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Review article

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Low Level Laser Therapy: Silent Revolution in Dentistry.

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Abstract

In virtually every area of dentistry the advent of lasers and more precisely soft lasers was revolutionary. Advantages of this particular laser is multidirectional, and thus the results are multifold. A major purpose in current dentistry is the non-invasive therapy in oral diseases. The search for a new treatment promotes a thorough review of the laser technology that currently provides opportunities for their use in all fields of dental practice. Improved knowledge and ongoing work in this direction have culminated in a stronger awareness of of Low Level Laser Therapy's (LLLT's) stimulatory, anti-inflammatory and biogenerative impacts, not just on soft tissue but also on hard tissue. Laser results have not yet been extensively studied, but they have the potential to become recognized as a better alternative than conventional therapy. The aim of this article is to put the use of LLLT in the field of dentistry into perspective through exploring the concepts of low-level laser therapy and their effect on soft and hard tissues in the oral cavity at a subclinical stage. This in turn reduces the dependence on medications and with it reduces the occurrences of drug interactions or complications.

Keywords: Low Level Laser Therapy (LLLT), Phototherapy, Teeth Whitening, Biostimulation, Flourescemce, Optical Coherence, Pain Management, Wound Healing, Orthodontics, Tooth Extraction, Endodontics, And Root Canal Therapy.

Introduction

For dental patients the application of LLLT includes almost entirely red and near-infrared light. For tissue at these wavelengths, there is a so-called "optical gap" (approx. 600–1300 nm), where the tissue's efficient light penetration is significantly enhanced. Main tissue chromophores (haemoglobin and melanin) (Fig. 1) have wide bands of absorption at shorter wavelengths, tissue light dispersion at shorter wavelengths is small, and water strongly absorbs infrared light at wavelengths > 1100-nm [1].

Cellular photo-receptors, e.g. cytochromophores, capture light energy inside living tissue. The event electromagnetic energy is converted by cellular mitochondria into ATP (adenosine tri-phosphate) [2]. Consequently, the induced rise in the production of ATP may indicate enhanced neuronal involvement in, e.g., tissue healing fibroblasts [3]. Additionally, the conversion of some of the incident energy to heat would suggest an increase in local microcirculation by vasodilation. Under the first law of thermodynamics, the energy supplied to the tissue must be conserved and there are three possible pathways to account for what happens when low-level laser therapy is delivered into the tissue: -

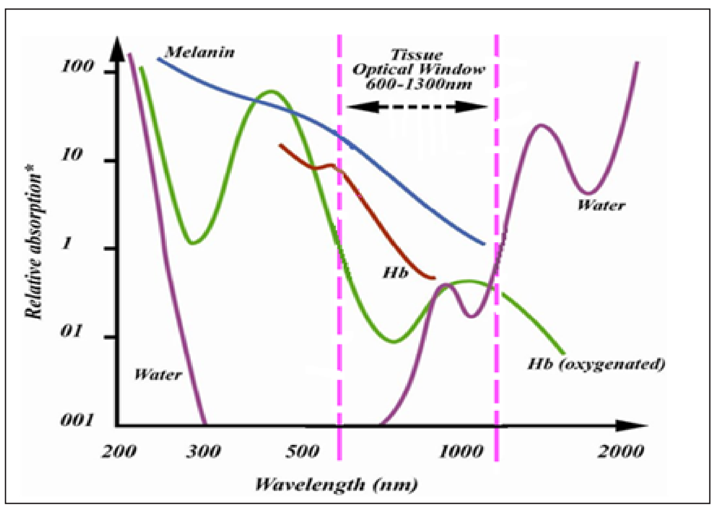

Figure 1: Absorption coefficient values of predominant chromophores (Haemoglobin, Melanin, and Water) relative to common laser wavelengths used in dentistry.

I-First pathway (photonic energy).

A tissue / cellular chromophore consumes photonic radiation, and this elevates the chromophore 's energy status to an unstable upper stage. A chromophore is a molecule (or part of a molecule) that gives the tissue to which it is a portion a definite "color" (absorptive capacity). The chromophore's consequent first excited singlet state undergoes a transition from a higher to a lower electronic state and the energy of the electronically excited state is given off to the molecule's vibrational modes, i.e. the excitation energy is transformed into heat [4]. Hemoglobin, cytochrome c oxidase (Cox), myoglobin, flavins, and porphyrins could be used as examples of chromophores [5].

II-Second pathway (Fluorescence).

Fluorescence is a luminescence in which a photon's molecular absorption triggers another photon's emission at a longer wavelength. The energy gap between the photons consumed and emitted ends up as molecular movements or heat.

III-Third pathway (Photochemistry).

The rates of irradiation and strength of the photons concerned are inadequate to induce breakage of covalent bonds. However, the energy is sufficient to form a first excited singlet state, and this can undergo inter-system crossing to the chromophore's longer-lived triplet status. It allows for reactions, such as the conversion of energy to ground molecular oxygen to form the reactive singlet oxygen (ROS) (Figure 2). Alternatively, the chromophore triplet state may undergo electron transfer (reduction) to form the radical anion which can then transfer a superoxide electron to oxygen. Stimulating the mitochondrial respiratory chain is a third photochemistry pathway that can occur after a photon is absorbed. In summary, the accumulation of photonic energy by cell mitochondria and related chromophores contributes to improvements in the biochemical system (positive and negative), signalling cells and transcription, from which instances of increased tissue regeneration and healing can be seen (Fig. 2).

First pathway effects— photobiomodulation (Biostimulation):

In order to obtain the biological result, biostimulation is the use of low-energy laser beam on the tiny amounts. It is fundamentally used in wound healing and in pain reduction. The laser application providing low-dose energy is described as "low-dose laser therapy"to increase the applied tissue temperature no more than the normal body temperature (36.5 ° C) [6]. Photochemical theory is the most well-known hypothesis describing the mode of operation of the therapeutic lasers. The light is consumed by different molecules according to this principle and is accompanied by any of the biological chain of events. These photoreceptors on the respiratory chain are endogenous porphyrins and molecules, and increase the production of ATP [7].

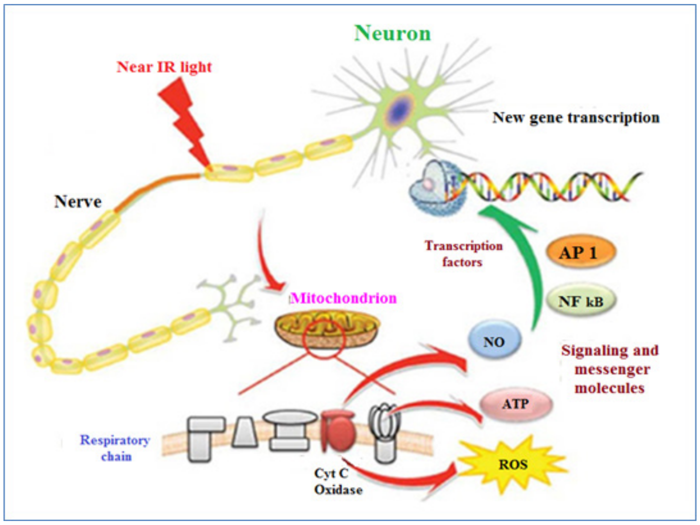

Figure 2: LLLT molecular and cellular system for repair and regeneration of nerves.

Biological Effects of LLLT

The biological effects of LLLT are [8]:

1. Induces Beta-Endorphine activation and synthesis
2. Increases cortisol synthesis (cortisol is the front mol of cortisone which helps the body to combat pain or disease stress)
3. Raises output of ATP
4. Ultimately improves both DNA and protein synthesis activities
5. Neurotransmission is easy when the serotonin and acetylcholine levels increase
6. Cell Replication enhances mitochondrial function
7. Modulation occurs in macrophages, fibroblasts and other cells
8. Na, Cl, and K ions regulated the cell membrane potential
9. The release of cytokines and other chemicals accelerate cell communication
10. Increase in arterial microcirculation
11. The edema reduces as venous and lymphatic movements rise
12. Inflammation reduces as leukocytes are more active in phagocytosis
13. Speedier division of cells, epithelial development and production of collagen
14. Minimal scarring and reduced formation of keloids occur.

Photobiomodulation (PBM):

It is the use of low intensity light sources to control cellular activites. Laser therapy (application of photonic energy at different wavelengths) operates on the concept of inducing by energy transmission a biological reaction. The photonic energy supplied to the tissue modulates biological processes within the tissue and throughout the biological framework of which the tissue is a portion. Within irradiated tissue PBM has no major thermal effect. Reported symptoms of LLLT photo-biomodulation in clinical dentistry can involve dentine hypersensitivity, post-extraction socket / post-trauma locations, drug-induced osteonecrosis / X-ray-induced osteonecrosis, orthodontic tooth movement, viral infections: herpes labialis, herpes simplex, neuropathy: trigeminal neuralgia, paraesthesia, Bell's paralysis, appropriate ulceration, implant osseointegration, tempro mandibular dysfunction syndrome (TMJDS), trismus, and post-oncology: mucositis, dermatitis, post-surgery healing [9,10]. Additionally, there is evidence to support LLLT's analgesic efficacy by enhanced endorphin and bradykinin production, reduced c-fibre activity, and an altered pain tolerance. Therapeutic analgesic symptoms may also exist, by centrally releasing serotonin and acetylcholine, and peripherally releasing histamine and prostaglandins [11].

Second pathway effects— fluorescence:

Fluorescent and photodynamic diagnosis can include screening services, or part of a tissue investigation hierarchy sequence. Suspect oral mucosal lesions can be exposed to biopsy and other tests. Auto-fluorescence imaging may produce good results for identifying lesions from regular mucosa, but using auto-fluorescence analysis in some other position than as an adjunctive scanning technique is inappropriate. To determine the best, most dysplastic position for biopsy, auto-fluorescence spectroscopy may be used wherever appropriate. The literature unfortunately indicates that auto-fluorescence is not adequately accurate for this reason.

The use of fluorescence in caries diagnosis was initially proposed more than a century ago, but gained greater importance with the advent of laser technologies into dental practice. Wavelengths ranging approximately 405 and 670 nm are typically used. A visual identification approach that was scientifically valid in the 1980s, based on the normal green fluorescence of tooth tissue, was developed [12]. The procedure used an argon-ion laser excitation wavelength of 488 nm to separate bright green fluorescence of good tooth tissue from carious lesions that are poorly fluoresced. In the early 1990s, the method was further evolved into what is now known as quantitative light-induced fluorescence (QLF), where the digitisation of fluorescence artifacts is used to calculate mineral damage measurements [13]. A Red Fluorescence Method evolved at that time. Yellow fluorescence, excited either with long wavelengths of UV (350–410 nm) or violet (550–670 nm), was detected on the teeth in advanced caries as well as plaque and calculus.

To comparison to the lack of green fluorescence reported to caries, a strong red fluorescence in caries lesions exists between 650 and 800 nm and this is much brighter than that associated with sound enamel or dentine [14]. In 1998 Kavo (Kavo GmbH) developed the first commercially usable device using a red laser, with an emission wavelength of 655 nm. The aetiology of dental caries is multifactorial. Diagnosis and treatment will recognize aetiology, location of lesion and 3-D severity. Methods of identification include techniques for visual, radiographic, chemical and illuminescence, and for photodiagnostic fluoroscopy [15]. Evidence appears to show that hybrid approaches allow for better accuracy.

Laser irradiation induces differentiated tissue / caries / plaque / calculus fluorescence in teeth. Fluorescence is a product of Laser wavelength (photonic energy). Narrow (non-coherent) waveband irradiation can provide for differential spectrometry. Laser fluorescence may be a valuable supplement for identifying early caries in the enamel. The energy standard used in this procedure raises no patient danger and provides possible benefits [16].

Optical Coherence Tomography (OCT):

OCT is a method used to produce sub-surface photographs of transparent or opaque materials at a resolution equal to a microscope with low strength. Conceptually it is analogous to a 'optical ultrasound' which provides cross-sectional images through capturing reflections from within the tissue [17]. Not all tests reliably diagnose early lesions, so there may be false positives or false negatives. It is important to identify early lesions in conjunction with an evaluation of the activity status to evaluate the prognosis and threshold needed for preventive intervention [18].

Third pathway effects— photochemistry:

The therapeutic implementation of the photochemical activities triggered by the laser includes: a) tooth whitening, b) screening methods, and c) Photodynamic Chemotherapy of antimicrobials.

a) Tooth whitening:

To counter the exponential growth in demand for tooth whitening, numerous treatment modalities have been created. Originally, the Argon 488 nm laser wavelength was developed to provide extreme photonic energy to assist in the action of hydrogen peroxide on darkened enamel and dentine, but the expense of the device coupled with the health criteria contributed to its decrease in use [19]. Many methods arose utilizing a pre-formed design tray device, varying from the usage of LED and plasma arc lights to home-use packages.

The current resurgence in laser-assisted tooth whitening has been the development of a KTP (Potassium Titanyl Phosphate) 532 nm laser based on diodes. This laser interacts in a photo-activated manner with bleaching gel comprising carbamide peroxide, as compared to the longer wavelengths (Diode 810 nm, CO2 10,600 nm), which work in a photothermal manner to supply heat to the gel and thus speed up the chemical reaction [20]. A red spray, comprising rhodamine B and hydrogen peroxide, is added to the tooth using the KTP laser technique and exposed to laser strength. The enzyme Rhodamine B has a median absorption of 539 nm. Once this dye is subjected to 532 nm light it consumes energy photons with resulting electron transfer to the excited singlet state. The molecule can then undergo molecular oxygen reactions, resulting in the formation of hydroxyl radicals, superoxide ions, peroxides, single labile oxygen or reactive oxygen species. In this sense, a photochemical process is the contact between the KTP laser energy and the dye [21].

In the type of thermal energy a part of the KTP laser energy consumed in the Rhodamine B dye is often passed from the excited molecule into the bleaching gel. This transition contributes to regulated gel heating and not tooth heating, reducing the risk of pulp thermal injury. The shallow heating of the gel accelerates the hydrogen peroxide degradation, thereby improving the total production of perhydroxyl radicals over a specified time span. Apart from extrinsic staining due to lifestyle causes, the administration of tetracycline antibiotics during the development of a tooth is a common cause of intrinsic staining. This staining has been shown to be immune to chemical bleaching agents that create oxidizing radicals, whereas the tetracycline molecule can be photo-oxidized with a laser of 532 nm [21].

b) Scanning and spectrometry:

The creation of laser-based measurement instruments (e.g. confocal micrometer), utilizing low-energy laser beam splitting and optical detector, allowed precise reproduction of the geometry of dental and oral structures and products used in dental restoration. In the area of orthodontics and facial growth the first application of laser scanning was to include 3D visualization and documentation of deformities pre- and post-treatment [22]. Scanned data was linked using CAD (computer-assisted design) to the computer software. During the last decade, this concept has been extended to enable the scanning of restorative cavities prior to cast or milled indirect reconstruction and documenting of oral and facial swelling [23].

The integration of Doppler laser flowmetry into dentistry applications has allowed comprehensive study of pulpal and gingival blood flow to assist in treatment planning [24,25]. An additional related application of laser light is by Raman spectroscopy in oral medicine. A Raman spectrum reflects the scattering of molecule or crystal motions of incident laser radiation. This activity is very sensitive to the molecular structure of the materials being studied, and work fields include the study of disease mechanisms such as cancer, atherosclerosis and bone disorder in vitro and in vivo. As for the above, Raman's in vivo spectroscopic study of improvements in mineral and matrix has been seen to be effective in measuring early shifts in bone tissue [26].

c) Photodynamic antimicrobial therapy (PDAT):

The idea of the light-activated drug therapy in the context of photo-dynamic therapy is well known in medicine. Photo-activated antimicrobial chemotherapy is a technology that goes beyond the traditional usage of chemical agents to accomplish bacterial decontamination in parodontal and the restorative aspects of dentistry. Acronyms to characterize this treatment vary, and opinion has continued to follow the usage of antimicrobial photodynamic therapy (PDAT). Currently, the most promising feature of PDAT seems to be the topical application of a photosensitizer to infected tissues and the subsequent illumination [27]. The procedure requires adding an effective chemical - a photosensitizer - to the treatment site. A photosensitiser is a chemical compound that undergoes rapid photo-excitation laser irradiation and then converts the energy to other molecules. Oxygen from the host tissue, thus passing inter-systems in near proximity to create oxygen radicals (O2−) and other free-radicals (H2O2 and OH−). In addition, reactive oxygen species (ROS) production — electronically activated and extremely reactive oxygen state known as singlet oxygen (1O2) that can associate with a wide variety of biological substrates that trigger oxidative harm to the cell membrane and cell wall. Such damaging reactions by apoptosis or necrosis can destroy cells [28].

Throughout the dental sector, bacterial diseases are a significant cause of discomfort for practitioners [29] and, at some rates, chemical disinfectants can be carcinogenic (such as glutaraldehyde) [30]. Some of them are no longer used, accordingly. Photodynamic antimicrobial chemotherapy (PACT) utilizes LLLT to enable a chemical capable of generating ROS, such as H2O2 and ozone gas, which may contribute to cell death. This approach is used to remove pathogens in the root canal [31]. A variant of this is a form of photodynamic antimicrobial therapy (PDTa) employed on cariogenic biofilms. The main molecule necessary for ROS development during this step is oxygen. The approach includes generating free radicals, which may happen by one of two methods. In the first step, the photosensitizer reacts through an electron transfer with a substrate material and produces the radical species. In the second step, the photosensitizer interacts with oxygen to allow singlet oxygen (the reactive species) to form (Fig. 3) [32]. This procedure was used as an alternative to the scaling and root planning as a parodontal operation.

Several photo-sensitizers were used to analyze PDAT. Each photosensitiser has a specific absorption peak equal to the laser wavelength added. Circumin (Yellow)—430 nm, Methylene Blue—660 nm, Radachlorin (chlorophyll derivative)—660 nm, Toluidine Blue—680 nm, and Indocyanine Green—810 nm are examples of commercially available dyes. And it has been shown that these induce statistically important bacteriocidal effects on a number of bacterial periopathic species [33]. The triple-state photosensitiser molecules activated by $\pi > 850$ nm have inadequate energy to cause ROS in neighboring tissue O2. The peak absorption at 810 nm with Indocyanine green provided the impression that its behavior is not solely photodynamic, but is primarily photothermal [34]. Work in the early 1990s, especially by Wilson and Pearson at the Eastman Dental Institute, London, established the sensitivity of Streptococcus mutans to PDT while the organism was found in a collagen matrix — an condition identical to that that might occur inside a carious tooth [35]. If bacterial contamination of the prepared cavity could be rendered sterile, the hypothesis suggested a significant reduction in the potential for recurrent caries. The principle has also been extended to include a more interceptive treatment of demineralised but otherwise intact enamel surfaces, where bacterial removal and fluoride therapy may prevent a more important carious cavity from developing [36].

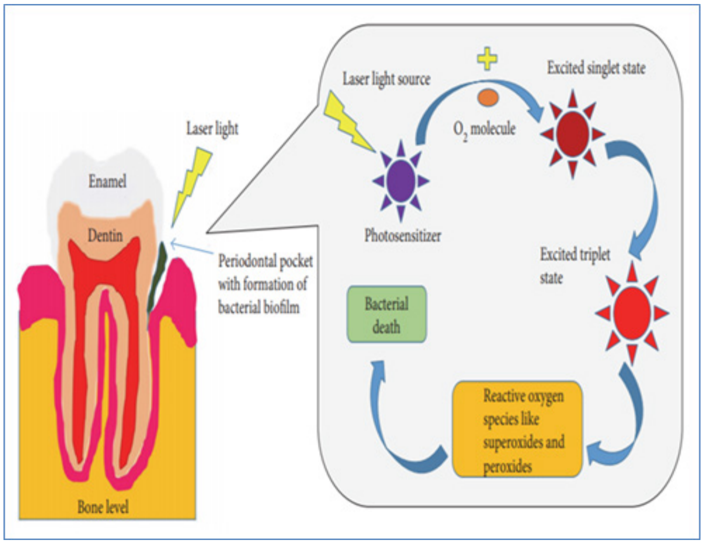

Figure 3: Mechanism of action of PDAT.

Latest in vitro and in vivo experiments on the usage of PAD in endodontics have shown this therapy ‘s efficacy against a variety of endodontic-associated anaerobic bacterial strains [37].

Applications of LLLT in dentistry

The production of pulp cell care includes low-level laser therapy (Low-level Laser therapy-LLLT). Studies focused on the 660 nm wavelength diode laser phototherapy indicate a positive response in the differentiation and growth of pulp stem cells, judging by their cellular mitochondrial activity. The prospect of laser-driven pulp stem cells in their differentiation provides an insight in the medical strategies for the management of dental pulp diseases [38].

LLLT will give patients therapeutic value including rapid wound healing and pain relief. The key benefit is that it is a non-surgical technique which reduces the occurrence of oedema and inflammation. Improving wound healing, remodeling and bone reconstruction, repairing neuronal functions after damage and encouraging immune system control and nociceptive signals are the advantages of utilizing soft lasers [39]. LLLT has developed itself well in clinical dentistry due to therapeutic benefits such as bio enhancement, regenerative ability, and lower heat anti-inflammatory effects. The diode laser is absorbed by the soft tissue pigmentation and has a good haemostatic agent, with a power output of 2 to 10 W [40].

LLLT controls the inflammatory cycle in surgical third molar extractions that induces little to no side effects by minimizing pain and swelling and restoring damaged tissues as these complications are normal in all patients following removal of the third molar. There has also been a rise in randomized clinical studies focused on the impact of LLLT on various variables such as wound healing, scarring, disorders of the temporomandibular joint, dental pain and oral mucositis [41]. Anaesthesia has had a beneficial impact on minimizing the damage of arteries or nerves that may in certain instances be induced by the needle puncture. Until application, LLLT can be added directly to the superficial mucosa, providing a strong cosmetic result, but it cannot be extended to the hard palate. Oedema is based on the lymphatic system, which is attributed to an intensified inflammatory response. When LLLT is added specifically to the lymph nodes, then oedema would be minimized. Widespread oedema can take large doses and frequent treatments to relieve this. Through medical lasers, discomfort is reduced as it decreases the amplitude of nerve conduction and action potentials as well as the removal of noxious stimulations [39].

LLLT was implemented with very minimal side effects particularly for treating the erosive lichen planus form. There are, however, two forms of results generated by a low-level laser: essential and auxiliary. It causes primarily vasodilation, lymphatic drainage, cellular activity and metabolism, blood flow enhancement, fibroblast and neutrophil activation, and pain threshold stimulation. The secondary result of tissue encephaline is the accumulation of prostaglandin, immunoglobulin and lymphocytes, and beta-endorphin. It would also rising bacteria, inflammation, discomfort, soreness and immune response [42]. LLLT technology has demonstrated a substantial decrease in the discomfort associated with oral mucositis, as well as a quicker healing of oral lesions [43].

A study examined the intraoral treatment of LLLT’s anti-inflammatory and analgesic activity. Authors of this paper reported that LLLT is a healthy successful therapy for accelerated regeneration, increased tissue remodeling, decreased pain and analgesia for use in a broad variety of oral pathologies. It is drug-free and fairly side effect-free, which tends to be beneficial when there are not many existing pharmaceuticals. In addition to a greater rate of postoperative recovery and improved tissue remodeling, LLLT is often a significant advantage for patients in distress, who are needle phobic or who can not handle NSAIDs [44].

An invivo study conducted to evaluate the use of low-level laser therapy (LLLT) in pain, discomfort, bleeding, and clot formation within the socket after removal of healthy adult patients’ upper anterior teeth. Conclusion was using a 0.8 W (output power) 940 nm diode laser in continuous mode as LLLT has a major impact on pain relief, irritation, and bleeding rates with the creation of a healthy blood clot within the tooth socket [45]. An article provided insight to the use of LLLT in the area of endodontics, be it drainage, disinfection, surgical treatment, pain relief or even an unincidental and quicker healing of the wound after endodontic operation. Based on the findings of these checked papers, it is hypothesized that LLLT will improve disinfection and healing in endodontics, with apicectomies consistent with periapical bony lesions and post-surgical analgesia and healing. The mechanism of action may be through the activation and differentiation of cellular proliferation and result in rapid healing process [46].

A comprehensive analysis was carried out to determine the utility of low-level laser therapy (LLLT) for the clinical treatment of orofacial neuropathic pain. The results were: 1) LLLT seems to be effective as a treatment alternative for various orofacial neuropathic pain disorders, such as trigeminal neuralgia; occipital neuralgia, and burning mouth syndrome as a single or combination therapy; 2) Furthermore, further clinical trials evaluating all outcome indicators of chronic pain are required in the medium and long term; and 3) In fact, the absence of standardization of the implementation methodology needs further well-designed experiments to validate the findings of this systematic review [47].

Lasers have numerous orthodontic uses, including accelerated teeth movement, bonding and debonding techniques, discomfort relief, bone healing, etching procedures, mini-implant protection, soft tissue procedures (gingivectomy, frenectomy, immediate anchorage uncovering, and welding procedures [8]. Owing to its reparative and anti-inflammatory activity LLLT was examined in many fields of dentistry. With regard to orthodontic tooth movement, LLLT accelerates tooth movement, reduces pain, enhances bone remodeling and reduces orthodontic inflammatory induced root resorption (OIIRR). A recent research measured the impact of LLLT on OIIRR under strong orthodontic force magnitude (50 g) in rat model, both histologically and histomorphometrically. The result of this research was that LLLT appears effective in the avoidance or elimination of orthodontic root resorption, as well as the improvement and enhancement of OIIRR healing and repair [48].

Contra indication:
For individuals with coagulation conditions LLLT has severe contraindications as it has a strong impact on blood supply and in instances with malignancies because it promotes cell growth [39].

Safety of LLLT:
Laser instruments which are used for LLLT are rated as Class III or Class IIIb relative to hot lasers (Class IV). Usage of special glasses is recommended for eye safety [44].

Conclusion
For virtually every area of dentistry the advent of lasers and more precisely soft lasers was revolutionary. The advantages of this particular laser is multidirectional, and thus the effects became multifold. Improved knowledge and ongoing work in this direction has culminated in a better awareness of the LLLT's stimulatory, anti-inflammatory and biogenerative activity, not just on soft tissue but also on hard tissue.

The use of LLLT in maxillofacial medicine has possible effects for quicker diagnosis and faster recovery. The soft tissue laser is a state-of-the-art tool for general dental care, delivering strong esthetic effects. Lasers have added greatly to dental clinical research in the 21st century and they will be playing a very important part in the dental profession in the future [49]. Any dentist will also understand and promote the usage of lasers as an effective and complementary option for delivering soft and hard tissue dental treatments for babies, teenagers, teens and people with specific health care requirements, including geriatric patients. At the same time, it is important to highlight the fact that the dental practitioners undergo adequate education and training to allow effective and consistent use of lasers [46].

Lastly but not leastly, authors are deeply believed that LLLT will widespread in dentistry in near future when more studies and researches will be published.

Conflicts of Interest:
Authors declare no conflicts of interest.

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