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Impact of Laser Therapy on Periodontal and Peri-Implant Diseases

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Abstract

Objective: In the last few decades, lasers in dentistry have encompassed all branches in dentistry, with more focus in periodontology. In recent years, the use of lasers against periodontitis and peri-implantitis has undergone a decisive development that has involved various operational areas. The broadest applications were probably found in the clinical approach to soft tissues.
Methods: Laser therapy is a novel technique that may provide further beneficial effects to conventional periodontal and peri-implant therapies. However, clinical evidence for the improvement of periodontal wound healing and tissue regeneration through laser treatment is still limited.
Results: This review is aimed at assessing the advantages and disadvantages of the use of lasers in dental procedures and pathologies, focusing more on protocols for the management of periodontal and peri-implant diseases.
Conclusions: The adjuvant action of laser therapy, in addition to conventional therapies for the management of periodontal and peri-implant disease, could induce benefits, but further investigation would be necessary to standardize better the protocols applied and to understand the actual tissue response to laser therapy.

Keywords: periodontitis, peri-implantitis, laser therapy, healing, regeneration

Introduction

The acronym laser stands for ''Light Amplification by the Stimulated Emission of Radiation.'' In 1917, Albert Einstein first theorized the process that made the development of laser possible, ''Stimulated Emission.''[1,2] This theory is based on the ability of light to be absorbed when it passes through a material, inducing the energy transition of the atoms it encounters. In fact, the atom's absorption of a quantum of energy induces its transition from a low energy state to an excited/activated state. However, the lowest energy state is the most stable, so the excited atom tends to return to normal by spontaneously emitting a quantum of energy called ''spontaneous emission.'' When the conversion to the low energy state is achieved by stimulating a medium with a quantum of light at the same transition frequency, it is called ''stimulated emission.''

During this process, a photon of the same size as the released atom is released, which strikes against the adjacent activated atom, triggering a chain reaction of photon release.[2] This is the principle on which all lasers work. However, stimulated emission can only occur if the incoming radiation causes the emission of outgoing radiation with the same properties such as wavelength, direction, polarization, and phase (coherent radiation).[2,3] In the 1960s, Theodore Miaman built the first working laser at Hughes Research I laboratories in Malibu, California, using a mixture of helium and neon.[4] Today, laser devices have countless applications and have influenced many fields, including medicine and dentistry, affecting patient care and well-being.

Lasers used in dentistry are classified according to the active medium that is stimulated, which can be a gas (argon or carbon dioxide), a liquid (dyes), or a crystal in the solid

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TABLE 1. MAIN TYPES OF LASERS USED IN DENTISTRY

Laser type	*Wavelength*
Diode	810–980 nm
CO_2	10,600 nm
Nd:YAG	1064 μm
Er:YAG	2940 nm
Er,Cr:YSGG	2780 nm

Er:YAG, Erbium Yttrium Aluminum Garnet; Nd:YAG, Neodymium Yttrium Aluminum Garnet.

state [Neodymium Yttrium Aluminum Garnet (Nd:YAG), Erbium Yttrium Aluminum Garnet (Er:YAG) or a semiconductor (diode laser)]. Stimulation of the active medium can take place using three methods: optical (xenon flash lamps, other lasers), electrical (gas discharge tubes, electric current in semiconductors), or chemical.[5] Laser light is unique in that it has the following characteristics: monochromaticity (the waves all have the same specific wavelength), directional (low divergence), and coherence (the waves are all in phase with each other),[6] which allow it to be delivered to the tissue as a continuous wave, that is, a very large laser energy is emitted for an extremely short period, microseconds, or as a free pulse (gated pulse), that is, on and off in periods.

Low-intensity laser therapy (LLLT) and high-intensity laser therapy (HILT) are used in the dentistry practice.[7] Low-intensity lasers operate at 500 mW and are used in biostimulation procedures, that is, to activate regenerative and healing processes. These include diode and helium-neon (HeNe) lasers. High-intensity lasers operate at an intensity greater than 500 mW and can generate a cutting in the tissue. They are also referred to as surgical lasers and include CO_2, Nd:YAG, Erbium (Er:YAG and Er,Cr:YSGG), and diode lasers.[7] Table 1 summarizes the main types of lasers used in dentistry and the related wavelengths.

The light energy can interact with the target tissue, generating reflection, transmission, scattering, or absorption.[8] When the tissue absorbs light energy, the temperature of the tissue increases and photochemical effects occur depending on the water content of the target tissue. Temperatures of 100°C result in the vaporization of water, a phenomenon known as ablation. Temperatures between 60°C and 100°C induce protein denaturation without vaporization of the underlying tissue. Finally, at temperatures above 200°C, the tissue undergoes dehydration and carbonization.[9,10] In addition, a chromophore, which has an affinity for specific wavelengths, is required for the laser light to be absorbed by the target tissue (Fig. 1). The main intraoral soft tissue chromophores are melanin, hemoglobin, and water. Hard tissue chromophores are water, dentin, and hydroxyapatite.

Therefore, both the wavelength of the device and the absorption coefficients of the target tissue components must be taken into account when selecting the laser to be used for a specific dental treatment.[10,11] The erbium laser has a high affinity for hydroxyapatite and high water absorption.[12] In contrast, the diode laser has a high affinity for hemoglobin and melanin.[13] Pigmented tissue is susceptible to the wavelengths of the Nd:YAG laser.[14] The CO_2 laser has a high affinity for water.[15,16] Therefore, each of these lasers has applications in specific dental procedures. Currently, the use of lasers in dentistry encompasses all its branches, especially oral surgery and periodontology. In the lights of the abovementioned findings, the aim of this review is to assess the advantages and disadvantages of the use of lasers in dental procedures and pathologies, focusing more on periodontal disease and peri-implantitis.

Laser in Dentistry

Today, lasers in dentistry are used in the treatment of both soft and hard tissue pathologies, spanning all branches of dentistry and inducing numerous advantages. The low-intensity laser (LLLT) plays a role in wound healing, as it promotes the maturation and locomotion of fibroblasts, increasing the tensile strength of healed wounds. In addition, a contraction of myofibroblasts and consequently wound contraction is observed 24 h after laser action.[17,18] Remarkable benefits have been observed in healing recurrent

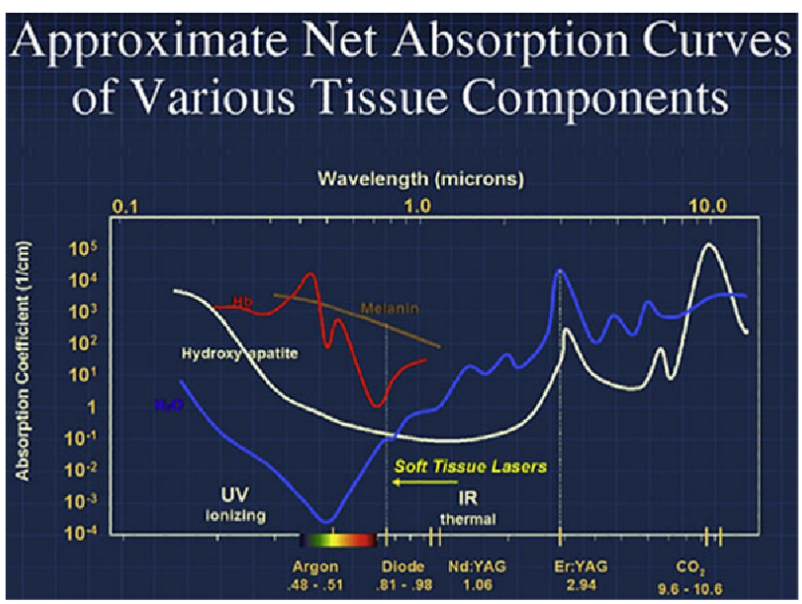

FIG. 1. Oral tissues absorption curves related to laser wavelengths, under permission from Low and Mott.[16]

aphthous stomatitis lesions in men,[19] and mucositis and oropharyngeal ulcers in patients undergoing radiotherapy for head and neck cancer.[20] HeNe laser-induced photostimulation can induce significant pain reduction and accelerate healing of aphthous ulcers and recurrent herpes lesions.[21] It can provide pain relief and accelerate healing. It has also been observed that in lesions with recurrent herpes simplex labialis, photostimulation reduces the prodromal stage (tingling) and stops the appearance of vesicular lesions, accelerating healing time.[22]

Photodynamic therapy (PDT) has attracted considerable interest in recent years. It has been used in the treatment of various neoplastic or pre-neoplastic diseases of the oral cavity, such as squamous cell carcinoma of the oral cavity and leukoplakia.[23] It generates reactive oxygen species that induce direct damage to cells and vascular tissue, triggering cell necrosis and apoptosis.[24] It also promotes antitumor immune activity by activating macrophages and T lymphocytes.[25] Several clinical studies have observed positive and promising results of PDT in the treatment of carcinoma *in situ*, leukoplakia, and squamous cell carcinoma of the oral cavity.[23,25] The diode laser has greatly improved several surgical procedures, facilitating intraoperative and post-operative management, as bleeding and discomfort are reduced, and the precision and esthetics of several procedures are improved.

One procedure in which the diode laser is widely used is gingivectomy and crown extension; compared to the conventional technique, it allows more favorable esthetic results.[26] Frenectomies have become very simple procedures when performed with a laser, as they allow the frenulum to be removed painlessly, without bleeding, sutures, or surgical packs and without the need for special post-operative care.[21] The Er:YAG laser has proven to reduce dentinal hypersensitivity more effectively and with longer-lasting effects than conventional techniques.[27] The Er:YAG laser could allow the removal of caries in both enamel and dentin by ablation without increasing the temperature of the pulp.[28]

Laser Therapy in Periodontal Diseases

Periodontitis is an inflammatory disease affecting the periodontium leading to progressive destruction of the tooth-supporting tissues.[29] The periodontal tissues are exposed to invasion by specific bacterial species that can alter many cell functions and trigger inflammatory reactions.[30,31] The inflammation has the role of protecting the host against biofilm aggression, leading to tissue damage and attachment loss. Therefore, the phenotypic severity of periodontal disease is the result of environmental, bacterial, and host genetic factors.[32,33] It has been estimated that about 35% of western adults will be affected by periodontitis.[34] Further, this pathology has been related to different systemic diseases such as diabetes, cardiopathies, and adverse pregnancy outcomes.[35–39] Therefore, the treatment of periodontal disease is of fundamental importance for the maintenance of a good state of health of the patient.

Periodontal therapy aims to disaggregate subgingival biofilm and reduce the concentration of pathogenic bacterial species, reducing inflammation and arresting periodontal attachment loss. Conventional nonsurgical periodontal therapy consists mainly in scaling and root planing (SRP). Scaling is aimed at calculus and scrubs removal from tooth's crown and root accessible surfaces, whereas root planing determines the removing of root cementum and/or superficial dentin contaminated from the biofilm's endotoxins.[16] These objectives are not always completely reachable, especially in deeper periodontal pockets and furcations.[40,41] The use of adjunctive therapies in periodontal disease aims to increase the clinical improvements induced by conventional therapy and to reduce the use of antibiotics and the risk of developing antibiotic resistance. Many investigations showed the potential of this kind of approach.[42]

Further, resective and conservative periodontal surgery techniques aimed at obtaining a further decrease in the probing depth (PD)[43] and a gain in the clinical attachment level (CAL).[44,45] Other approaches, including regenerative techniques, showed effectiveness and predictability for periodontal disease.[46,47] However, the main limitation of surgical periodontal treatment is related to pain and discomfort for the patients.

Lasers (with or without the photosensitizers) employed in periodontal therapy include mainly CO_2, Nd:YAG and Er:YAG and diode lasers. In this regard, laser therapy has been investigated as an adjunctive treatment for the management of periodontal disease.[48] More specifically, it has improved periodontal healing as an adjunct to nonsurgical periodontal treatment;[49] however, this is still much debated.[49] Further, laser therapy may be advantageous regarding root debridement and over periodontal surgical therapies through different actions, including hemostasis, morbidity reduction, ablation, pocket sterilization, and vaporization.[50,51]

CO_2 lasers (wavelength 10,600 nm) are characterized by high water absorption coefficient. Thus, it represents a possible treatment option in soft tissue surgery, but its role efficiency for oral hard tissues must be validated.[48] CO_2 lasers have been effectively employed in the flap de-epithelialization during traditional periodontal surgical treatment[49] and in nonsurgical approaches (in defocused pulsed mode), obtaining smooth root surfaces, disinfection, and dentinal tubule sealing to improve fibroblast attachment.[50]

Further, it seems that CO_2 laser combined to coronally advanced flap may induce in deep pockets a more marked PD reduction and CAL gain compared to surgical approach only.[51] The removal action of bacterial cells may explain this from root surfaces and the possible reduction of myofibroblasts responsible for tissue contraction after CO_2 laser treatment.[52,53] However, these findings contrast with the results of previous studies.[52,54,55] Moreover, diode, Nd:YAG, and CO_2 lasers are not effective in removing dental calculus.[50,56] A clinical trial revealed that CO_2 laser treatment alone showed weaker effects on subgingival plaque compared to Nd:YAG laser and ultrasonic scaling; it determined a significant mean PD reduction.[57] However, low power defocused CO_2 laser treatment associated with mechanical instrumentation may improve root debridement.[58]

Er,Cr:YSGG (wavelength 2780 nm) and Er: YAG lasers (wavelength 2940 nm) are characterized by higher water and hydroxyapatite absorption coefficients.[48] A randomized clinical trial (RCT) showed that erbium lasers associated to SRP determined improvements in clinical parameters and induced a more marked reduction of periodontal inflammation and interleukin-1β (IL-1β) levels compared to SRP alone.[59] Erbium lasers showed to be able to ablate calculus without overheating adjacent tissues.[60–62] However, the effectiveness was less or similar to SRP, but taking twice the time for the same result.[63,64]

Nd:YAG (wavelength 1064 nm) and diode lasers (wavelength 810–980 nm) are characterized by lower water absorption coefficients and are better absorbed in pigmented tissues.[48,65,66] Nd:YAG laser may be employed for pocket decontamination and has been approved by Food and Drug Administration (FDA) for the laser-assisted new attachment procedure.[65] Nd:YAG laser-assisted new attachment procedure associated with SRP has been demonstrated efficacious than SRP alone.[67] An RCT revealed that a combined Nd:YAG and Er:YAG laser therapy used as an adjunct may improve the clinical treatment results compared to conventional nonsurgical periodontal therapy alone.[68]

IL-1β crevicular levels (related to bone resorption) were significantly decremented in patients treated with SRP compared to Nd:YAG laser treated. However, combining the two therapies determined a further IL-1β level reduction than the combination monotherapies.[69] Diode laser has been employed mainly with a wavelength of 810, 940, and 980 nm for periodontal pocket decontamination after SRP and for maintenance therapy.[65] Nine hundred eighty-nanometer diode laser is batter absorbed by water and it is safer than the 810 nm;[70] however, one study showed better safety and efficacy of the 940 nm diode laser compared to the other wavelengths.[71] Further, a study conducted by Katsikanis et al. showed that high-intensity 940 nm diode laser or PDT through low-level GaAlAs (Aluminum Gallium Arsenide) 670 nm diode laser (with methylene blue photosensitizer) as adjuncts to SRP did not induce additional benefits compared to SRP alone in patients with moderate or severe periodontitis.[40]

In 2008, a systematic review found that there is no evidence supporting the use of lasers as an adjunct to conventional nonsurgical periodontal treatment in patients with periodontal disease.[34] However, a recent network meta-analysis of randomized controlled clinical trials reported that after 6 months, diode lasers showed better CAL gain compared to Nd:YAG and Er:YAG in that order. The authors concluded that periodontal patients could benefit from further clinical improvements through laser-assisted periodontal therapy than SRP alone.[42] Similar effects have been proven for the adjunctive use of diode laser in periodontal disease[72,73] treatment as well as for the treatment of periodontal conditions as lateral periodontal cysts.[31] Table 2 resumes the proposed uses of lasers in the management of periodontal disease.

Table 2. Effects and Application of Lasers for Periodontal Disease

Laser type	*Effects and application*	*Study*
Diode	Bactericidal, root debridement.	72,73
CO_2	Bactericidal, root debridement, crevicular epithelium removal.	58,73
Nd:YAG	Bactericidal, crevicular epithelium removal, periodontal regeneration.	66,73
Er:YAG	Bactericidal, root debridement.	63,64,73

Laser Therapy in Peri-Implant Diseases

Marginal soft tissue around the implants is similar to those that envelope natural teeth.[74] Both teeth and dental implants are characterized by an apical intraosseous part anchored in the alveolar bone and a transmucosal component that separates the apical tissues from the external oral environment. More specifically, the supra-alveolar peri-implant soft tissues comprehend a connective attachment, a junctional and sulcular epithelium (Fig. 2). Therefore, although peri-dental and peri-implant tissues show similarities on the histological level, there are also fundamental differences that are implicated in the prevention, diagnosis, and management of peri-implantitis.

After surgical implant placement (usually due to mucosal incision and osteotomy), the transmucosal attachment results from the mucosal adaptation to the supracrestal implant component. Otherwise, marginal tooth attachment is not the result of the surgery, but from the natural process of dental development and eruption. Following implant placement, the epithelial cells proliferate and adhere to the transmucosal implant surface producing hemidesmosome structures and basal lamina, thus simulating the biologic width around tooth surfaces.[75] Around the tooth, the connective attachment is characterized by connective tissue fibers extending laterally, coronally, and apically from the root cementum to the soft and hard components of the marginal periodontium (Fig. 2). On the contrary, dental implants are not provided with cementum and periodontal ligament.

Therefore, below the bony crest, the alveolar bone is directly in contact with the intraosseous implant component.[76] The epithelial attachment terminates 1–1.5 mm coronally to the bony crest and it is separated from the alveolar bone by a connective layer rich in collagen fibers and poor in cells.[77] The peri-implant connective tissue differs from that of natural teeth in terms of cellular composition and fiber

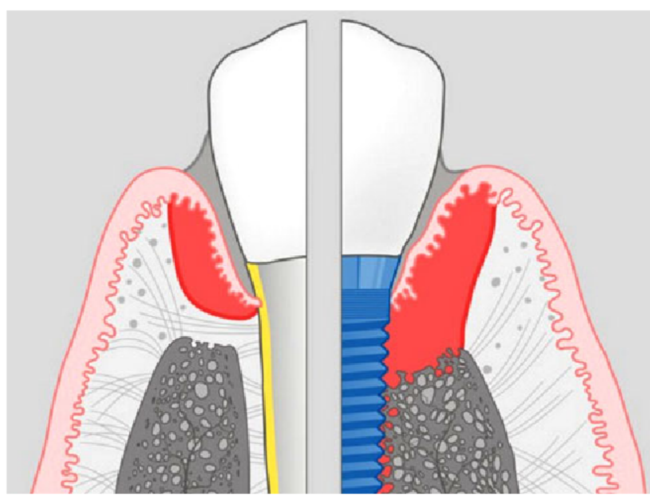

FIG. 2. Comparison of periodontal and peri-implant marginal soft tissues. Both teeth and dental implants share similar supra-alveolar soft tissues composed of connective attachment, junctional epithelium, and sulcus. However, important differences are related to the absence of periodontal ligament and cementum and the different architecture of the connective tissue fibers around dental implants.

orientation. In fact, the connective tissue fibers extend from bone crest periosteum to the mucosal margin, thus orienting themselves parallel to the implant (Fig. 2).[76,77] On the contrary, the connective tissue fibers around the tooth are oriented perpendicularly and inserted directly into the root cementum.[77]

In this regard, the control of bacterial plaque in the implant site is of fundamental importance. Peri-implant mucositis is characterized by an inflammatory peri-implant mucosal reaction without marginal bone loss.[78,79] Peri-implantitis is an inflammatory reaction of the peri-implant soft and hard tissues with infective etiology, at least 2 mm marginal bone loss, suppuration, and bleeding on probing (BOP).[80,81] Studies pointed out that periodontal and peri-implant diseases share similar characteristics in terms of etiopathogenesis, risk factors, and clinical presentation. However, bacterial biofilm's persistent colonization of implant sites could cause a more marked inflammatory reaction in the peri-implant tissues compared to what happens in periodontal disease.[82]

The more aggressive progression of peri-implant disease is related to the structural characteristics of dental implants, in particular, the implant-abutment connection and the implant surface. Bacterial biofilm is able to colonize the implant-abutment connection micro gap, a hidden environment from the host immune cells.[83,84] The larger the micro gap, the greater the biofilm infiltration and the inflammatory reaction of the peri-implant tissues.[85,86] Further, the extent and type of biofilm that interact with the implant surface are related to the chemical composition and roughness of the latter.[87]

Regardless of peri-implant disease etiology, multiple investigations have been conducted to find predictable surgical and nonsurgical protocols for managing diseased peri-implant tissues. In general, peri-implant mucositis may be managed through nonsurgical approaches,[78] whereas peri-implantitis usually requires surgical therapy[80,88] since the inflammation is not normally resolved through nonsurgical treatment.[89]

Nonsurgical protocols for peri-implant diseases consist of the debridement of oral biofilm and calculus accumulated on the implant surface through the use of mechanical instruments (such as stainless steel curettes),[90] with the possible adjunct of antiseptics or antibiotics to improve clinical outcomes.[78] Ultrasonic devices showed similar efficacy in the implant surface debridement compared to mechanical instruments.[91,92] Air-abrasive devices, particularly the low-abrasive glycine powder, have also been used to decontaminate the implant surface.[89] Especially, for peri-implantitis, nonsurgical protocols represent a basic approach for the management of implant stability.

The surgical therapy is more predictable for managing severe forms of peri-implantitis with marginal bone loss and PD at least 5 mm,[93–95] and must be performed after the resolution of acute infection.[96] Different approaches have been proposed: (1) access flap approach for surgical debridement,[97] (2) resective surgical treatment,[98] and (3) regenerative approaches with the use of grafting materials.[94]

The adjunct use of lasers in the management of peri-implant diseases has been proposed, in particular, high-power (surgical) lasers, low-power (nonsurgical) lasers, and PDT for implant decontamination.[99,100]

CO_2 lasers, with a wavelength of 10,600 nm, do not induce negative changes on the titanium implant surfaces and do not have negative effects on osteoblast proliferation and attachment.[101,102] Temperature elevation on implant surface may be avoided when CO_2 laser is used with 2–4 W power density, a continuous mode for up to 4 s.[103] For these reasons, CO_2 laser is usually employed for implant surface decontamination.[104–106] More specifically, it has been successfully employed in combination with resective surgery[104] and regenerative techniques without and with the use of a membrane.[105,106]

Even the diode laser does not damage the implant surface and has decontaminating effects.[107,108] However, it is essential to use suitable irradiation and technique to avoid overheating of the peri-implant alveolar bone tissue.[109] A 5-year follow-up study showed that conventional nonsurgical debridement of the implant surfaces associated with the use of 810 nm diode laser treatment was more effective than the nonsurgical debridement alone in patients with peri-implantitis.[110]

Nd:YAG laser is not indicated for the management of peri-implant diseases because its irradiation produces damage to the implant surface such as crater formation, cracks, and melting because of overheating[107,108]

Erbium lasers (Er:YAG and Er,Cr:YSGG) do not produce negative alteration and overheating to the implant surface using proper irradiation protocols.[111–114] Further, Er:YAG laser irradiation does not affect osteoblast attachment on the implant surface.[113] Erbium lasers showed favorable effects for peri-implant surgical approaches, thanks to their potential to improve bone healing, and allow more efficient debridement into narrow and deep bone defects.[115,116] Er:YAG laser showed similar efficacy in the management of peri-implantitis compared to mechanical debridement with the use of curettes.[117] However, histologically chronic inflammatory infiltrate persisted after the treatment.[118] A systematic review concluded that Er:YAG lasers could be able to improve clinical inflammatory parameters in peri-implantitis-affected tissues.[119] However, nonsurgical therapy usually is not sufficient for the complete resolution of diseased peri-implant tissues.[118]

However, despite good results in some studies, laser employment for peri-implant diseases is still debated.[120,121] A recent American Academy of Periodontology best evidence review[122] concluded that laser employment (only CO_2, diode, and Er:YAG lasers), in combination with nonsurgical and surgical protocols for peri-implant diseases, produced minimal improvements in clinical periodontal parameters. In particular, it was revealed that the adjunct use of lasers to conventional nonsurgical treatment might provide more BOP reduction in the short term. Investigation on other types of lasers failed to support their clinical employment for peri-implant diseases. Therefore, more investigations are needed to demonstrate the possible advantages of employing lasers for managing peri-implant diseases with valid treatment protocols.[123]

Discussion

The efficiency and usefulness of lasers in periodontology are currently a subject of heated debate. This is due to the conflicting results in the literature, the protocol heterogeneity, the presence and severity of biofilm adhesion, the type of laser used, the anatomy of the periodontal pockets, and the different surface implants and fixture-abutment characteristics. To date, protocols involving the adjunct use of laser therapy are increasingly widespread for the management of periodontal and peri-implant diseases. Regarding periodontal disease treatment, the gold standard is represented by conventional nonsurgical therapy; where this is not sufficient, further clinical benefits can be obtained through open flap, respective, or regenerative periodontal surgery.

In particular, the latter is developing increasingly refined operative protocols that involve the use of enamel matrix protein derivative, cell sheet engineering, growth factors, and membranes.[117,118] Laser therapy in the treatment of periodontal disease, both surgical and nonsurgical, is claimed to resolve inflammation and induce rapid healing and tissue regeneration by decontaminating periodontal pockets and modulating cellular metabolism.[118] However, from what emerges from the above review, evidence on the adjuvant effects of laser therapy in the treatment of periodontitis is low, especially in the long term. In this regard, further investigations are needed to better understand the biological response at a molecular level in the periodontal tissues after laser phototherapy and how these modifications could be useful in terms of healing of periodontal and peri-implant disease-affected sites.

For the maintenance of peri-implant tissue health, the integrity maintenance of peri-implant soft tissues is fundamental. In particular, the key differences compared to periodontal tissues around the tooth are related to the absence of periodontal ligament and cementum and the different architecture of the connective tissue fibers around dental implants. Reduced cellularity and vascularity of peri-implant soft tissues make them more susceptible to disease progression. Further, the characteristics of implant surface and the implant-abutment connection may affect the maintenance of the soft-tissue integrity around implants.[76]

Conclusions

This review was aimed to analyze the role of laser therapy as adjuvants for treating both periodontitis and peri-implantitis. In case the nonsurgical approach does not allow the periodontal and peri-implant treatment success, a surgical approach is often required for the treatment. In this regard, laser therapy without an open flap is not enough to achieve tissue healing. In this context, the use of lasers as an adjunct to conventional surgical and nonsurgical treatment in the management of peri-implantitis is still debated.

In conclusion, the use of lasers in the management of periodontal and peri-implant disease could provide benefits, in addition to conventional therapies, but further investigations are needed to better understand the biological reaction of soft tissues to different light energies and to develop and study new homogeneous protocols for the management of periodontal and peri-implant disease.

Authors' Contributions

G.I., S.S., and A.P. have drafted the work and written the article; and R.C., A.C., and G.S. have validated the results of the literature review. All authors have read and agreed to the published version of the article.

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