Chapter

Laser Applications in Periodontology

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Abstract

Laser have various periodontal applications including calculus removal (erbium yttrium scandium gallium garnet and erbium yttrium aluminum garnet lasers), decontamination of root and implant surfaces and bio stimulation, incision and ablation, osseous surgery, excision of the soft tissue, and bacterial reduction. This chapter analyzes the most important occasions in which lasers are used in implant and periodontal field practices. There is a strong evidence that laser is used for surgical and nonsurgical periodontal therapies including root bio modification, bacterial decline and decontamination of infected implant surface (in peri-implantitis), and removal of the pocket epithelium. This chapter also highlights the most common disadvantages as well as the advantages of using lasers in periodontal therapy. Waterlase® and Periowave™ systems are recent devices that have further revolutionized the laser technology for its favorable clinical applications; however, the procedural cost with the laser device constitutes an obstacle for its routine application.

Keywords: erbium yttrium scandium gallium garnet laser, erbium yttrium aluminum garnet laser, periodontal therapy, peri-implantitis, bacterial reduction

1. Introduction

LASER, an abbreviation of light amplification by stimulated emission of radiation, was first established by Maiman in 1960 [1], a scientist of the Hughes Aircraft Company. Based on the theory originally proposed by Albert Einstein, Maiman used the ruby crystal that produces a coherent radiant light when activated by energy. Goldman et al. [2], a dermatologist experimenting laser for tattoo removal, showed painless surface crazing of enamel after focusing two pulses of red light beam from ruby crystal. Following experiments by Stern and Sognnaes [3], pendulum shifted from ruby laser to CO_2 and Nd:YAG lasers for better interactions with dental hard tissues. The 1970s and 1980s sought use of lasers for soft tissue surgical procedures, and Lenz et al. [4] were among the pioneers to report oral surgical application of CO_2 laser, together with Frame [5], Pecaro [6], and Pick [7] who used the same for oral soft tissue lesions and periodontal procedures. Myers and Myers [8] described the use of modified ophthalmic Nd:YAG laser for removal of dental caries and received the US FDA's permission for selling Nd:YAG laser device in 1989 [9]. After Myers's suggested use in soft tissue surgery [10], Nd:YAG laser was eventually used in periodontal procedures [11, 12], and since then lasers have been used largely by researchers and clinical periodontal practitioners.

Lasers can be used in a focused beam (for excisions and incisions) and in an unfocused beam (for ablation and coagulation). Some evidence suggests that lasers used as an adjunct to scaling and root planning (SRP) may provide additional benefits [13]. It had been shown that using lasers in periodontal treatment had a beneficial role in controlling of bacteremia, bacterial reduction, effective subgingival calculus elimination (using Er:YAG lasers), improved eradication of the pocket epithelium in pockets involving teeth, and enhancement of periodontal regeneration in humans and animals without a destructive effect on the neighboring pulp tissues and bone [14–21]. In India the capability of using laser device at laboratories and institutes offers a huge chance to the researchers and scientists concerned in the field of free electron lasers, semiconductor lasers, solid-state lasers, and gas lasers [22]. So because of the importance of the subject and the wide use of laser in India, this chapter focuses on the most important types of laser used in the India as well as in Iraq.

2. Types of laser

In dental field, lasers can be categorized by different ways: according to the type of the affected tissue, soft tissue and hard tissue lasers; according to the medium of laser used, like solid laser and gas laser; and finally according to wavelength of laser that is being used.

2.1 Neodymium yttrium aluminum garnet laser

The neodymium yttrium aluminum garnet laser (Nd:YAG) wavelength is strongly absorbed by the pigmented tissue. There has been research on using the Nd:YAG laser for nonsurgical sulcular debridement in periodontal disease control [23]. Neodymium yttrium aluminum garnet laser is a very effective surgical laser for coagulating and cutting periodontal soft tissues, with good hemostasis [24]. In addition Nd:YAG laser is used in laser-assisted new attachment procedure (LANAP) [25].

2.2 Carbon dioxide laser

The CO_2 laser has the advantage of rapid soft tissue elimination and hemostasis with a very shallow depth of penetration, and this advantage is due to its wavelength which has a great affinity for water. Carbon dioxide laser has the highest absorbance of any laser [26], but it is associated with several disadvantages including its high cost, relative large size, and its interactive destruction to the hard tissue.

2.3 Diode laser

Diode wavelengths are absorbed mainly by hemoglobin and pigmented tissue (melanin). On the other hand, they are poorly absorbed by the enamel and hydroxyapatite. Laser wavelengths, ranging from 810 to 980 nm, are produced from the active medium of the diode laser which is a solid-state semiconductor made of gallium, aluminum, arsenide, and infrequently indium. Diode laser is used in particular procedures including soft tissue crown lengthening, aesthetic gingival (gingivoplasty), removal of inflamed soft tissue, exposure of soft tissue impacted teeth, frenectomies, and photostimulation of the herpetic and aphthous lesions [27].

2.4 Erbium laser

The erbium wavelengths have the highest absorption of water in any dental laser wavelengths and have a great affinity for hydroxyapatite. Two distinct wavelengths of erbium lasers had been developed, including Er:YAG (yttrium aluminum garnet) lasers and Er,Cr:YSGG (yttrium scandium gallium garnet) lasers. Because of its great affinity for hydroxyapatite, it is the laser of choice for dealing with dental hard tissues [28], and because of its high absorption of water, erbium lasers can be used for periodontal soft tissue ablation, as dental soft tissue is composed of a high proportion of water [29].

3. Laser applications in periodontology

1. Soft tissue surgical applications
2. Removal of the pocket epithelium
3. Laser root conditioning
4. Bacterial reduction
5. Implant therapy

3.1 Soft tissue surgical applications

Lasers such as diode, CO_2,Nd:YAG, Er:YAG, and Er,Cr:YSGG are being extensively used in periodontal treatments including gingival soft tissue procedures such as gingivoplasty, gingivectomy, frenectomy, benign tumors or epulis elimination [30], irradiation of aphthous ulcers, gingival depigmentation, coagulation of free graft donor sites, second-stage exposure of dental implants [13], and crown lengthening procedures [30]. This diversity of laser use is due to its superior properties over conventional scalpel procedures which include bacteremia reduction, ease of soft tissue ablation, hemostasis [30], slight wound contraction and slight scarring, immediate sterilization, edema reduction, mechanical trauma reduction, no or little operative and postoperative pain [13, 31, 32], improved patient acceptance [13], more rapid healing, little need for suturing, much easier technique, and necessitating no topical anesthesia [33].

The penetration depth of lasers differs, and therefore their performance differs, and lasers possibly cause a hazardous effect on the underlying tissues by thermal injury. Laser light is absorbed in the superficial layers in Er:YAG,CO_2 and Er,Cr:YSGG lasers, and hence it has the advantage of being simple and rapidly vaporized from soft tissues, while other type of laser such as diode lasers and deeply penetrating Nd:YAG associate with more thermal influences, which consequently lead to formation of thick coagulation zone on the treated surface [21, 29, 30] and hence used similar to electrosurgical procedures [30]. Finkbeiner [34] has suggested the usefulness of argon laser in soft tissue welding and soldering compared to conventional tissue closure method. Epithelial exclusion using CO_2 laser had been suggested to retard its downward growth, and studies have shown effective removal of epithelium from gingival tissues without damaging the underlying connective tissues [35, 36].

3.2 Removal of the pocket epithelium

Lasers are also used for soft tissue periodontal applications. The Nd:YAG was the first laser wavelength to be compared to the scalpel for treating periodontal pockets [16] and controlling bacteremia and gingival bleeding [16, 18]. The probing pocket depth and bleeding index scores were reduced using the pulsed Nd:YAG laser. Furthermore, clinical evaluation of soft tissue biopsies taken from human subjects using the Nd:YAG laser versus a curette presented a complete removal of the epithelium of the pocket after use of the pulsed Nd:YAG laser compared to the curette [15]. Similar effects presented in pig jaws (in vitro) after the use of a 980 nm diode laser with 2–4 W power settings and continuous wave compared to the conventional curette [37]. There are advantages in the postsurgical outcomes with the removal of pocket epithelium. A recent clinical study in India showed that the modified Widman flap with removal of the pocket epithelium was more effective in reducing mean probing depth than access flap with intrasulcular incision. It showed greater gain of clinical attachment and demonstrated less gingival recession [38]. When deep periodontal pockets are present, removal of the pocket epithelium using a fiber-optic glass laser offers benefits. With or without flap elevation and a conventional periodontal access flap procedure, the pocket epithelium will be removed from the inner and the outer part of the pocket. Depending on how the patient heals, the epithelium can later be ablated every 7–10 days from the outer part of the pocket, usually under the use of topical anesthesia, in order to control apical migration. This can result in long-term, stable connective tissue attachment, without gingival recession. The principle underlying this approach is guided tissue regeneration; it has been called "laser-assisted guided tissue regeneration" [39]. This approach should be evaluated in different prospective clinical studies involving many patients and following exactly the same protocol in order to establish that it is a technological improvement that should be incorporated routinely in daily practice. Both clinical case series and clinical research have shown the potential of this application using the CO_2 laser, since the noncontact handpiece is able to ablate tissues very quickly, controlling the epithelial cell proliferation and further apical migration of a long junctional epithelium. Israel et al. [20] were able to demonstrate histologically the effects of this de-epithelialization technique in humans. The technique involves using the CO_2 laser to remove (ablate) the inner part of flap after conventional periodontal flap elevation and then using the same method in the outer part of the flap to achieve epithelial retardation. Case series in patients with generalized advanced periodontal disease have shown that the laser de-epithelialization technique leads to good results without the need for multiple membrane therapy [40, 41].

3.3 Laser root conditioning

The use of CO_2 lasers to decontaminate root surfaces has been investigated, providing more information about the exact power settings and parameters required to avoid root damage. Barone et al. [42] showed that a defocused, pulsed CO_2 laser is able to create smooth and clean root surfaces compared to a focused, continuous wave; the latter leads to melting and root surface damage. Later studies using the same parameters for CO_2 lasers reported root conditioning with a better fibroblastic activity, cellular proliferation, and greater fibroblast attachment [43]. Different clinical case reports have demonstrated these advantages of CO_2 laser de-epithelialization [44]. This technique has also been used in clinical studies and has shown that coronal flap advancement in conjunction with CO_2 laser root conditioning leads to improvements in clinical parameters and long-term tissue stability after 15 years, compared to the modified Widman periodontal flap procedure [45]. The authors concluded that this laser technique seemed to have greater effects and should be used in treating deep periodontal pockets (more than 7 mm deep).

3.4 Bacterial reduction

A laser application that has been especially promoted in the past is for the reduction of bacteria in pockets, due to the high absorption of specific laser wavelengths by the chromophores. Initially, the use of an Nd:YAG laser was shown to reduce the load of *Porphyromonas gingivalis* and *Prevotella intermedia* [46]. A study by Assaf et al. [47] is of special interest. Using a diode laser in conjunction with ultrasonic scaling for treatment of gingivitis, they were able to show a significantly lower incidence of bacteremia in the diode + ultrasonic group (36%) than the ultrasonic only group (68%). They suggested that diode lasers should be used to prevent bacteremia, especially in immunocompromised patients. Using a 980 nm diode laser to reduce periodonto-pathogenic bacteria in patients with aggressive periodontitis has also been investigated. Kamma et al. [48] confirmed that it was possible to reduce the total bacterial load in pockets without the use of any systemic antibiotic therapy. Clinical case series with 10 patients using in the same patient (in a randomized protocol) SRP in conjunction with 980 nm diode laser, SRP and an Nd:YAG laser, and SRP with photodynamic therapy (PDT) showed that the PDT was able to reduce significantly the bacteria in the pockets and provide a predictable clinical outcome for 3 months. In contrast to that, the use of Nd:YAG laser was not very beneficial and was similar to the control (SRP) group [49]. Due to the bacteria reduction and the reduced bleeding on probing provided by the PDT, the PDT was recommended for periodontal patients especially for the maintenance appointments.

3.5 Laser applications in implant dentistry

In the previous years the important role of laser in dental implant treatment has been discussed widely [50]. Because of the lack of comparable test and control sites, it is difficult nowadays to know if lasers, with their different types, can be used to treat peri-implantitis using randomized clinical trials [51]. Removal of peri-implant soft tissues and bacterial reduction, uses of laser in second-stage surgery [52], and decontamination of failing implants [53] are the most important applications for lasers in implant dentistry. However there are a lot of limitations of using laser in implant dentistry including the serious alarms about the overheating of the implant and the concern about the melting of the implant surface [54, 55], as well as the fears regarding missing of the re-osseointegration after peri-implantitis treatment with lasers. In recent years a lot of reviews have concentrated on these limitations and gave additional facts about re-stabilization and re-osseointegration of the implants subsequent to the laser decontamination of the implant surface [56]. Deppe et al. [57] showed that CO_2 laser decontamination of the surface of implants placed in dogs allowed new bone to grow and be in contact with the implant surface (re-osseointegration). In vitro studies of osteoblasts have confirmed these effects for CO_2 and Er,Cr:YSGG lasers [58]. Previous clinical case series were able to demonstrate new bone fill and long-term success of failing implants that were decontaminated with a CO_2 laser [59, 60]. The main advantage of using CO_2 laser irradiation on implant surfaces is that this wavelength does not pose the risk of overheating [61], unlike other wavelengths, such as that of diode, Nd:YAG, and Er:YAG lasers [62, 63]. A significant increase of the implant surface temperature has been demonstrated when irradiating implant surfaces with a diode laser in vitro for more than 10 s [62–64]. It is possible that authors have presented unsuccessful and nonpredictable clinical results from their studies because of overheating resulting from inconsistent power settings [65]. Limited facts available regarding laser-assisted decontamination of implant surfaces, with a limited number of included studies, as well as the great heterogeneity of the results had been pointed out by a recent systematic review. Nevertheless, even though data is incomplete regarding the clinical use of CO_2 (10.6 nm) lasers in the surgical treatment of peri-implantitis, its use appears promising [66].

The following summary of advantages and disadvantages of using lasers for periodontal therapy is based on the literature and the author's experience.

4. Advantages of using lasers in the periodontal therapy

Less pain. Less need for anesthetics (an advantage for medically compromised patients). No risk of bacteremia. Excellent wound healing. No scar tissue formation. Bleeding control (dependent on the wavelength and power settings). Usually no need for sutures. Use of fewer instruments and materials and no need for autoclaving (economic advantages). Ability to remove both hard and soft tissues. Lasers can be used in combination with scalpels (however, the laser is a tool and not a panacea) [67].

5. Disadvantages of using lasers in periodontal therapy

Relatively high cost of the devices. A need for additional education (especially in basic physics). Lasers do not eliminate the need for anesthesia. Every wavelength has different properties. The need for implementation of safety measures (i.e., goggle use, etc.) [68].

6. Healing following laser therapy

Despite apparent benefits of lasers regarding patient compliance and clinical observation, there are no enough data to support that laser is associated with reduced scarring, which itself appears to be different according to the wavelength and extremely related to the energy density, and there are no enough data to support quicker healing associated with laser therapy [13]. Limited experimental animal studies [68, 69] involving CO_2,Nd:YAG, diode lasers, or Er:YAG have evaluated the histological and immunohistochemical patterns of periodontal tissue healing following surgical and nonsurgical periodontal therapy. Sculean et al. [70] and Yukna et al. [71] reported healing response of intrabony defects after open flap surgery or treatment using a laser-assisted new attachment procedure in humans using Er:YAG and Nd:YAG lasers, respectively. Lippert et al. [72] claimed that CO_2 laser-induced wounds in oral and oropharyngeal mucosa healed significantly faster (in 32.8 ± 9.2 days) than those created by Nd:YAG laser (in 40.4 ± 9.2). However, in contrast to conventional scalpel surgery, the histological findings showed that the beginning of wound healing was delayed after laser surgery, and it depends on the size of the initial defect. Due to the more pronounced zone of necrosis at the base of the wound ground, this effect is more evident using the Nd:YAG laser [72]. Although, as compared to conventional treatment, overall [72] as well as initial periodontal wound healing laser application [73] has been shown to be delayed, few studies have reported that laser-induced wounds show a reduced propensity of contraction of the scar in comparison to the usual surgeries of scalpel [13]. Low-level laser treatment by GaAIAs radiation in milliwatt range has been shown to be effective in recent studies, as it absolutely affects proliferation of fibroblasts in gingiva or periodontal ligament, so it consequently maintains peri-implant and periodontal wound healing [73].

7. Latest advances

Waterlase® system is a revolutionary dental device that uses laser-energized water to cut or ablate soft and hard tissues and provide periodontists with the opportunity to perform more procedures in fewer appointments with less need for anesthesia, scalpels, and drill [74]. Periowave™, a photodynamic disinfection system, utilizes nontoxic dye (photosensitizer) in combination with a low-intensity laser, enabling singlet oxygen molecules to destroy bacteria [75]. After applying a light-sensitive drug (photosensitizer), low-intensity laser is directed on the area treated with the drug resulting in phototoxic reactions. Although the use of photosensitizers for complete suppression of the anaerobic perio-pathogens has been suggested, the same is not true for facultative anaerobes [76].

8. Cost and safety

Laser safety officer (LSO) is an elected, well-trained individual who guides safety of laser performs and confirms a harmless surroundings for exhausting it, as an important part of giving dental treatment with laser device is protection and safety. All clinicians must be aware and take care of the prevention of accidental and hazardous irradiation. The patient, clinician, and assistant must wear a protective eyewear particular for the wavelength and the type of laser in use. Additionally, the clinician should follow laser safety rules and join certificate courses by dental laser organizations; however the size and the cost of laser device still create a difficulty and a struggle for its practical application [77].

9. Conclusion

Lasers have been suggested as an adjunctive or alternative to conventional techniques for various periodontal procedures and considered superior in respect to easy ablation, decontamination, and hemostasis besides less postoperative pain and less operative pain. Application of lasers with their different types in implant dentistry and the recent laser practical modalities had revolutionized the outcome of periodontal therapy with patient acceptance. But, procedural cost and patient risk should be kept in mind and completely assumed before laser use.

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