Review / Derleme

Low Level Laser Therapy in Orthodontics

Düşük Doz Lazerlerin Ortodonti Alanında Kullanımı

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Abstract

Lasers are widely used in most of the fields in dentistry for many years and they have recently gained popularity in orthodontic practice. Most common procedures with laser applications in orthodontics could be summarized as acceleration of tooth movement, pain reduction after force application, bone regeneration in the median palatal suture area during maxillary expansion or consolidation phase after distraction osteogenesis, enamel etching during bonding procedure, reduction of enamel decalcification, debonding of ceramic brackets, soft tissue applications such as gingival recontouring and attachment placement for impacted teeth. In this review, biostimulation effect or low level laser therapy in orthodontics will be exclusively evaluated.

Öz

Lazerler genellikle yıllardır diş hekimliğinin birçok alanında kullanılmaktadır ve son yıllarda ortodonti pratiğinde popülarite kazanmıştır. Ortodontide lazerin en yaygın kullanım alanları; diş hareketinin hızlandırılması, kuvvet uygulanmasını takiben ağrının azaltılması, maksiller genişletme esnasında veya distraksiyon osteogenezisin konsolidasyon safhasında midpalatal sütur alanında kemik rejenerasyonu, bonding prosedürü esnasında minenin pürüzlendirilmesi, mine dekalsifikasyonunun azaltılması, seramik braketlerin debonding işlemi esnasında kullanımı, diş eti konturlaması ve gömülü dişler için ataçman yerleştirmeyi içeren yumuşak doku uygulamaları şeklinde özetlenebilir. Bu derlemede ortodontide lazerin biyostimülasyon etkisi veya düşük doz lazer tedavisi detaylı bir şekilde değerlendirilecektir.

Keywords
Biostimulation, low level laser, orthodontics

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Introduction

Laser is an acronym for “light amplification by stimulated emission of radiation”, which is one of the greatest technological advances of the 20th century. Introduction of lasers to medical world was in 1963. One year later, the first laser applications in the field of dentistry were performed with the use of ruby laser on the hard tissues (1). A laser is a single wavelength (or color) of light, travelling through a collimated tube delivering a concentrated source of energy (2). Laser light has some exclusive properties such as monochromaticity (the same color), coherence (all the light waves are in phase both spatially and temporally) and collimation (all rays are parallel to each other and do not diverge significantly even over long distances) (3). When laser wavelengths reach the target area, depending on the optical characteristics of the applied tissue different interactions such as reflection, absorption, scattering, transmission can occur (4). Additionally, various photobiological effects including photothermal, photochemical, fluorescence, photoacoustic or biostimulation have been produced by the use of a dental laser. By changing the laser parameters such as beam diameter, energy, exposure time, different formed of photothermal laser-tissue interactions (e.g. incision/excision, ablation, hemostasis/coagulation) can be used for dissimilar procedures (5).

Currently, the most popular types of lasers used in dentistry are the argon, carbon dioxide (CO_2), diode, neodymium-doped yttrium aluminum garnet (Nd:YAG) and the erbium lasers (6). Dental lasers can be categorized as soft and hard tissue lasers according to their applicability of tissues. For example, erbium and CO_2 lasers are effective on both tissues. However, soft tissue applications with erbium lasers have less coagulation and hemostasis capacities on target tissues than CO_2 lasers (7). Not only CO_2 lasers but also Nd:YAG and diode lasers stimulate the natural healing process in the cells. Soft lasers that can be used in nonsurgical mode for biostimulation, for more rapid wound healing, pain relief, increased collagen growth and general anti-inflammatory effects (8). At the same time, this group can be termed as low-level lasers, low level laser therapy (LLLT) and laser-phototherapy (9).

Effects of Low Level Laser Therapy on Tooth Movement

Tooth movement induced by a physical stimulus/force consists of a series of phenomena involving physiological and pathological reactions of the alveolar bone, periodontal ligament, gingiva, vascular and neural networks (10). According to the limited research available, it is assumed that LLLT is dose-dependent and can stimulate or inhibit biological processes depend on physical features and parameters of laser device (e.g., wavelength, output power, frequency, irradiation dose, type of probe size), irradiation protocol, and properties of target tissue (e.g., absorption coefficient, density, depth, thickness).

Many studies evaluated the influences of LLLT with the various mediators such as the receptor activator of nuclear factor kappa B (RANK)/RANK ligand (RANKL) (11), the macrophage colony-stimulating factor/its receptor (12), tartrate-resistant acid phosphatase (13), matrix metalloproteinase-9, cathepsin K, and alpha(v) beta(3) [a(v)b3] integrin (14), and consequently suggested that low level therapy had an influence on the acceleration of the tooth movement by supporting the alveolar bone remodeling.

In the literature, the effects of LLLT on the tooth movement were evaluated with both clinical (15-20) and animal studies (14,21-24). Numerous studies on human subjects demonstrated that LLLT stimulated the velocity of tooth movement (15,17-20). At that point, it is emphasized that the effects of laser application on biostimulation depend on the irradiation dose (25). In previous studies, the preferred dose of irradiation was extended from 0.71 J/cm^2 to 8 J/cm^2 with diode laser and increased the tooth movement in human subjects (15,17-19). Cruz et al. (15) applied low level diode laser gallium-aluminum-arsenide (wavelength of 780 nm, output power of 20 mW, energy dose of 5 J/cm^2) for 10 seconds on 0, 3, 7, 14 day intervals of each two month and showed significant higher acceleration of the canine retraction on the irradiated side when compared to the control. Similarly, Youssef et al. (17) evaluated the effect of the different GaAlAs diode laser parameters (809 nm, 100 mW) with the increased dose of irradiation energy (8 J/cm^2) with the same time intervals applied by Cruz et al. (15) during the canine retraction. Later, Sousa et al. (18) evaluated the effect of diode laser (780 nm, 20 mW) for 10 seconds with the same dose of energy (5 J/cm^2) used by Cruz et al. (15) during three days of each three month during canine retraction. They demonstrated significantly an increased rate of movement (approximately 1.49 mm) in irradiated group when compared to non-irradiated group in accordance with the previous studies (15,17,19).

Contrary to these, Genc et al. (20) applied very low amount of irradiation with a dose of 0.71 J/cm^2 using semiconductor GaAlAs diode laser (808 nm, 20 mW) with an application time of 10 seconds on the day 0, and the 3rd, 7th, 14th, 21st, and 28th days. They reported that the application of LLLT accelerated the orthodontic tooth movement significantly.

On the other hand, many researchers found that the laser stimulation influenced the tooth movement rate neither positively or negatively. In a study published by Limpanichkul et al. (16), no significant differences were determined in the rate of orthodontic tooth movement with the application of GaAlAs laser (860 nm, 100 mW) between irradiated and control groups. Nonetheless, these authors suggested that energy density of LLLT at the level of 25 J/cm^2 was incompetent for accelerating tooth movement.

From clinical point of view, different laser parameters have been used and controversial results have been reported in previous studies depending on doses of laser energy and irradiation times. Clinical results have been supported by ongoing animal experiments at the same time. Altan et al. (21) studied the effects of LLLT on osteoclastic and osteoblastic cell proliferation-activity and RANKL/osteoprotegerin release during orthodontic tooth movement. In this metrical and histological investigation, they concluded that low-level GaAlAs diode laser (820 nm, 100 mW) with different irradiation doses (54 and 15 joules) accelerated the bone remodeling process by stimulating osteoblastic and osteoclastic cell proliferation and function in rats. However, there were some contradictory findings in this issue. Seifi et al. (22) evaluated the effects of two different types of low level laser wavelength (630 nm continuous and 850 nm pulsed, output powers of 10 and 5 mW, respectively) on rate of tooth movement in rabbits. The results of this study showed the inhibitory effect of LLLT, with other words, the amount of orthodontic tooth movement was decreased. In another study, Marquezan et al. (23) evaluated the influence of different irradiation protocols (daily irradiations and irradiations on the first two days of tooth movement) on the velocity of tooth movement. They used GaAlAs diode laser (830 nm, 100 mW) a with a total energy of 54 J and reported that laser irradiation increased the number of blood vessels but was not able to accelerate the orthodontic tooth movement on rats. In a recent study, Salehi et al. (24) investigated the effect of LLLT on the rate of movement and the amount of relapse during rotational tooth movement in dogs. For this purpose, GaAlAs diode laser (810 nm, 200 mW, 2J/session) was preferred for irradiation after the beginning of force application. However, the total energy dose of laser (2J/session: 32 J/cm^2/point) was reported as insufficient to accelerate the rotational tooth movement, although this dose reduced the relapse up to 3 months after force application and laser irradiation.

In summary, some researchers reported that LLLT has an accelerating effect on tooth movement, while others suggested no positive effects. These controversial results may be influenced the applied laser parameters and treatment protocols. For that reason, additional randomized clinical studies to determine the optimal dose or energy density for accelerating the orthodontic tooth movement must be performed.

Pain Relief by Low Level Laser Therapy

Pain during orthodontic therapy is a common clinical symptom, as well as a reason for patients to discontinue to treatment. To eliminate the patient complaints and have a comfortable orthodontic treatment process, it is necessary to find new methods for pain control. Several different methods such as transcutaneous nerve stimulation (25,26), induction of periodontal ligament by vibration (27), chewing or biting stimulating compression of ligament area and recently, use of analgesics (28) have been developed to control pain. Side effects of the use of analgesics including reduction in amount on tooth movement led the clinicians to find other methods (29). One of these methods is the LLLT, which is claimed as an efficient method to relieve pain in orthodontic therapy.

Mechanisms of pain reduction by the effect of LLLT during orthodontic treatment have been explained by several hypothesis; such as suppression of cyclooxygenase-2 mRNA expression (30,31), an alteration in the transmission (32), induction of stimulating action potentials in peripheral nerves stimulate a reduction in endogenous endorphins (33).

A wide range of laser types (GaAlAs diode, HeNe, CO_2 lasers) with different wavelengths and energy doses to reduce pain during orthodontic treatment are described in literature. Researchers have evaluated the different stages of orthodontic treatment with using lasers to have a better understanding of their effect on pain relief; after application of elastomeric separators, after initial arch wire placement, during canine retraction (17,19,34-40). Lim et al. (34) presented that LLLT could not provide immediate pain relief, whereas it was found to be effective in reducing pain about 24 to 48 hours after application of elastic separators with GaAlAs laser (830 nm, 30 mW, 59.7 mW/cm^2) irradiation. These data also corroborated by Bicakci et al. (37) that used LLLT (820 nm, 50 mW, 7.96 J/cm²). As a result of this study, there were significantly increased mean prostaglandin E2 (PGE2) levels in control group, whereas a gradual decrease occurred in laser group. The differences in PGE2 levels at both 1 hour and 24 hours were statistically significant between the groups.

With contradiction to these studies above, Fujiyama et al. (35) found that pain sensation was significantly lower with CO_2 laser treatment from immediately through 4 days, but after that, there was no significant difference between the study groups. This result was confirmed by another study (38) in which pain intensity was found significantly lower in the laser treated quadrant than in the placebo treated quadrant. The researchers suggested that LLLT at the parameters (830 nm laser, 100 mW, 5 J/cm²) reduced pain in patients following placement of orthodontic rubber separators.

In a recent meta-analysis (39) that evaluated pain relief with laser irradiation (varies between 635- 910 nm, 6-160 mW, 2- 4 J/cm² per point) after application of elastomeric separators, they found that LLLT had good analgesic effect at 6 hours, 1 day, 2 days, 3 days after placement of separators. The evaluated six studies in this meta-analysis applied LLLT in several times regarding the study design. While at 2 hours, 4 days, 5 days after the placement, the results tend to support LLLT, but found statistically insignificant (39). Some studies evaluated the effect of lasers in pain relief after application of initial arch wire during fixed orthodontic therapy (36,40). Tortamano et al. (36) found lower mean numeric rating scale scores' in the LLLT group for intensity and duration of pain, as well as for oral pain. However, they concluded that there was not any significant effect of GaAlAs diode laser (830 nm laser, 30 mW, 2,5 J/cm²) neither at start nor in the alteration of pain. On the other hand, Turhani et al. (40) reported that there was a significant difference at 6 and 30 hours after LLLT (670 nm, 75 mW). However, there was no significant difference at 54 hours after application.

Moreover, different studies assessed the efficiency of laser treatment on reduction of pain during canine retraction and it was found that pain was decreased in the irradiated sides (17,19).

Bone Regeneration in the Midpalatal Suture

Expansion of the midpalatal suture, a common procedure in orthodontic practice produced an increase in the transverse width of the maxillary basal bone (41). In the literature, it is emphasized that the velocity and quality of new bone formation in the midpalatal suture affect post-expansion relapse. Histological studies on animal (42-44) and human subjects (45-48) with maxillary expansion procedures demonstrated that LLLT stimulated the increased fibroblast proliferation and amount of osteoid tissue, faster ossification and increased bone mineral density when compared with non-irradiated group.

Saito and Shimizu (42) investigated the effects of GaAlAs laser (830 nm, 100 mW, 35.3 J/second/cm²) during the expansion of midpalatal sutures using different treatment protocols and found that late irradiation (4–6 days) had no effect on expansion but that radiation within 0–2 days was effective in the 3-day irradiation groups. In another study, Amini et al. (43) evaluated the efficiency of GaAlAs laser (810 nm, 4J/cm²) on rats after expansion of midpalatal suture in three different time intervals (7,14 and 30 days) and reported that the highest extent of bone regeneration was occurred in the first 7 days, the highest efficacy of laser was observed in 3rd and 4th weeks by conforming the late effects of laser. In a recent study, Rosa et al. (44) applied the increased energy density with diode laser irradiation (780 nm, 70 mW, 18 J/cm²) and demonstrated increased hydroxyapatite deposition in the midpalatal suture after rapid maxilla expansion on rats.

In regard to this, the positive effect of LLLT on bone regeneration during maxillary expansion procedures was clarified with the clinical studies. Angeletti et al. (45) evaluated the effects of LLLT in the midpalatal anterior suture after surgically assisted rapid maxillary expansion using GaAlAs laser (830 nm, 100 mW) with the total energy of 25.2 J at an energy density of 420 J/cm². In this study, LLLT accelerated bone regeneration with an approximately 30% higher mineralization rate in laser group when compared to the control group.

In another clinical study, Cepera et al. (46) applied diode laser (780 nm, 40 mW, 10 J/cm²) to evaluate the effects of LLLT on bone regeneration in patients treated with rapid maxillary expansion. They reported that LLLT provided efficient opening of the midpalatal suture and influenced the bone regeneration by accelerating the healing process. Similarly, Ferreira et al. (47) used GaAlAs (780 nm, 70 mW) and found that LLLT had a positive influence on bone regeneration of the midpalatal suture by stimulating the repair process.

Although most of the studies demonstrated the efficacy of diode lasers with different parameters and application procedures on bone regeneration, Moawad et al. (48) used Er:YAG laser by applying mucosal-bony perforations along the midpalatal suture every month for three consecutive months. These authors observed significant differences in the laser group after rapid maxillery expansion phase, but no significant differences with retention or total treatment duration.

According to most studies that evaluated the effects of low level laser treatment on the expansion of a midpalatal suture, LLLT stimulated the regeneration process based on the total amount of irradiation, frequency, and duration of application.

Effects of Low Level Laser Therapy in Distraction Osteogenesis

Over the last few years, distraction osteogenesis (DO) has become an effective treatment method for facial bone reconstruction (49), for the patients with several congenital (hemifacial macrosomia) or acquired dentofacial deformities (oncologic surgery) (50).

The aim of DO is to generate new bone on the treated side where adjacent bone segments are separated by distraction (49). The distraction devices (distractors) necessary to perform osteodistraction are also crucial for stabilization after accomplishing the distraction needed. The rather complicated distraction appliances can become discomfortable and unpleasant for the patients functionally, esthetically and psychologically (51). The use of LLLT seems to have a positive effect on osteoblastic activity, the repair of bone and soft tissues in this way reducing the retention time (51,52).

In the literature, several studies with different designs evaluated the effect of LLLT on animal subjects (51-54). Miloro et al. (51) aimed to determine the effects of LLLT (820 nm, 400 mW) for acceleration of bone regeneration and diminish the length of the consolidation phase of DO. They concluded that LLLT advanced the bone regeneration process during the consolidation phase. Hübler et al. (52) evaluated the effect of LLLT (GaAlAs; 830 nm, 40 mW, 10 J/cm^2) in an animal experiment on bone at the distraction site in terms of chemical composition, crystallinity as well as crystalline structure. They found a positive effect on the percentage of newly formed bone on the chemical composition according to the Ca/P ratios, and on the crystallinity and crystalline structure according to the detection of hydroxyapatite phases. Kreisner et al. (53) evaluated the efficacy of LLLT using the same laser parameters on newly formed bone with DO during the consolidation phase and suggested the positive effect of LLLT on the amount of newly formed bone with better quality. This could allow earlier removal of the distractors and resulting in reduction of total treatment time. On the other hand, Mayer et al. (54) evaluated the area of bone neoformation after DO through histological analysis and also with measurement of the amount of neoformed bone after LLLT (830 nm laser, 40 mW, 10 J/cm^2) performing the irradiation protocol immediately after activation of the distractor. They found significantly higher amount of neoformed bone in the laser treated group (62.68%) than in the control group (43.09%). Recently, Medeiros et al. (55) evaluated the effects of laser therapy (808 nm laser, 100 mW, 6 J/cm^2) and ultrasound on animal subjects after the 2-day latency period. Although the greatest effects were observed with combined ultrasound and laser treatment, bone healing was accelerated with the application of laser irradiation. The studies that evaluated the effects of LLLT in DO had limited information due the several facts including absence of power analysis, different study designs, limited numbers of subjects. In the framework of our knowledge, the reported findings could not be clarified with human subjects. On the other hand, despite of these limited information, most of the studies used the same laser parameters (830 nm, 40 mW) with the same type of laser (GaAlAs) due to its improved tissue penetration profile (52-54).

Conclusion

Low level laser therapy may be effective especially in orthodontic clinical practice in order to reduce total treatment duration and increase patient comfort during treatment. Although laser systems have higher costs and require intensive safety instructions in clinical conditions, LLLT will be frequently preferred in future by converting disadvantages into advantages.

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Ethics

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