

Analgesic effect of a low-level laser therapy (830 nm) in early orthodontic treatment

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Received: 18 February 2012 / Accepted: 31 May 2012 / Published online: 21 July 2012
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Abstract The aim of this study was to evaluate the pain sensation that orthodontic patients experience when elastic separators are placed between molars and premolars and to determine the degree of analgesic efficacy of low-level laser therapy (LLLT) compared to a placebo treatment. The study was conducted with 20 volunteers who were fitted with elastic separators between the maxillary molars and premolars. One quadrant was randomly chosen to be irradiated with an 830-nm laser, 100 mW, beam diameter of 7 mm, 250 mW/cm² applied for 20 s per point (5 J/cm²). Three points were irradiated in the buccal face and three were irradiated in the palate. The same procedure was applied in the contralateral quadrant with a placebo light. A visual analogue scale was used to assess pain 5 min, 6 h, 24 h, 48 h, and 72 h after placement of the separators. Maximum pain occurred 6–24 h after placement of the elastic separators. Pain intensity was significantly lower in the laser-treated quadrant (mean, 7.7 mm) than in the placebo-treated quadrant (mean, 14.14 mm; $p=0.0001$). LLLT at these parameters can reduce pain in patients following placement of orthodontic rubber separators.

Keywords Low-power laser · LLLT · Orthodontics · Pain

Introduction

Despite the recent progress that has been made in the area of orthodontics, patients still associate orthodontic treatments with pain [1]. Most orthodontists use analgesics or nonsteroidal anti-inflammatory drugs (NSAIDs) to reduce pain in adult patients [2]. Adult patients often exhibit a great degree of discomfort and pain during treatment, and in some cases, the fear of pain may even discourage them from seeking treatment at all [3, 4].

The mechanism that induces tooth movement is related to the release of inflammatory mediators. These mediators have been shown to be associated with pain and discomfort by orthodontic patients [5]. The type of pain that occurs during orthodontic treatment is an inflammatory type of pain, not an infection-related pain; it is localized and of short duration. For this reason, some authors have recommended the use of local analgesic therapy in order to avoid drug regimens.

One local treatment that has been proposed for pain control by various authors is low-level laser therapy (LLLT) [6–10]. Since Mester discovered laser biostimulation in 1967 [11], this approach has been used in many different medical fields to regenerate tissue and reduce inflammation, and as an analgesic. LLLT is used in dentistry after third molar surgery [12], craniomandibular disorders [13], dentin hyperesthesia [14], sensory disturbances of the inferior alveolar nerve [15], and chemotherapy-induced mucositis [16]. Its effects in orthodontics as an analgesic and as an accelerator of orthodontic movement have also been studied [17].

There are two different reasons as to why low-power laser irradiation can alter pain perception and induce an

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analgesic effect. Honmura et al. have shown that LLLT can modulate the inflammatory process and thus reduce pain [18]. Another hypothesis is that LLLT alters nerve conduction and excitation in peripheral nerves [19, 20], and the third view suggests that LLLT may stimulate and activate the production of endogenous endorphins [21].

LLLT appears to produce photobiomodulation in the body (including cell function regulation) without inducing any direct thermal effects in the area where it was applied. According to Tiina Karu, lasers that can provide this type of effect are within the wavelength range of 600–1000 nm [22]. However, some high-power lasers (CO₂, Er:YAG), when not used in proper focus (broadening the area of irradiation), can also behave like a low-level laser [23].

Intracellular effects in the cytoplasm due to photochemical changes have been attributed to visible laser effects, whereas effects at the level of cellular membranes due to physical changes have been attributed to infrared-range wavelengths [24]. The primary effects produced by low-level lasers are related to intracellular activity, such as increases in ATP levels, DNA, redox reactions, and oxygen exchange [25]. From these primary effects, other secondary effects are induced in target tissues, such as reduced pain, accelerated healing, vasodilation, reduction of edema, and hyperemia in inflammatory processes [25].

Low-level laser effects on cells are related to various parameters, such as wavelength, pulse frequency, power density, and time. According to the Arndt-Schulz law [26], the light stimulus will be insufficient to trigger the target functions if it is delivered below the recommended doses, and it may inhibit activation of these functions if a dose higher than indicated is given. Studies examining the analgesic effects of LLLT have suggested that one should use a somewhat higher total dose to achieve an inhibitory effect [26].

Confirmation that implementation of a low-level laser can reduce pain in orthodontic patients would make it a viable alternative to the drug regimens that are usually recommended. Furthermore, if the efficacy of LLLT is confirmed, then prescribing NSAIDs [27], which are widely known to slow down tooth movement, could be avoided. Hence, the aim of this study was to evaluate pain sensations in orthodontic patients after placement of elastic separators and to determine the degree of analgesic efficacy of a low-power 830-nm laser vs. placebo.

Materials and methods

Patients

This study was conducted with 20 volunteers, 18 years of age or older (6 men, 14 women) with a mean age of 26.4 years (range, 19–33.8). The following inclusion criteria

were adhered to: written informed consent, absence of acute or chronic dental disease, absence of periodontal or gum disease, free from severe systemic disease, no fixed orthodontic retainer in the dental arcade, no ankylosis or tooth implants in the arcade, and no consumption of analgesic drugs during the 48 h preceding the test. The study was approved by the Ethics Committee of the International University of Catalunya (study F-07-APP-10).

Laser and parameters

Following the guidelines of the Jenkins and Carroll report, we present our data in a tabular format in order to improve the standardization and the reproducibility methods [28] (Tables 1 and 2). Before each laser irradiation, we checked the laser power output through a POW-105 power meter (Lasotronic GmbH, Hengersberg, Germany).

Irradiation procedure

All patients were given separator elastics GAC[®] (ref-radiopaque separators 34-000-10) in the mesial and distal premolars of the maxilla (Fig. 1). Five minutes following placement of elastic separators, patients were treated with the laser application and placebo procedure. At the time of laser irradiation, both the patient and orthodontist used goggles designed to block the wavelength of the laser used in accordance with safety standards. The patient was also fitted with an opaque mask beneath the glasses to obscure his or her vision. A randomization number table was used to determine which quadrant in each patient would be irradiated and which (the contralateral) would serve as the control.

Three points were irradiated in the vestibular zone (two points in the third cervical, mesial, or distal regions and one in the apical third), and three points were irradiated in the palatal zone in the experimental quadrant (Fig. 2). The total energy released in all laser-treated teeth was 12 J (vestibular area, 6 J, and palatal area, 6 J). The laser was applied in such a way that it was in direct contact with the mucosa without any pressure.

The same procedure was repeated in the contralateral quadrant, but with a placebo light (polymerizing light with a similar fiber diameter of 0.7 cm) (Fig. 3) and emitted the same whistle sound that a laser emits to reproduce the exact

Table 1 Device information

Manufacturer	Lasotronic (GmbH, Hengersberg, Germany)
Model identifier	MED 200-duo
Number of emitters	1
Lasing medium	GaAlAs
Beam delivery system	Light guide

Table 2 Irradiation and treatment parameters

	Value	Unit	Measurement method or information source
Center wavelength	830	nm	
Operating mode	CW		
Average radiant power	100	mW	Lasotronic POW-105 power meter
Beam area	0.4	cm ²	
Irradiance at target	250	mW/cm ²	
Beam shape	7	mm	Round
Exposure duration	20	s	
Energy per point	2	J	
Energy density per point	5	J/cm ²	
Total energy per tooth	12	J	
Number of points irradiated	6		3 points in the vestibular area and 3 in the palatal area
Application technique			Contact

conditions and thus prevent the subject from discerning whether the laser or placebo was being applied. A single operator placed the elastic separators and applied the laser and placebo light.

Pain assessment

A visual analogue scale (VAS), 10 cm in length (0=no pain, 10=worst pain imaginable), for each of the quadrants was used. Patients were trained to assess pain in the following periods: T1, before placing the rubber separator; T2, 5 min after placement of elastic separators (when the laser or placebo light was applied); T3, 6 h post-treatment; T4, 24 h post-treatment; T5, 48 h post-treatment, and T6, 72 h post-treatment. Each patient was required to indicate whether s/he had taken any rescue analgesic in any of the periods recorded. Four days after the treatment, the questionnaires were collected and the separators were removed.

Statistical analysis

Microsoft Excel[®] Software was used for data collection. Statistical analysis was performed using Statgraphics[®] Plus,

version 5.1. Multivariate analysis of variance of three factors (pain, treatment, and time) was applied on data collected from 20 patients. A *p* values less than 0.05 was considered statistically significant.

Results

Pain perception of the experimental side vs. placebo side

The level of pain in the quadrant where the laser was applied was lower than the one reported for the control side. As shown in Fig. 4, the mean VAS pain level reported for the experimental laser side (7.7083 mm) was significantly less than that reported for the control placebo side (14.1417 mm; $p=0.0001$).

Progression of pain

A significant time–laser interaction was observed ($p<0.0001$). As shown in Fig. 5, the quadrant exposed to placebo light was associated with higher pain scores than the laser-irradiated quadrant at all experimental time points. The progression of pain in relation to time is summarized in



Fig. 1 Elastic separators placed in an arcade



Fig. 2 Laser application sites



Fig. 3 Laser and polymerizing light (control) application tips with similar diameters (0.7 cm)

Fig. 6. During the 72-h experimental period, the presence of pain was first reported at 5 min (T2), with pain intensity peaking between 6 and 24 h (T3–T4) and then decreasing thereafter at the 48- and 72-h time points.

Analgesic need

None of the 20 volunteer subjects required pharmacological analgesia (rescue medication) during the study period.

Discussion

This study investigated the efficacy of LLLT in the prevention of pain following the placement of elastic separators during early orthodontic treatment. It was found that the laser-irradiated quadrant presented with less pain compared with the control quadrant in all cases studied.

The forces applied to produce orthodontic movements almost always generate a certain degree of discomfort or pain, and the intensity of that pain varies among patients. Achieving an effective method of pain control without

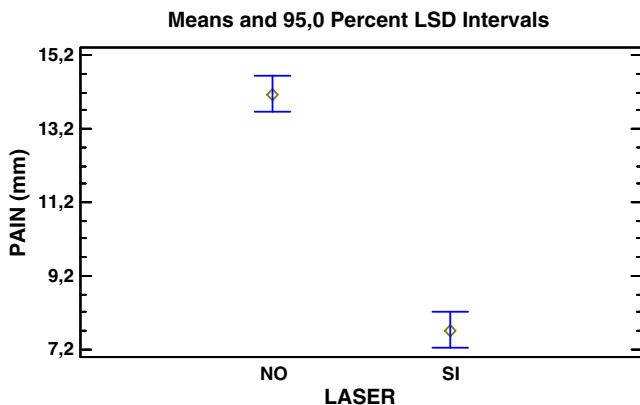


Fig. 4 Pain–laser interaction. Overall mean pain on the placebo side (14.1417) was greater than that on the laser side (7.7083 mm)

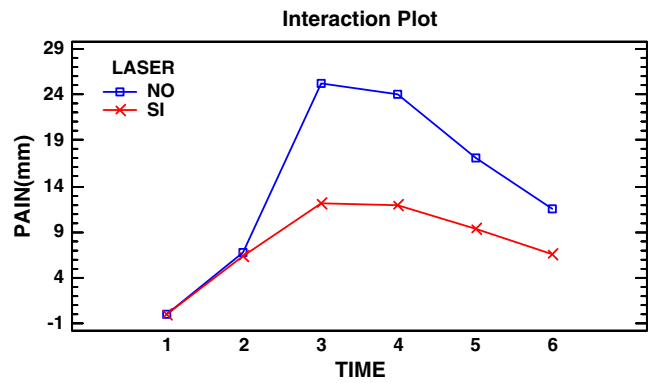


Fig. 5 Pain–time interaction. Mean VAS data are shown for T1 (prior to placement of elastic separators), T2 (5 min after placement and laser irradiation), T3 (6 h after treatment), T4 (24 h after treatment), T5 (48 h after treatment), and T6 (72 h after treatment)

administration of drugs is a common research goal in all areas of the health sciences [29].

The present clinical study was performed with volunteers who were all young adults not in need of orthodontic treatment and in good health. This experimental group was chosen over patients undergoing orthodontic treatment to prevent the anxiety component that may come with the initiation of treatment [2, 30]. The study was performed with a “split mouth” design, allowing for within-subject controls. This method is very well suited for the study of pain because it nullifies the effect of inter-individual variation in pain perception [10].

Although the VAS pain assessment is a subjective method in which there is great variability across individuals, it is one of the best methods available for pain studies [13, 30–32]. In this study, VAS data were collected at multiple time points: time of separator placement and 5 min later (at the time of irradiation), as well as 6, 24, 48, and 72 h post-treatment. Similar studies that have also assessed pain intensity over time have shown that pain onset occurs 2 h after placement of orthodontic appliances [10].

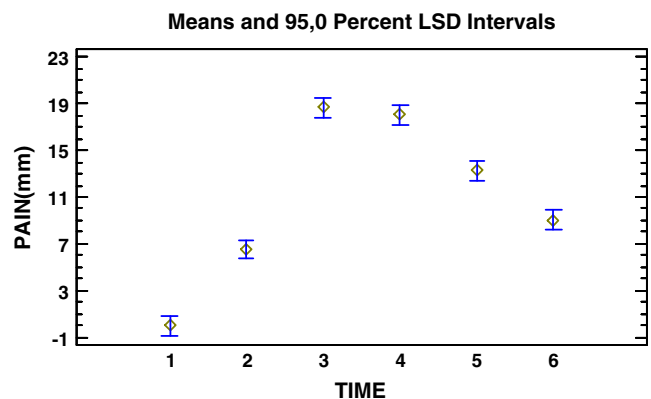


Fig. 6 Summary of pain progression of overall pain in the whole study sample over time

Several prior studies in different fields of, have demonstrated LLLT to be effective in reducing pain. Several hypotheses proposed for the mechanism by which LLLT reduces pain have been proposed. In one hypothesis, LLLT is suggested to interfere with the modulation of inflammation in a manner that results in reduced levels of cytokines and COX-2 mRNA levels, which then results in reduced pain [33–35]. According to another hypothesis, LLLT irradiation results in an alteration in the conduction of action potentials in peripheral nerves. In support of this notion, it has been shown that 830-nm lasers can produce varicosities at the axon level [36]. These varicosities slow the velocity of fast axonal flow and decrease mitochondrial membrane potentials, thereby resulting in a reduced availability of ATP and neurotransmission failure in nociceptive A δ and C fibers. Finally, a third hypothesis posits that LLLT can stimulate a reduction in endogenous endorphins as described by Cabot and Laasko [21] in reports of experiments performed with a 780-nm laser at a dose of 2.5 J/cm².

Different wavelengths can be used in LLLT. The most commonly used are 632.8-, 660-, 780-, 810-, 830-, 904-, and 980-nm lasers. The type of laser used in this study was chosen based on a careful literature review through which it was determined that the 830-nm diode laser appeared to be the one with the greatest analgesic capacity. Meta-analysis results by Enwemeka [37] showed that the 830-nm laser has a robust analgesic efficacy, and this finding was corroborated by both clinical and in vitro studies, including the noteworthy studies performed by Chow et al. [28]. Other wavelengths (e.g., 670-nm diode laser) have also been used to achieve pain reduction after multiband placement [8].

Yamaguchi et al. [38] showed that during orthodontic movement, 8–72 h post-treatment, there is an increase in crevicular fluid, prostaglandin, and interleukin levels. The present pain reduction findings fit well with prior work showing phototherapy can induce inhibition of inflammatory mediators such as prostaglandin E2 and interleukin 1- β [39, 40].

Other types of lasers, such as CO² and Er, Cr:YSGG lasers, have also been used to obtain an analgesic effect, but with mixed results. While Fujiyama et al. [23] obtained good results with a CO² laser in unfocused mode, no other significant improvements have been found. However, there appears to be an analgesic trend when an Er, Cr:YSGG laser is used [41].

The dose used in this study was chosen based on the advice and recommendations of various studies. Harazaki et al. [7] determined that the minimum time of application for LLLT to be effective should be 2–3 min per tooth, with three applications in the palate and three applications in the buccal zone (one cervical, one in the middle, and one in the apical region). In this study, the laser was applied for 20 s on the mesial, distal, and apical regions of the palatal and

vestibular face with a total irradiation time of 2 min per tooth and a dose of 5 J/cm² per site. We used a total dose of 12 J, which fits with that described in Bjordal et al.'s systematic review [42] wherein it was advised that the total dose used should be in the range of 6–10 J to achieve anti-inflammatory effects with an 830-nm laser.

The progression of pain during orthodontic movement has been described in several studies. Furstman and Bernick [43] concluded that pain usually occurs approximately 2 h after the placement of orthodontic appliances. According to Ngan et al., perceived discomfort peaked 4–24 h after insertion of separators [2]. In another study, pain was reported to be shown between 3 and 24 h after placement of the first arches for orthodontic movements [44]. Our finding of pain peaking between 6 and 24 h after the treatment is consistent with these studies. Clinically, it may be necessary to recommend an analgesic regimen during the first 24 h of orthodontic treatment. Our patients reported less pain in the laser-treated than in the contralateral quadrant where placebo was applied, and this difference was greatest 6 and 24 h after LLLT.

Pain is a complex phenomenon with immense individual variability in perception that can be influenced by many external factors, such as the degree of anxiety prior to orthodontic treatment [2–4]. Some of the volunteers reported that they perceived more of a discomfort than a sharp pain, as evidenced by the fact that none of them needed to take drugs for pain. However, at all times, they reported feeling less pain or discomfort on the side where the laser had been applied than on the control side. This study showed that pain on the laser-irradiated side was significantly less than that on non-irradiated side. It is also worth noting that the LLLT resulted in favorable pain reduction, as indexed by the VAS scale, without producing any secondary effects in any of the 20 cases.

Orthodontic patients are sometimes given NSAIDs to reduce pain, but these drugs have been shown to decrease the rate of tooth movement [45]. Use of low-laser power density treatments (i.e., phototherapy, LLLT) in orthodontic treatments can reduce pain and discomfort in a noninvasive manner, removing the need for anti-inflammatory drugs.

Conclusions

The results of this study demonstrate that application of a low-power laser at 830 nm with the parameters specified herein is an effective method of pain control in orthodontic patients after elastic separator placement. Pain intensity was significantly lower in the laser-treated quadrant than in the control side. Peak discomfort was documented 6–24 h after elastic separator placement, and pain intensity began to be reduced 48 h post-treatment.

References

- Brown DF, Moerenhout RG (1991) The pain experience and psychological adjustment to orthodontic treatment of preadolescents, adolescents, and adults. *Am J Orthod Dentofacial Orthop* 100:349–356
- Ngan P, Kess B, Wilson S (1989) Perception of discomfort by patients undergoing orthodontic treatment. *Am J Orthod Dentofacial Orthop* 96:47–53
- Oliver RG, Knapman YM (1985) Attitudes to orthodontic treatment. *Br J Orthod* 12:179–188
- Tayer BH, Burek MJ (1981) A survey of adults' attitudes toward orthodontic therapy. *Am J Orthod* 79:305–315
- Gianopoulou C, Dudic A, Kiliaridis S (2006) Pain discomfort and crevicular fluid changes induced by orthodontic elastic separators in children. *J Pain* 7(5):367–376
- Youssef M, Ashkar S, Hamade E, Gutknecht N, Lampert F, Mir M (2008) The effect of low-level laser therapy during orthodontic movement: a preliminary study. *Lasers Med Sci* 23:27–33
- Harazaki M, Isshiki Y (1998) Soft laser irradiation effects on pain reduction in orthodontic treatment. *Bull Tokyo Dent Coll* 39:95–101
- Turhani D, Scheriau M, Kapral D, Benesch T, Jonke E, Bantleon HP (2006) Pain relief by single low-level laser irradiation in orthodontic patients undergoing fixed appliance therapy. *Am J Orthod Dentofacial Orthop* 130:371–377
- Lim HM, Lew KK, Tay DK (1995) A clinical investigation of the efficacy of low level laser therapy in reducing orthodontic post-adjustment pain. *Am J Orthod Dentofacial Orthop* 108:614–622
- Tortamano A, Lenzi D, Haddad AC, Bottino MC, Dominguez G, Vigorito JW (2009) Low-level laser therapy for pain caused by placement of the first orthodontic archwire: a randomized clinical trial. *Am J Orthod Dentofacial Orthop* 136:662–667
- Mester E, Szende B (1967) Influence of laser on hair growth of mice. *Kiserl Orvostud* 19:628–631
- Amarillas-Escobar ED, Toranzo-Fernández JM, Martínez-Rider R, Noyola-Frías MA, Hidalgo-Hurtado JA, Serna VM, Gordillo-Moscoso A, Pozos-Guillén AJ (2010) Use of therapeutic laser after surgical removal of impacted lower third molars. *J Oral Maxillofac Surg* 68(2):319–324
- Shirani AM, Gutknecht N, Taghizadeh M, Mir M (2009) Low-level laser therapy and myofascial pain dysfunction syndrome: a randomized controlled clinical trial. *Lasers Med Sci* 24:715–720
- Brugnera A, Garrini dos Santos AL, Donnamaria E, Pinheiro TCh (2006) Atlas of laser therapy applied to clinical dentistry. Ed Quintessence, Sau Paulo
- Ozen T, Orhan K, Gorur I, Ozturk A (2006) Efficacy of low level laser therapy on neurosensory recovery after injury to the inferior alveolar nerve. *Head Face Med* 2:3
- Simoes A, Eduardo FP, Luiz AC, Campos L, Sa PH, Cristofaro M et al (2009) Laser phototherapy as topical prophylaxis against head and neck cancer radiotherapy-induced oral mucositis: comparison between low and high/low power lasers. *Lasers Surg Med* 41:264–270
- Oltra-Arimon D, España-Tost AJ, Berini-Aytés L, Gay-Escoda C (2004) Aplicaciones del láser de baja potencia en Odontología. *RCOE* 9(5):517–524
- Honmura A, Yanase M, Obata J, Haruki E (1992) Therapeutic effect of Ga-Al-As diode laser irradiation on experimentally induced inflammation in rats. *Lasers Surg Med* 12(4):441–449
- Chow R, Armati P, Laakso EL, Bjordal JM, Baxter GD (2011) Inhibitory effects of laser irradiation on peripheral mammalian nerves and relevance to analgesic effects: a systematic review. *Photomed Laser Surg* 29(6):356–381
- Basford JR, Hallman HO, Matsumoto JY, Moyer SK, Buss JM, Baxter GD (1993) Effects of 830 nm continuous wave laser diode irradiation on median nerve function in normal subjects. *Lasers Surg Med* 13(6):597–604
- Laakso EL, Cabot PJ (2005) Nociceptive scores and endorphin-containing cells reduced by low-level laser therapy (LLLT) in inflamed paws of Wistar rat. *Photomed Laser Surg* 23(1):32–35
- Karu TM (1988) Molecular mechanism of the therapeutic effect of low intensity laser radiation. *Laser Life Sci* 2:53–74
- Fujiyama K, Deguchi T, Murakami T, Fujii A, Kushima K, Yamamoto TT (2008) Clinical effect of CO₂ laser in reducing pain in orthodontics. *Angle Orthod* 78(2):299–303
- Tunér J, Hode L (1999) Low level laser therapy—clinical practice and scientific background, 1st edn. Prima Books, Sweden
- Karu T (1999) Primary and secondary mechanisms of action of visible to near-IR radiation on cells. *J Photochem Photobiol Biol* 49:1–17
- Huang YY, Chen AC, Carroll JD, Hamblin MR (2009) Biphasic dose response in low level light therapy. *Dose Response* 7(4):358–383
- Zhan D, Hughes B, King GJ (1997) Histomorfometric and biomechanical study of osteoclasts at orthodontic compression sites in the rat during indomethacin inhibition. *Arch Oral Biol* 42:717–726
- Jenkins PA, Carroll J (2011) How to report low-level laser therapy (LLLT)/photomedicine dose and beam parameters in clinical and laboratory studies. *Photomed Laser Surg* 29(12):1–4
- Chow R, Johnson M, Lopes-Martins R, Bjordal J (2009) Efficacy of low-level laser therapy in the management of neck pain: a systematic review and meta-analysis of randomised placebo or active-treatment controlled trials. *Lancet* 374:1897–908
- Firestone AR, Scheurer AP, Burgin WB (1999) Patient's anticipation of pain and pain-related side effects, and their perception of pain as a result of orthodontic treatment with fixed appliances. *Eur J Orthod* 21:387–396
- Dundar U, Evcik D, Samli F, Pusak H, Kavuncu V (2007) The effect of gallium arsenide aluminum laser therapy in the management of cervical myofascial pain syndrome: a double blind, placebo-controlled study. *Clin Rheumatol* 26:930–934
- Kreisler MB, Haj HA, Noroozi N, Willershausen B (2004) Efficacy of low level laser therapy in reducing postoperative pain after endodontic surgery—a randomized double blind clinical study. *Int J Oral Maxillofac Surg* 33:38–41
- Albertini R, Villaverde AB, Aimbire F, Salgado M, Bjordal JM, Alves LP, Munin E, Costa MS (2007) Anti-inflammatory effects of low-level laser therapy (LLLT) with two different red wavelengths (660 nm and 684 nm) in carrageenan-induced rat paw edema. *Journal of Photochemistry and Photobiology Biology* 89:50–55
- Albertini R, Villaverde AB, Aimbire F, Bjordal J, Brugnera A, Mittmann J, Silva JA, Costa M (2008) Cytokine mRNA expression is decreased in the subplantar muscle of rat paw subjected to carrageenan-induced inflammation after low-level laser therapy. *Photomed Laser Surg* 26(1):19–24
- Albertini R, Aimbire F, Villaverde AB, Silva JA Jr, Costa MS (2007) COX-2 mRNA expression decreases in the subplantar muscle of rat paw subjected to carrageenan-induced inflammation after low level laser therapy. *Inflamm Res* 56(6):228–229
- Chow RT, David MA, Armati PJ (2007) 830 nm laser irradiation induces varicosity formation, reduces mitochondrial membrane potential and blocks fast axonal flow in small and medium diameter rat dorsal root ganglion neurons: implications for the analgesic effects of 830 nm laser. *J Peripher Nerv Syst* 12(1):28–39
- Enwemeka CS, Parker JC, Dowdy DS, Harkness EE, Sanford LE, Woodruff LD (2004) The efficacy of low-power lasers in tissue repair and pain control: a meta-analysis study. *Photomed Laser Surg* 22(4):323–329
- Yamaguchi M, Yoshii M, Kasai K (2006) Relationship between substance P and interleukin -1 B in gingival crevicular fluid during orthodontic tooth movement in adults. *Eur J Orthod* 28:241–246

39. Trelles MA, Mayayo E (1987) Bone fracture consolidates faster with low power laser. *Lasers Surg Med* 7:36–45
40. Shimizu N, Yamaguchi M, Goseki T, Shibata Y, Takiguchi H, Iwasawa T, Abiko Y (1995) Inhibition of prostaglandin E2 and interleukin 1-beta production by low-power laser irradiation in stretched human periodontal ligament cells. *J Dent Res* 74(7):1382–1388
41. Duran Fernandez-Feijo M (2008) Efecto analgésico del laser Erbium,Cromium: Yttrium-Selenium-Gallium-Garnet en Ortodoncia. Tesina Doctoral, Universidad Internacional de Catalunya. Julio
42. Bjordal JM, Johnson MI, Iversen V, Aimbire F, Lopes-Martins RA (2006) Photoradiation in acute pain: a systematic review of possible mechanisms of action and clinical effects in randomized placebo-controlled trials. *Photomed Laser Surg* 24:158–168
43. Furstman L, Bernick S (1972) Clinical considerations of the periodontium. *Am J Orthod* 61(2):138–155
44. Harazaki M, Takahashi H, Isshiki Y (1997) Soft laser irradiation induced pain reduction in orthodontic treatment. *Bull Tokyo Dent Coll* 38:291–295
45. Bernhart MK, Southard KA, Batterson KD, Logan HL, Baker KA, Jakobsen JR (2001) The effect of preemptive and/or postoperative ibuprofen therapy for orthodontic pain. *Am J Orthod Dentofac Orthop* 120:20–27