by Turhani et al., 76 patients with a mean age of approximately 23 years were randomly assigned to either a group receiving low level laser therapy or a group receiving placebo laser treatment. After initial banding and bonding, each tooth was treated separately with LLLT (Table 1). Although the subjects were blinded in regards to which group they were in, the operator who applied the laser treatment was not blinded and therefore able to differentiate between the two treatments. It is possible that the operator's knowledge transferred unknowingly

to the subjects. The results of this study showed a significant decrease in the amount of pain experienced for the actual laser group at the 6 and 30 hour time intervals, but there were no significant differences at the final evaluation time of 54 hours.[5]

Tortamano et al. also studied the effects of low level laser therapy on pain created by the placement of the first orthodontic arch wires.[6] Sixty patients with a mean age of approximately 16 years were randomly assigned to one of six groups. Two groups received experimental laser treatment, one in the maxilla and one in the mandible. Two groups received simulated laser treatment in either arch and two groups served as controls. Each tooth in the arch receiving treatment was irradiated in 5 areas on both the buccal surface of the root and the lingual surface of the root. The blind groups had the laser probe positioned in the mouth over those same areas and could hear a sound every 10 seconds. Since the operator was merely pretending to apply the laser treatment, the subjects might have known that they were not receiving any treatment, which could have significantly affected their perception of pain. The results of this study showed that LLLT did not significantly affect the onset of pain in any of the groups; 7.6 hours for the control groups, 5 hours for the placebo groups, and 8.9 hours for the experimental groups. LLLT also did not alter the time point during the experiment which was the most painful which occurred during the first 24 to 48 hours after activation for all groups. However, compared to the other two groups, the LLLT group experienced a significant reduction in the duration of pain. It reached a negligible level by the fourth day in the LLLT group, whereas it did not reach the same level until

the seventh day for the other groups. In addition, the level of oral pain experienced and the intensity of the pain were lower for the LLLT group.[6]

In a study by Eslamian et al., orthodontic elastomeric separators were used to determine the ability of low level laser therapy to decrease orthodontic pain.[7] Either the maxillary or the mandibular first molars were separated using four separators. The experimental side was randomly chosen and the other side received placebo treatment. Each experimental area received 10 doses of laser therapy after separator placement and another 10 doses 24 hours later. For the placebo quadrant, a similar procedure was performed but without laser irradiation. There was no mention of operator blindness, which again could have influenced the subjects' pain perception. In addition, it might be difficult for patients to differentiate and localize pain in studies using a split mouth design. Nevertheless, the results showed significantly less pain on the laser side after at 6, 24, and 30 hours and at day 3 of the experiment.[7]

Dominguez et al. also used a split mouth design to study the effect of LLLT on pain after the activation of orthodontic final archwires. Sixty patients were randomly allocated to either have their maxillary or mandibular arch receive low level laser therapy. The opposite arch was placebo treated for the amount of time, with the laser turned off. The arch receiving the actual treatment could easily have been differentiated from that of the placebo, thus influencing the patients' pain perceptions. Pain was evaluated using a VAS after 2, 6, and 24 hours, and after 2, 3, and 7 days of application. At all time points, the pain measured in the arch that received low level laser therapy was significantly less than the pain measured in the placebo arch.[8]

Youssef et al. studied the effects of low level laser therapy during the retraction of canines after first premolar extractions.[9] In their study, 15 patients had their upper and lower first premolars extracted and then received laser irradiation on the right side of their upper and lower jaws at 0, 3, 7, and 14 day intervals. Serving as a control, the tip of the laser was held on the left side of the mouth without activating it. The results of this study indicated that the patients reported significantly less pain on the experimental side than on the control side.

In a very similar study, Doshi-Mehta et al. evaluated the effects of low level laser therapy on canine retraction in 20 patients. The results showed significantly lower pain scores on the experimental side than on the control side after 3 and 30 days of canine retraction.[10]

In 2013, Nobrega et al. published a study using LLLT for the treatment of pain associated with orthodontic elastomeric separator placement.[45] Sixty orthodontic patients were randomly assigned to either a laser or placebo group. All patients received elastomeric separators on the mesial and distal surfaces of one of the mandibular first molars. Immediately after insertion of the separators the subjects received the actual laser or placebo treatment. Unlike the previous studies, this study stated that the operator was blinded. Two different probes were used that were similar in appearance, shape, size, and weight. The article stated that operator/researcher was blinded throughout the data collection process. Subjects filled out questionnaires at 2, 6, and 24 hours, and 3 and 5 days after separator placement. Except on day 5, the subjects in the

LLLT group had significantly lower mean pain scores for both spontaneous pain and with the teeth in occlusion.

In other studies, low level laser therapy did not demonstrate a statistically significant reduction in orthodontic pain. Lim et al. used a within subject experimental design that exposed subjects to 15, 30, and 60 seconds of LLLT, and 30 seconds of placebo application in the four different quadrants of the mouth. This experimental design assumed that the effects of LLLT did not have any interaction between the quadrants where it was differentially applied.[36] Esper et al. compared the effects of low level laser therapy and low level LED therapy in reducing orthodontic pain, and showed no significant decreases in pain levels for the laser group.[46]

In addition to orthodontics, low level laser therapy has been used in general medicine for its potential pain relieving effects. Jang et al. conducted a meta-analysis of pain relief effects by laser irradiation on joint areas, including different types of arthritis, temporomandibular disorder, and low back pain.[47] After the literature search, 22 trials that met the inclusion criteria were selected. Of these, half of the studies showed LLLT to be effective in decreasing pain. The other 11 studies showed LLLT to be ineffective. The laser therapy parameters for each study were compared with each other. The studies were found to have used an extremely wide range of laser specifications suggesting that the external application of LLLT currently is very poorly understood. The results of this analysis showed that the controversial effects of low level laser therapy also exist when used externally directly over the site of pain.

A major factor to consider when using low level laser therapy externally in an attempt to decrease pain is the depth of tissue penetration. Byrnes et al. projected LLLT through the dorsal skin over the thoracic vertebrae and used an optical fiber probe attached to a spectrophotometer to collect data at different tissue layers.[48] They found that the depth of penetration is wavelength dependent, with a maximum penetration achieved using wavelengths between 770 and 850 nm. Hudson et al. compared the penetration of 808 and 980 nm laser light through bovine tissue samples 18-95 mm thick.[49] It was determined that light with a wavelength of 808 nm penetrates as much as 54% deeper than 980 nm light in bovine tissue. They also showed that the depth of penetration increases for increasing power levels. At a wavelength of 808 nm, the depth of penetration of 1 mW/cm^2 was measured at 3.4 cm, while at 1000 mW/cm^2 the penetration depth was 8.4 cm.

Besides the study by Nobrega et al., the previously mentioned LLLT studies showing statistically significant effects on orthodontic pain had major flaws. For the six studies showing significant effects, the laser was held in place but not activated in an attempt to maintain "blindness" for the patients. As such, the success of the studies relied on the extremely difficult task of applying the known placebo treatments in a convincing manner. The treatment had to be delivered without giving off any verbal or nonverbal cues as to which treatment was the placebo. If the patients were able to distinguish differences in the operators' behavior, it could easily have skewed the subjects' perception of pain. With only one study reporting adequate blinding procedures, further studies are needed evaluating the effects of low level laser therapy on

orthodontic pain using both complete operator and patient blindness as to which treatment is experimental and placebo. In addition, the possibility of decreasing orthodontic pain using extraoral application of LLLT needs to be studied.

CHAPTER II

BACKGROUND

Research has shown that approximately 95% of all patients experience pain due to their orthodontic treatment. [1, 2] Oliver et al., who conducted a survey to assess attitudes towards active orthodontic treatment, found that approximately 40% of the patients reported pain as the worst aspect of wearing orthodontic appliances.[3] Almost 30% of the sample also reported that pain was their primary reason for wanting to stop treatment. In a more recent survey, O'Connor assessed patients' perceptions before, during, and after orthodontic treatment.[4] Based on anonymous questionnaires distributed to 146 consecutive patients being treated in a single orthodontic practice, pain was ranked as the number one dislike during orthodontic treatment and the fourth greatest fear and apprehension that orthodontic patients had prior to their treatment.

The placement of separators is a common procedure used in orthodontics to fit and cement molar bands for palatal expanders, head gears, or full fixed appliances, which produces pain and discomfort. Ngan et al. demonstrated that the placement of separators significantly increased the amount of pain experienced both 4 and 24 hours after placement.[28] After 4 hours, the pain produced while chewing, biting, and fitting of back teeth together was approximately 40% of the subjects' maximum possible pain. After 7 days the pain had returned to a non-significant level. These pain intensities after 4 and 24 hours were comparable to the pain caused by the placement of the first orthodontic archwire.[28] Bondemark et al., who also studied the pain caused by the

placement of orthodontic separators, concluded that significant pain of moderate intensity occurs during the separation period.[24] Pain gradually increased after separator insertion until it peaked on day 2 (VAS mean ≈ 45%). On the third day, the pain began to subside and by the fifth day, it was almost completely resolved. Bergius et al. reported the highest intensity of pain the day after placement of separators (VAS mean = 43.7%). When evaluated after 7 days, 42% of these patients reported experiencing some degree of pain.[27]

Low level laser therapy (LLLT) has been shown to decrease different types of pain including orthodontic pain.[5, 6, 8-10, 45] LLLT can be defined as treatment using lasers that have low enough energy output so that the temperature of the tissue being treated does not rise above normal body temperature (36.5° C). Since the low energy and intensity do not create thermal changes, the effects are biostimulatory in nature, causing an increase in ATP availability which can lead to neuron membrane stabilization.[36, 41] LLLT has also been hypothesized to decrease inflammation by inhibiting the production of inflammatory factors and pain-related neurotransmitters.[43, 44]

Previous studies utilizing low level laser therapy to decrease orthodontic pain are controversial. Some studies have shown that LLLT does not reduce orthodontic pain.[36, 46] The majority of studies reporting significant reductions in orthodontic pain with LLLT had major design flaws.[5, 6, 8-10] The operators applying the laser/placebo treatments were not blinded and the subjects could have distinguished differences in the operator's behavior which could have easily skewed their perception of pain.

The aim of the current study was to determine the effectiveness of low level laser therapy applied extra orally on the reduction of orthodontic pain. Due to the subjective nature of pain, the operator and all subjects were completely blinded with regards to whether they were in the experimental or placebo groups. Extra oral application was chosen because it more accurately reflects the way in which orthodontic patients might use LLLT in private practice settings.

CHAPTER III

MATERIALS AND METHODS

Sixty dental students at TAMU Baylor College of Dentistry volunteered to participate in this randomized, double-blinded, placebo-controlled, prospective clinical trial. Subjects were eligible to participate in this study if they had their premolars, first molars, and second molars in mesiodistal contact with each other. They had to be in contact on at least one side of both the maxillary and mandibular arches. Subjects were excluded from participating if they met any of the following criteria: (1) currently taking any pain medication; (2) currently experiencing any dental/oral pain; (3) needed antibiotic prophylaxis prior to dental treatment; (4) currently undergoing orthodontic treatment; (5) had a neurological or psychiatric disorder; (6) currently pregnant; (6) had a history of or current carcinoma near the area of laser therapy; (7) currently had a fever (body temperature higher than 100.4°F/38°C unless antibiotics have been started); (8) had hemorrhages near the area of laser application. The study was approved by Baylor College of Dentistry's Institutional Review Board (IRB) and informed consent was obtained from all of the subjects.

The subjects were randomly assigned to one of three groups using a random numbers table. Subjects in the experimental group received a device emitting low level laser therapy. The placebo group received an identical device that had the laser output dismantled internally. Multi Radiance Medical provided their TQ Solo units to be used as the laser and placebo devices. Both the laser and placebo devices appeared to

function in the exact same manner and were identical to both the subjects and operator. They both emitted visible similar red "light", at a wavelength of 660 nm, via LEDs that were decreased to a minimum output. The laser device emitted laser radiation with a wavelength of 905 nm. The energy density of the laser was 0.85 J/cm^2 per 60 seconds of activation. Each placement of the device lasted for 5 minutes for a total of 4.26 J/cm^2. The laser device also emitted energy via infrared LEDs at a wavelength of 875 nm. Since the lasers in this study were designed to be used externally, they had a circular output window that measured 4 cm in diameter. However, only a 0.4 cm laser beam was emitted from the center of the window. The subjects in group three served as controls and did not receive either a laser or placebo device. Each group included 20 subjects, 10 males and 10 females.

To measure pain, subjects completed questionnaires using the online computer software SurveyMonkey®. Questionnaires were separately emailed at seven intervals to ensure timely completion of the surveys: 1) prior to placement of separators, 2) 6 hours after separator placement, 3) 1 day after separator placement, 4) 2 days after separator placement, 5) 3 days after separator placement, 6) 4 days after separator placement, and 7) 5 days after separator placement. This timeframe was chosen based on previous findings showing that the pain is almost completely resolved by the fifth day.[24] In order to collect baseline data, the subjects completed their first questionnaire prior to separator placement. During this initial questionnaire, the subjects were given instructions on filling out the online questionnaires. An identical questionnaire was emailed to the subjects that evening and five evenings thereafter.

Figure 1 shows the questionnaire that the subjects completed at each of the seven time points. The questionnaire first asks the subjects to mark the intensity/unpleasantness of the worst physical pain that they have ever experienced. This question was asked to ascertain if the three groups were comparable in their previous pain experiences and to determine if their responses were consistent over time. The next two questions examined the amount of pain the subjects were currently experiencing, both at rest and while chewing. The subjects answered these three pain questions using a modified Visual Analog Scale, which was anchored with "no pain" and "worst pain imaginable". The VAS scale was modified so that there were sixteen distinct choices between the two anchors, rather than a continuous line. The next two questions assessed quality of life differences among the groups, by asking about possible dietary changes to softer foods and the consumption of pain relieving medications. Lastly, the subjects were asked how many times they had applied the laser therapy over the last 24 hours.

After completing the initial questionnaire, subjects in the experimental and placebo groups were given detailed instructions on how to use the laser and placebo devices. Written instructions were also given to the subjects. Each treatment consisted of two placement locations on one side of the face. The instructions were to:

1. Press and hold the power button to turn on the device. Press the mode button to change setting to severe. Place the laser device between ear and temporal mandibular joint applying gentle pressure. Press power button again to activate the device. Hold device in position, without moving it, until the unit

automatically turns itself off (one cycle = 5 minutes). Only treat the side with the separators.

2. Place the laser device over the most painful area of the face. Press the power button to activate device, with the severe setting selected. With direct skin contact and gentle pressure, move the device in a circular movement over the entire painful area until the unit automatically turns itself off (one cycle = 5 minutes). Only treat the side with the separators.

The subjects demonstrated their understanding of the instructions by applying the laser treatment to themselves (i.e. first time interval) on the side of the face that was randomly selected for the study. They were instructed to always use the laser therapy as their first method of pain control. The subjects were allowed a maximum of three treatments per day, as needed, for pain during waking hours, with at least four hours between sessions. If they were awake during the night with pain, they could perform an additional treatment, as long as there were at least four hours between sessions.

Immediately after applying the initial laser/placebo treatment, four elastomeric orthodontic separators (GAC Molded Radiopaque Separators) were placed mesial and distal to their first molars, in both the maxillary and mandibular arches, on the side previously randomly selected. In the control group, the separators were placed immediately after filling out the initial questionnaire. Floss was used to slide the separator gingival to the contact and then to pull it occlusally to the contact. After having the separators engaged between the contacts for five days and having completed all seven questionnaires, the subjects returned to the clinic to have the separators

removed. At this point, the experimental and placebo groups returned their devices and all of the subjects were compensated.

Parametric statistics were used because the skewness and kurtosis statistics indicated this data were normally distributed. The measures were described using means and standard deviations. The comparison of group means was performed using ANOVA tests. Group frequencies were compared using Chi-Square tests.

CHAPTER IV

RESULTS

There were no statistically significant group differences in response to the first question (Table 2), which asked the subjects to "Please mark the intensity/unpleasantness of the worst physical pain that you have ever experienced." The Cronbach's Alpha (0.96; prob <.001) showed that the subjects' responses were consistent throughout the duration of the study.

There also were no statistically significant differences in the highest levels of dental/oral pain (Question 2) that the groups experienced at rest (Table 3). Pain increased significantly in all three groups, reaching maximum levels between 6 and 48 hours. The experimental group showed the earliest (6 hours) and the control group showed the latest (48 hours) peak pain response.

The third question, which asked the subjects "Over the last 24 hours, what was the highest level of dental/oral pain you experienced while chewing?", showed significant increases in pain through 24-48 hours in all three groups (Table 4). There were no statistically significant differences between the groups during any of the time points.

Over 50% of the subjects reported changing their food habits to softer foods between 24-120 hours (Figure 2). There were no significant group differences for dietary changes at any of the time points.

In order to determine if there was a difference between the laser and placebo groups in terms of device usage, the question "Over the last 24 hours, how many times have you applied the laser therapy?" was asked (Figure 3). More than 75% of the subjects in both the laser and placebo groups used the devices at least one time each day. Approximately 50% of the subjects used the devices two times per day. There were no significant group differences in device usage at any of the time points studied.

The subjects consumed only limited amounts of analgesic drugs (Figure 4). On average, fewer than 25% of the subjects consumed any type of analgesic at any time point. Once again, there were no significant group differences in the frequency of drugs consumed at any of the time points.

CHAPTER V

DISCUSSION

The timing of peak pain produced by the placement of the orthodontic separators in the current study was consistent with previous orthodontic separator studies. Studies have shown that pain from orthodontic separators peaks 24 to 48 hours after placement.[24, 27, 28] Pain levels in the present study, when analyzed both at rest and while chewing, attained their highest values during this same 24 to 48 hour time period. The orthodontic pain in this and previous separator studies peaked after 24-48 hours due to the hyperalgesia of the periodontal ligament. After separator placement, the nerve fibers of the PDL are more sensitive to noxious stimuli such as prostaglandins, histamines, and substance P released from the inflammatory process of moving teeth.[13, 50] These inflammatory mediators reach their highest concentration during this 24-48 hour window, which explains the peak pain response seen during this time period.

The amount of pain that the subjects reported in the present study was less than previously reported. Previous separator studies showed that pain intensity peaked at around 40% of the VAS that were used.[24, 27, 28] In the present study, the peak intensity was approximately 30% of the VAS while chewing. These differences in peak pain intensity could be due to the age of the subjects. In the present study, the subjects were young adults with an average age of 26 years, whereas the previous studies pertained to younger subjects, approximately 15 years of age.[24, 27] Pain thresholds are known to increase with age.[13] Tucker et al., who evaluated 520 subjects 5 to 105 years of age,

found that pain thresholds increased rapidly to the age of 25 years, after which they plateaued.[51] Moreover, the present study used dental students instead of orthodontic patients. Dental students might be expected to perceive and report less pain from elastomeric separator placement than the general orthodontic patient population. This is due to the fact that the perception of acute pain is highly dependent on the context of which it occurs.[52] Laboratory studies of experimental pain where fear and anxiety are controlled have shown decreased effectiveness of both opioids and placebos because both function, in part, by reducing these negative emotions.

When comparing the pain levels of the current study, overall higher (≈10%) peak pain levels were found while chewing than at rest. A difference between peak resting and chewing pain was also reported by Bondemark et al.[24] and Nobrega et al.[45] Increased pain while chewing is probably due to the fact that the periodontal ligament has a rich supply of pressure receptors located mainly in the apical two thirds of the root. The increased pain during pressure corresponds with the inflammation at the apex and mild pulpitis during the inflammatory process of tooth movement.[13, 38]

Most importantly, the results of this study showed that low level laser therapy had no effect on orthodontic pain. The lack of significant effects of LLLT on orthodontic pain has been previously reported.[36, 46] However, there have also been studies that have shown LLLT to have significant effects on orthodontic pain.[5-10, 45]

The lack of treatment effect in the present study could have been due to the amount of light given off by the laser that was used. The lasers used in the present study had similar specifications to those used in previous studies. The clinical results of LLLT

depends on many factors, including wavelength, energy density (J/cm^2), treatment time, and treatment repetition rate.[11] The transmission of light through tissue is highly wavelength specific. Therefore LLLT generally uses the "optical window" of approximately 500 to 1200 nm.[41] The wavelength of the lasers used in the current study was 905 nm, which is well within the general accepted range for low level laser therapy. As stated previously, the relationship between the specifications of low level laser therapy and its ability to decrease pain is not well understood.[11, 47] However, the fact that this study used an external delivery of LLLT further complicates the matter. It has been shown that maximum penetration of LLLT is achieved when using wavelengths between 770 and 850 nm.[48] In addition, it was shown that light with a wavelength of 808 nm penetrates up to 54% deeper than a light with a wavelength of 980 nm in bovine tissue.[49] The current study used a wavelength of 905 nm, which is somewhat above the level shown to penetrate tissues the deepest. Most previous studies using LLLT on orthodontic pain used lasers with energy densities between 0.45 and 5 J/cm^2. It has been suggested that the energy density should be kept within the range of 0.5-10 J per treatment point, to improve pain relief effects.[11] The energy density of the lasers in the present study was 0.85 J/cm^2 per 60 seconds of activation; each session lasted 5 minutes for a total of 4.26 J/cm^2, which is within the suggested range. LLLT studies typically have only used a single course of laser irradiation, most likely for the practicality of the study. However, it is believed that it might be possible to improve pain control effects by increasing the frequency of laser therapy.[11]

The biggest difference between this study and previous studies pertains to the extra-oral application of the LLLT. All of the other studies utilized an intraoral application. An external application was used in the present study for ease of patient application. The medical literature pertaining to the external application of LLLT to decrease pain is controversial. A meta-analysis of the pain relief of external applications of LLLT on joint areas identified 22 studies; 11 of which showed that laser irradiation was effective in decreasing pain.[47] Five of the 22 studies evaluated patients with pain in their temporomandibular joints and used energy densities ranging from 1.5-80 J/cm^2. Such a large range of energy densities shows that the properties of LLLT for decreasing pain externally remain poorly understood. Two studies showed this modality of pain relief to be effective; one used an energy density of 7 J/cm^2 and the other used 80 J/cm^2.

Since the lasers in this study were designed to be used externally, they had a circular output window that measured 4 cm in diameter. However, only a 0.4 cm laser beam was emitted in the center of the window. The subjects were instructed to "move the device in a circular movement over the entire painful area." With the actual laser beam consisting of only a small portion of the total output window, and the subjects moving the device over the entire painful area, it is possible that the PDLs of the affected teeth received a smaller amount of laser therapy than was necessary. In contrast, the lasers in the other studies had small output probes that emitted laser irradiation and were held in place over the PDLs of the affected teeth. It is possible that the external delivery of LLLT in this study could have produced significant results by increasing the energy density that was delivered.

Given the subjective nature of pain perception, the majority of previous orthodontic studies showing significant effects of LLLT were limited by potential operator bias. Only one previous study showing significant effects blinded the operator,[45] whereas the six other studies showing statistically significant treatment effects did not.[5-10] The operators pretended to apply a treatment by simply not activating the device, or by having the device turned off. The success of these studies depended on the operator applying a known placebo treatments in a convincing manner, without conveying any verbal or nonverbal cues. In contrast, throughout the entire data collection process of the present study, the operator and subjects were completely blinded with regards to the device that emitted laser irradiation.

Another potential limitation of the previous studies was the manner in which the data was collected. They used questionnaires that were completed at each of the assessment times by the subjects at home. There was no control as to when they actually answered the questions. The fact that the questionnaires in the present study were completed online allowed the operator to verify that all of the subjects were answering their questionnaires in a timely manner. This ensured that they did not have to try to remember previous pain experiences. In addition, several of the previous orthodontic pain studies reporting significant LLLT effects did not use a VAS. [5, 6, 9, 10] The VAS has been shown to be the most reliable scale used for evaluating pain intensity.[14, 16, 53] Studies using Verbal Rating Scales or Numerical Rating Scales are limited by the small range of choices they provide and by the potential difficulty with interpretation, which decreases their reliability.[13, 15] A modified VAS used in the present study was less

precise than the conventional VAS because the subjects were not given complete freedom to choose any point along a continuous spectrum.

Unlike previous studies, the subjects in this study took the lasers home with them and applied the treatment themselves. This was deemed to be important because it more accurately reflected the way in which orthodontic patients might use LLLT in private practice settings. It is possible that some of the subjects were not performing the laser therapy according to the instructions they were given. Importantly, all of the subjects understood how to properly work the laser; they demonstrated this by performing their initial treatment session on themselves under the supervision of the operator. It is also possible that the subjects did not apply the laser therapy for the amount of time they reported. However, initial laser therapy was applied by all of the subjects, and previous studies showing positive effects only applied the laser initially.[5-10, 45]

As the results of this study showed, there was no placebo effect. In 1955, Henry Beecher became the first scientist to quantify and therefore popularize the placebo effect. In his classic article "The Powerful Placebo," Beecher claimed that during fifteen trials with various diseases, 35% of the over one thousand patients were satisfactorily relieved from their symptoms by a placebo alone.[54] More recently however, it was shown that other factors could have accounted for the reported improvements of these patients, and that most likely there was no placebo effect whatsoever.[55]

Further studies are needed to reach definitive conclusions concerning the ability of low level laser therapy to decrease orthodontic pain. Due to the lack of definitive unambiguous results, future studies should use lasers with the same specifications and

same modes of application as those used in previous studies showing significant results. However, they should use the experimental design of this current study to prevent potential bias and increase the reliability of the results.

CHAPTER VI

CONCLUSIONS

Based on the analysis of the results, many conclusions can be drawn from this study. Pain levels peaked 24 to 48 hours after separator placement. Although pain decreased, it was still present 5 days after separator placement. Overall higher (≈10%) peak pain levels were found while chewing than at rest. Pain was severe enough at 24 hours and after, that more than 50% of the subjects changed their diets to softer foods. Less than or equal to 25% of the subjects felt the need to take analgesics at any time point of the study. Most importantly, it can be concluded that extra-oral application of low level laser therapy using a unit with a 4 cm output window and a 0.4 cm laser beam is not an effective way to decrease orthodontic pain.

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APPENDIX A

FIGURES

Figure 1: Separator Pain Questionnaire

Questionnaire should be completed approximately the same time each day (evening).

If you have taken any pain medications, please answer questions based on pain level PRIOR to taking any medication.

***1. At what time point is this questionnaire being completed?**

- ○ Prior to placement of separators
- ○ 6 hours after placement of separators
- ○ 1 day after placement of separators
- ○ 2 days after placement of separators
- ○ 3 days after placement of separators
- ○ 4 days after placement of separators
- ○ 5 days after placement of separators

Please mark the circle on the scale nearest to where you believe your pain level is. The far left of the scale corresponds to "No noticable pain" while the far right indicates "Worst pain ever experienced."

***2. Please mark the intensity/unpleasantness of the worst physical pain that you have ever experienced.**

No Pain — Worst Pain Imaginable

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

***3. Over the last 24 hours, what was the highest level of dental/oral pain you experienced at rest?**

No pain — Worst Pain Imaginable

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

***4. Over the last 24 hours, what was the highest level of dental/oral pain you experienced while chewing?**

No pain — Worst Pain Imaginable

○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

***5. Over the last 24 hours, have your food habits changed to softer foods because of the pain?**

- ○ Yes
- ○ No

***6. Over the last 24 hours, how many times have you applied the laser therapy?**

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4

***7. Have you taken any drugs (analgesics, pain killers, NSAIDs, etc.) to help control pain since last completing your questionnaire?**

- ○ Yes
- ○ No

Figure 2: Subjects' responses to the question "Over the last 24 hours, have your food habits changed to softer foods because of the pain?"

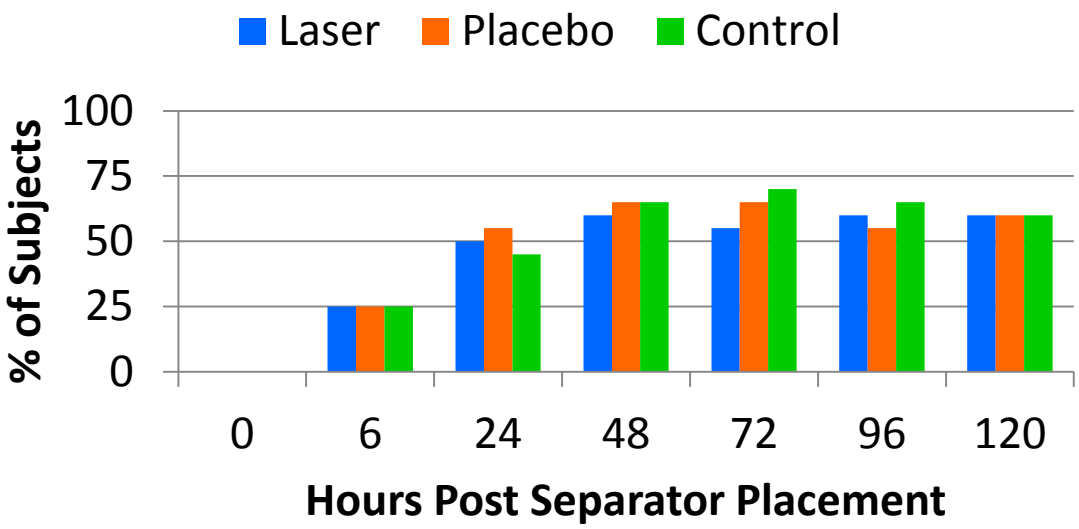
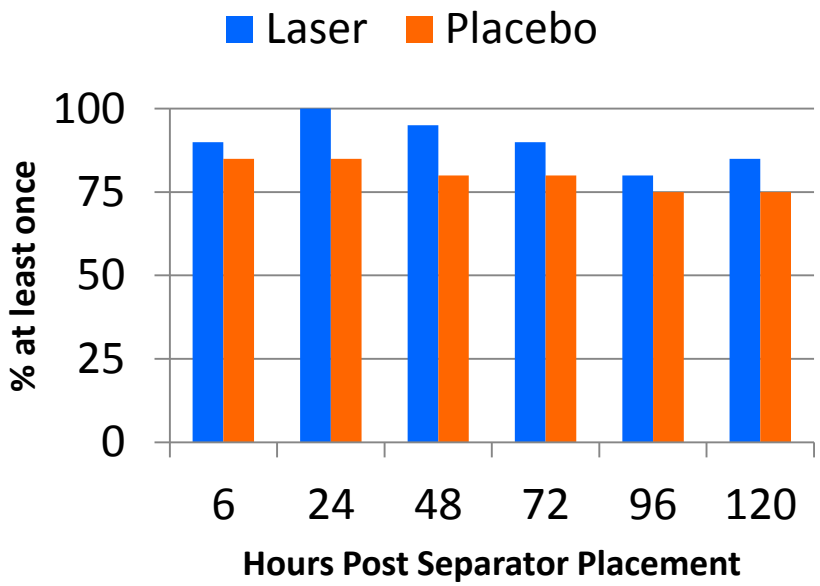


Figure 3: Subjects' responses to the question "Over the last 24 hours, how many times have you applied the laser therapy?"



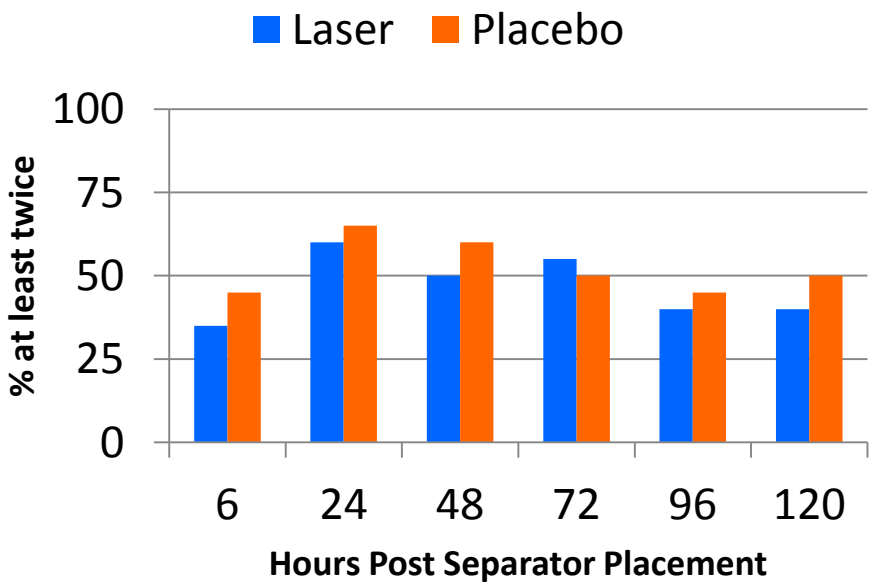
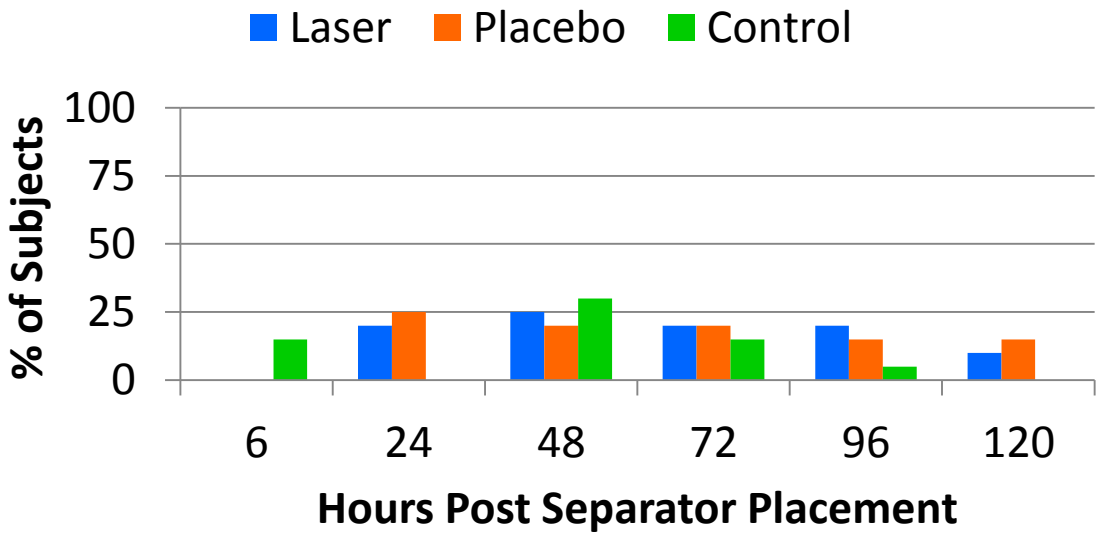


Figure 4: Subjects' responses to the question "Have you taken any drugs (analgesics, pain killers, NSAIDs, etc.) to help control pain since last completing your questionnaire?"



APPENDIX B

TABLES

Table 1: Previous LLLT Study Descriptions

Study	LLLT Description
Turhani et al.	670 nm; 75 mW; 30 seconds per tooth at a distance of 5 to 8 mm; at the level of the center of resistance; power density at 5.5 cm is 140 mW/cm^2
Tortamano et al.	830 nm; constant wave w/ mean output of 30mW; 2.5 J/cm^2 on each side (buccal and lingual) per tooth (5 areas of 0.5 J/cm^2 for 16 seconds)
Eslamian et al.	810 nm; patients received 10 doses (2 J/cm^2, 100 mW, 20 s) of laser irradiation on the buccal side (at the cervical third of the roots), for distal and mesial of the second premolars and first permanent molars, as well as distal of second permanent molars (five doses). Same procedure was repeated for the lingual/palatal side (five doses).
Dominguez et al.	830 nm; 100mW; 22 seconds along the vestibular surface of the root and 22 seconds along the palatal surface of the root
Youssef et al.	809 nm; 100 mW output; irradiated buccal and lingual PDL of canines; 3 areas: cervical (10s), middle (20s), apical (10s); Total energy density (dose) at each application was 8 J (2 x 40s x 100 mW)
Doshi-Mehta et al.	800 nm; continuous wave mode, 0.7 mW, 30 seconds; 2 irradiations (middle third of canine root on buccal and palatal)
Lim et al.	830 nm; 30 mW; three different treatment durations of 15, 30, and 60 seconds and one placebo treatment of 30 seconds
Esper et al.	660 nm; 4 J/cm^2, 0.03 W, 25 seconds
Nobrega et al.	830 nm; total dose of 5 J/cm^2: 2 J/cm^2 at the root apex, 1 J/cm^2 along the radicular axis of the buccal surface at 3 areas

Table 2: Subjects' responses to the statement "Please mark the intensity/unpleasantness of the worst physical pain that you have ever experienced."

	0 Hours		6 Hours		24 Hours		48 Hours		72 Hours		96 Hours		120 Hours	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Laser	59.69	21.81	56.88	25.56	60.63	19.75	59.69	19.81	60.00	19.50	62.81	17.94	62.19	17.94
Placebo	61.56	16.25	58.44	22.13	58.75	20.94	59.69	18.75	60.00	20.44	59.69	20.31	59.06	20.63
Control	60.94	17.19	64.38	15.56	61.88	20.38	65.31	13.81	62.50	17.19	64.38	12.50	64.06	13.25
ANOVA	0.95		0.51		0.89		0.51		0.89		0.68		0.66	

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Table 3: Subjects' responses to the question "Over the last 24 hours, what was the highest level of dental/oral pain you experienced at rest?"

	0 Hours		6 Hours		24 Hours		48 Hours		72 Hours		96 Hours		120 Hours	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Laser	0.00	0.00	19.69	15.88	18.75	13.31	17.81	8.19	15.00	11.19	12.50	9.94	10.63	9.75
Placebo	0.00	0.00	18.13	20.69	16.88	14.19	16.56	15.63	15.63	15.75	13.13	12.00	11.25	14.56
Control	0.00	0.00	17.81	13.94	19.06	15.13	20.94	15.63	16.88	17.13	11.56	13.81	10.00	10.44
ANOVA	1.00		0.93		0.87		0.58		0.92		0.92		0.95	

Table 4: Subjects' responses to the question "Over the last 24 hours, what was the highest level of dental/oral pain you experienced while chewing?"

	0 Hours		6 Hours		24 Hours		48 Hours		72 Hours		96 Hours		120 Hours	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Laser	0.00	0.00	20.94	18.38	26.25	12.75	28.13	16.44	26.25	16.56	24.06	16.88	20.63	15.75
Placebo	0.00	0.00	17.19	18.13	26.88	15.06	26.25	16.56	26.25	17.19	22.50	11.88	20.94	16.13
Control	0.00	0.00	16.56	13.94	28.13	14.69	28.75	15.25	25.94	17.69	19.06	12.44	17.19	14.00
ANOVA	1.00		0.68		0.91		0.88		0.99		0.51		0.69	