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Review Article

Advancements in Periodontal Therapy: Harnessing the Power of Lasers - A Narrative Review

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Abstract

Laser therapy is a rapidly advancing method in periodontology that enhances accessibility and affordability of basic procedures. It is a monochromatic light generated through the stimulation of synthetic material, exhibiting a single wavelength. Laser devices consist of an active medium, two mirrors, and systems for delivering lasers. The interaction between laser and tissue initiates a photothermal reaction, resulting in an elevation of the tissue's internal temperature and the production of thermal energy. Laser therapy has shown significant efficacy in promoting periodontal healing, offering advantages such as haemostasis, sterilisation of periodontal pockets, bio-stimulation, and decreased morbidity compared to surgical techniques.

Peri-implantitis is a clinical condition characterized by an inflammatory response in the soft and hard tissues of osteo-integrated dental implants. Various clinical procedures have been proposed for managing peri-implant diseases, including non-surgical interventions, surgical interventions, flap elevation, laser disinfection, implantoplasty, resection procedures, and guided tissue and bone regeneration procedures.

Low-level laser therapy, also known as soft or therapeutic lasers, has minimal adverse effects due to the absence of noticeable temperature fluctuations when applied to soft tissues. Photo-biomodulation therapy stimulates and modulates cellular components, enhancing bone healing, periodontal tissue healing, osteointegration of implants, and bone reconstruction.

Keywords: Periodontics; Laser Therapy; Gum Diseases; Advancements

Introduction

LASER is an initialism denoting the process of amplifying light through the stimulated emission of radiation [1]. While lasers were initially employed for soft-tissue procedures, the advent of the latest laser technology has also expanded their application to dental hard tissue. Hard tissue lasers can be regarded as a viable substitute for traditional lasers, providing clinicians with an enhanced professional domain that facilitates favourable results and improved treatment outcomes. Furthermore, it is possible to prevent using sharp dental instruments, drilling noise, and vibration while performing dental implants [2].

The laser is emerging as a prominent tool in the field of periodontics in the foreseeable future. Laser therapy is a cutting-edge and rapidly advancing modality within the field of periodontology, known for its remarkable efficacy in enhancing the accessibility and affordability of even the most basic procedures. The existing body of literature on lasers in the field of periodontology is presently substantial and experiencing rapid expansion. The present study aims to showcase novel applications of this contemporary technology in regular periodontal procedures.

Historical Background

The theory of stimulated emission was described by Albert Einstein in 1917 [1]. The laser was introduced in 1959 through an article authored by Columbia University's graduate student Gordon Gould. The inaugural operational laser was developed by Theodore Maiman at Hughes Research Laboratories in 1960 [3]. In 1961, Javan., *et al*. developed the first gas laser, which operated continuously. Patel developed the CO_2 laser at Bell Laboratories in 1964 [1]. In 1971, Hall and Jako., *et al*. conducted a study on tissue reactions to laser light and wound healing.

In 1974, Geusic., *et al*. introduced the Nd: YAG laser. In 1977, Kiefhaber introduced the Ar laser. In the 1980s, laser technology was employed in the field of oral surgery to eliminate soft-tissue lesions [4,5]. The development of the neodymium-yttrium aluminium garnet (Nd YAG) laser for dental procedures was undertaken explicitly in 1987. In 1988, Hibst and Paghdiwala introduced the Er: YAG laser. In 1989, Midda., *et al*. examined the use of Nd: YAG laser in soft tissue surgery.

Laser light is a type of monochromatic light that is generated through the stimulation of synthetic material, exhibiting a single wavelength [6]. Light energy is utilised in this technique, wherein a light chamber emits light continuously and uniformly to target tissue for the purposes of incising, cutting, and ablation [2]. When a laser is stimulated, its active medium, which can be a gas, crystal, solid-state, or semiconductor, generates photons that carry energy. The determination of clinical applications for numerous lasers is contingent upon their respective wavelengths [7]. Oral and dental hard tissue contain chromophores, which are pigments that absorb light and are responsible for absorbing laser energy of a specific wavelength [8-10].

Components of laser devices

The components of all lasers are as follows [11] (Figure 1). The active medium of a laser can encompass various states, including gas, crystal, solid-state, or semiconductor. A laser tube or optical cavity has two mirrors positioned at opposite ends, serving as either fully reflective or partially transmissive surfaces.

The atoms within the laser medium are stimulated or elevated to higher energy levels by an external source of mechanical, chemical, or optical energy.

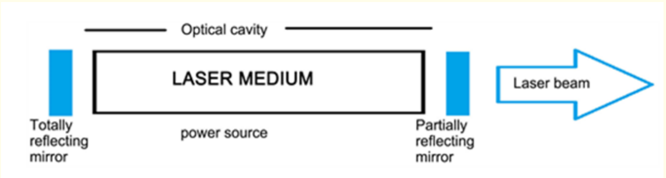

Figure 1: Laser device components.

Systems for delivering lasers

The current assortment of laser delivery systems encompasses the subsequent options [11]: Arms are equipped with mirrors at 45-degree angles, designed to accommodate UV, visible, and infrared lasers. Hollow waveguides, semi-rigid tubes with internal surfaces that reflect light, are utilised for middle and far-infrared lasers.

The fibre optics system utilises rigid tips composed of quartz-silica flexible fibre with quartz and sapphire, designed explicitly for visible and near-infrared lasers. Portable devices, such as lasers, with low power output.

Laser operational modes

Lasers exhibit multiple emission modes, as depicted in figure 2.

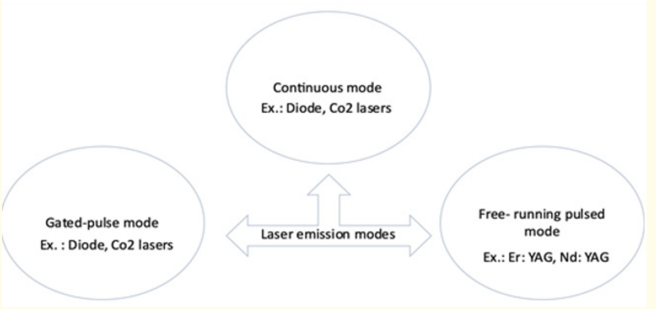

Figure 2: Laser operation modes.

The continuous wave feature operates by releasing a single power level of a beam as long as the foot switch is pressed. The gated pulse mode involves the periodic alteration of laser energy through the physical gating of the beam. The free-running pulsed mode, a characteristic of the active medium, involves a notable release of energy for a brief duration, succeeded by a substantial interval during which the laser is deactivated.

Interaction between laser and tissue

The application of laser light to the target tissue initiates a photothermal reaction, resulting in an elevation of the tissue's internal temperature and the production of thermal energy [12]. When the temperature exceeds 60ºC, the proteins within the tissue undergo coagulation [4]. Nevertheless, when the temperature surpasses 100ºC, it leads to water molecules' evaporation and soft tissue eradication [4]. In the context of hard-tissue procedures, it is imperative to maintain a temperature exceeding 200ºC [10].

When laser light interacts with a target tissue, it gives rise to four distinct interactions, contingent upon the tissue's optical properties and the wavelength of the laser light. The aforementioned interactions are depicted in figure 3.

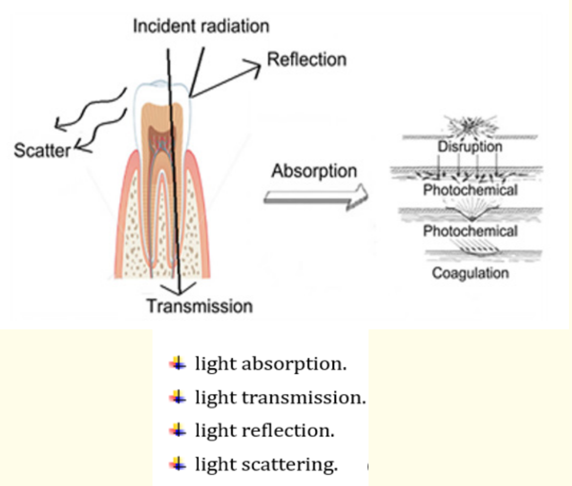

Figure 3: Laser tissue interaction.

Laser therapy for the treatment of periodontal disease

Periodontal disease is a pathological state characterised by inflammation resulting from the presence of opportunistic bacteria residing in the oral cavity. These bacteria have the ability to impact the marginal periodontium under specific circumstances. Modern periodontal therapy now focuses on halting the disease's advancement and regeneration of damaged tissues, employing various treatment approaches [13]. The primary treatment approach for periodontal disease is root planning and scaling, a non-surgical procedure [13,14]. This clinical procedure entails extracting the impacted tissues from the dental root using various manual and ultrasonic instruments to promote the reconnection of periodontal ligament fibres and the gingival junctional epithelium with healthy tissue [15]. Aside from these extensive procedures, alternative surgical or non-surgical approaches like gingival curettage, gingivectomy, and different types of flaps like apical or modified Widman repositioning flaps are employed to decrease the depth of periodontal pockets and enhance the degree of clinical gingival attachment [13,16]. Additional treatment options for periodontal disease include guided tissue regeneration and the use of growth factors. These methods have different levels of success and predictability. However, regardless of the surgical approach chosen, they are associated with pain and discomfort [13].

The utilisation of laser as a non-surgical adjunct therapy in the field of periodontology has exhibited its efficacy in promoting periodontal healing [13,17]. Compared to surgical techniques, this method offers several advantages, such as haemostasis, sterilisation of periodontal pockets, bio-stimulation, and decreased morbidity [13]. Using CO2, Nd: YAG, Er: YAG, and diode lasers offers several benefits in the context of root surface debridement. However, it has been observed that Er: YAG lasers yield the most optimal outcomes, primarily attributed to their ability to effectively eliminate dental calculus while avoiding excessive heating of the surrounding tissue [18]. Soft tissue surgery in gingivectomy and frenectomies uses laser systems such as CO2, diode, and Nd: YAG [7,12]. The utilisation of the CO2 laser has proven to be effective in the de-epithelization of mucoperiosteal flaps as an adjunctive technique in the context of periodontal surgery [19]. The utilisation of laser treatment, either as a standalone intervention or in conjunction with mechanical treatment for gingival debridement, has yielded favourable results regarding gingival reattachment, reduction in periodontal pockets, and decreased bleeding during periodontal probing. These outcomes have been observed in both generalised and localised cases of chronic periodontitis, and the outcomes have been consistently predictable over a span of five years [13]. Moreover, comparable treatment protocols yielded favourable outcomes regarding alveolar bone, cement, and periodontal ligament regeneration for natural teeth and compromised dental implants [20].

Laser therapy for peri-implantitis

Peri-implantitis is a clinical condition distinguished by the manifestation of an inflammatory response in the soft and hard tissues of the osteo-integrated dental implant, accompanied by the presence of pathological periodontal pockets and the depletion of the supporting bone. Recently, dental implants have emerged as the prevailing choice for replacing compromised teeth, with a notable success rate observed after a decade. However, practitioners must consider the potential occurrence of complications associated with this treatment modality [21]. Mucositis, as defined by the American Academy of Periodontology, is an inflammatory condition that occurs around dental implants, without causing any loss of the supporting bone, beyond the natural process of bone remodelling. Recent research findings show that the occurrence rates of peri-implant mucositis and peri-implantitis range from 19% to 65% and 1-47%, respectively. On average, mucositis accounts for 43% of cases, while peri-implantitis accounts for 22% [22]. The causes of these conditions are bacterial in nature, resembling the aetiology observed in periodontal disease. Gram-negative anaerobic bacilli, fusiform bacteria, spirochetes, and various inflammatory cells are the primary microbial components that have been isolated. These components are commonly found in periodontal pockets [21].

Numerous clinical procedures have been proposed for the management of peri-implant diseases, encompassing non-surgical interventions, surgical interventions involving flap elevation, laser disinfection, implantoplasty, resection procedures, as well as guided tissue and bone regeneration procedures [22,23]. Carbon fibre and/or titanium curettes are the prevailing protocols due to their minimal detrimental effects on dental implant surfaces. The successful execution of the procedure necessitates the decontamination of the implant surface. To eliminate bacterial contamination and facilitate bone regeneration and osteo-integration, various techniques such as chemical, mechanical, and laser decontamination are employed [21,24].

Romeo., *et al*. (2005) found that implantoplasty is more advantageous than resection surgery alone in preserving the amount of bone surrounding implants affected by peri-implantitis [21,25]. The study subsequently compared implantationoplasty and Er: YAG laser therapy regarding decontamination of the implantation surface during resection and regenerative surgery. The results demonstrated that both approaches yielded satisfactory outcomes in reducing bleeding during probing and enhancing the clinical gingival attachment [21].

Applications of low-level laser therapy

Some practitioners employ high-frequency lasers such as Er: YAG, Nd: YAG, or diode as an adjunct treatment to optimise the efficacy of non-surgical and surgical therapy and achieve optimal outcomes in treating periodontal conditions. These procedures include eliminating subgingival calculus, cleansing periodontal pockets, and potent antibacterial effects. [26,27]. In contrast to the thermal effects of high-power lasers, it is advisable to utilise low-power laser therapy due to its photo-chemical anti-inflammatory, bio-stimulation, and analgesic properties. These beneficial effects are achieved by utilising low-power devices that operate within the wavelength range of 600-1000 nm [28]. Although using high heat-release lasers during incision and ablation can have adverse effects on the surface of roots [29], the use of low-power lasers, also referred to as soft or therapeutic lasers, has been associated with minimal adverse effects. This phenomenon arises due to the absence of noticeable temperature fluctuations when applied to soft tissues [30]. The prevailing low-power laser types include He-Ne lasers and the progressively favoured diode lasers (GaAlAS, In GaAlP) [30]. Since its introduction in 1960, the low-power laser has found extensive application in diverse domains of dentistry, including post-surgical care, bone remodelling, pain management in the oral and maxillofacial region, and, more recently, the management of periodontal disease [28,30]. The absorption of water and chromophores from tissues, such as haemoglobin and melanin, is reduced by lasers with red or infrared wavelengths. This is the reason why tissue penetration is greater than 5-10 mm [34,39]. It is hypothesised that low-power lasers exert their effects on the mitochondrial respiratory chain, elevating adenosine-triphosphate levels. This, in turn, promotes the proliferation of growth-releasing fibroblasts and facilitates collagen synthesis [28,30]. The efficacy of low-power lasers in suppressing inflammation in periodontal tissues has been demonstrated through *in vitro* animal studies. This effect is achieved by modulating the local immune response and reducing the production and release of specific pro-inflammatory cytokines, including alpha tumour growth factor, interleukin-1β, and prostaglandin E2. This particular laser system also enhances microcirculation by promoting angiogenesis and vasodilation, reducing oedema and inflammation [28]. Qadri., *et al.* found that using low-power laser treatment as an additional treatment helps reduce gums' short-term inflammation. This is evidenced by a decrease in the gingival index, plaque index, periodontal pocket depth, and low levels of metal-proteinase eight matrix in the fluid surrounding the gums [29-32].

Subsequent evidence demonstrated that this therapy not only stimulates cellular components but modulates them, resulting in the emergence of photo-biomodulation therapy. This therapy exhibits anti-inflammatory, anti-allergic, healing, and stimulating effects on cell growth factors [33].

Photo-biomodulation therapy utilises electromagnetic energy technology within the wavelength range of 600-1100 nm, delivering a constant light beam with low-density energy (0.04-60 J/cm2). Helium-neon (HeNe) and gallium-aluminium arsenic (GaAlAs) are laser light sources that possess excellent tissue penetrability [33,34].

The utilisation of photo-biostimulation in bone tissue has been observed to enhance the process of fracture healing, periodontal tissue healing, osteointegration of implants, and bone reconstruction, both with and without the assistance of biomaterials [33,35]. It is widely recognised that conditions characterised by tooth loss and substantial bone tissue loss, particularly in the oral and maxillofacial regions, can significantly impact an individual's quality of life. The impairment experienced by patients undergoing surgical interventions for bone reconstruction encompasses not only physical but also mental, emotional, and financial aspects. Physiological bone remodelling is inherently synchronised, although there can be an imbalance between the processes of apposition and resorption [36]. Therefore, in cases with significant bone defects, the process of repair and wound healing becomes difficult, leading healthcare professionals to adopt the utilisation of bone grafts, dental implants, or biomaterials [33].

Irrespective of their source, whether they are autografts (grafting materials from the same individual), allografts (grafting materials from different individuals within the same species), alloplastic (laboratory grafting materials), or xenografts (grafting materials from individuals outside the same species), bone grafting materials must possess the essential biological, physical, and chemical properties required for the bone repair process. These materials must demonstrate characteristics of osteointegration, osteo-conduction, osteo-induction, and osteo-genetic factors. Autologous materials are the sole entities that demonstrate such properties. When a significant bone defect is present, the use of a bone graft becomes necessary, with autologous grafts being the preferred option in the majority of cases. These procedures involve an intricate surgical technique that is challenging due to the potential morbidity of the donor site and the tendency of these grafts to resorb before the osteointegration process is fully established. The bone reconstructive materials must possess a combination of osteoconductive properties, inductive characteristics, and the presence of bone-forming cells together [33]. Bovine-derived materials are a suitable substitute for repairing bone defects because they are biocompatible. Physical techniques, such as photo-biomodulation therapy, can enhance bone reconstruction, whether employed independently or in conjunction with bone grafts [33].

Orthodontic tooth movement using laser therapy

The process of orthodontic tooth movement is a multifaceted and adaptive biological phenomenon that occurs in response to disruptions in the physiological equilibrium of dental and oral structures utilising an external force. Applying orthodontic force leads to the reorganisation of periodontal tissue, which causes bone remodelling during tooth movement. This biological mechanism involves an acute inflammatory response, in which patients report experiencing pain as a result [38].

Recent studies have demonstrated the efficacy of low-level laser therapy in promoting the remodelling of soft and hard oral tissue during orthodontic movement. This therapy aids in the healing process by generating a photo-biostimulation effect [38]. Previous studies have demonstrated the efficacy of low-power laser technology in orthodontic tooth movement procedures. This technique has been found to effectively alleviate pain resulting from applied forces, expedite tooth movement, and suppress the release of analgesic mediators. The absorption of light by cells in the targeted tissue, induced by low-level lasers, leads to the activation of intracellular cascade signals. This activation increases cellular metabolism and anti-inflammatory changes in hard and soft oral tissues. Over an extended duration, this procedure has exhibited enhanced tooth mobility and an augmentation in the rate of osteoclast generation within the compressed region of the teeth, reducing treatment duration [38].

Previous research conducted by Kawasaki and Shimizu in live rats has demonstrated that applying low-power laser therapy induces orthodontic tooth movement and promotes the development of osteoclasts in the compression region. Previous studies have demonstrated that the expedited progression of orthodontic movement can be attributed to the activation of kappa B nuclear factor receptors (RANK), RANK ligand (RANKL), and macrophage colony stimulation factors in conjunction with their respective receptors [38].

Conclusion

The integration of laser therapies into clinical dentistry has gradually occurred in recent years. However, certain practitioners remain uncertain about incorporating these therapies into their daily practice due to a lack of clear information. Therefore, this review aims to emphasise the existing methods for diagnosing and planning treatment. Recent research has demonstrated the efficacy of laser therapies in the field of periodontology, highlighting their advantageous outcomes and the enhancement of periodontal treatments, resection procedures, and regenerative surgical interventions. Furthermore, it elucidates the advantages of employing this substance in guided bone and tissue regeneration procedures and in the supplementary management of photo-biostimulation originating from the periodontal field. It also highlights the anti-inflammatory and analgesic properties produced when utilised in orthodontic interventions.

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