Lasers in Periodontal Surgery

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5.1 Introduction

The term laser, which stands for **l**ight **a**mplification by **s**timulation of **e**mitted **r**adiation, refers to the production of a coherent form of light, usually of a single wavelength. In dentistry, clinical lasers emit either visible or infrared light energy (nonionizing forms of radiation) for surgical, photobiomodulatory, and diagnostic purposes.

Investigations into the possible intraoral uses of lasers began in the 1960s, not long after the first laser was developed by American physicist Theodore H. Maiman in 1960 [1]. Reports of clinical applications in periodontology and oral surgery became evident in the 1980s and 1990s. Since then, the use of lasers in dental practice has become increasingly widespread.

5.2 Laser-Tissue Interactions

The primary laser-tissue interaction in soft tissue surgery is thermal, whereby the laser light energy is converted to heat. This occurs either when the target tissue itself directly absorbs the laser energy or when heat is conducted to the tissue from contact with a hot fiber tip that has been heated by laser energy. Laser photothermal reactions in soft tissue include incision, excision, vaporization, ablation, hemostasis, and coagulation. Table 5.1 summarizes the effects of temperature on soft tissue.

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Table 5.1 Effects of temperature on soft tissue [2, 3]

Temperature	Visual change	Biological change
37–60 °C	No visual change	Warming
60–65 °C	Blanching	Coagulation, hemostasis
65–90 °C	White/gray	Protein denaturation
90–100 °C	Puckering	Drying, tissue desiccation
100 °C	Smoke plume	Vaporization

Another type of laser-tissue interaction relevant to the use of lasers in periodontal surgery is nonthermal, whereby visible or infrared laser energy is used at lower power (subablative) levels to elicit photophysical and photochemical events that produce beneficial therapeutic outcomes. Such photobiomodulation outcomes may include alleviation of pain or inflammation and promotion of wound healing and tissue regeneration [4].

Laser energy may be absorbed, reflected, or scattered. However, it is only when the laser is absorbed by the substrate that useful interactions occur. Absorption of the laser energy by the target tissue is dependent on the laser wavelength, tissue composition, pigmentation, and water content.

5.3 Types of Lasers

The commonly used surgical lasers in the dental profession range from 445 to 10,600 nm in wavelength and can be classified based on the types of tissue with which they interact:

5.3.1 Hard Tissue Lasers

Erbium lasers (2780-nm Er,Cr:YSGG and 2940-nm Er:YAG) are well absorbed by water and hydroxyapatite and are mainly used for cutting tooth structure and bone. They can also be used for soft tissue procedures. However, due to their absorption characteristics, they have shallow penetration into soft tissue and provide limited hemostasis.

5.3.2 Soft Tissue Lasers

9250-nm and 10,600-nm carbon dioxide (CO_2) lasers are well absorbed by hydroxyapatite and water. They are used mostly for soft tissue surgery. Like the erbium lasers, they have relatively shallow penetration and provide reasonable hemostasis. The 10,600-nm laser is contraindicated for use on teeth and bone, whereas the 9250-nm laser can be used for cavity preparation and bone modification.

Diode lasers (445, 450, 457, 808, 810, 940, 970, 980, 1064 nm) are absorbed by melanin and hemoglobin and are most commonly used in the general dental office for soft tissue surgery via the aforementioned hot tip methodology. These wavelengths penetrate soft tissue more deeply than the erbium and CO_2 lasers and provide excellent hemostasis. Diode lasers are contraindicated for use on bone.

The Nd:YAG laser (1064 nm) is absorbed by melanin and hemoglobin and, like the diode lasers, has a deeper penetration into soft tissue and provides excellent hemostasis. The use on osseous tissue is contraindicated. The tissue absorption and pulsing characteristics of the Nd:YAG laser make it an effective instrument for treatment of moderate-to-severe periodontal disease.

5.4 Lasers in Periodontal Surgery

Collectively, the erbium, CO_2, diode, and Nd:YAG lasers enable a variety of soft tissue surgical procedures, including gingivectomy [5–7], reduction of gingival hyperplasia [8–11], frenectomy [12–16], operculectomy [17], vestibuloplasty [18, 19], free gingival graft [20–22], second-stage recovery of implants [23–25], incisional and excisional biopsy [26, 27], and fibroma removal [28, 29].

Photobiomodulation studies using various laser wavelengths have demonstrated their ability to promote conditions conducive to wound healing in gingivectomy and gingival graft sites and in the management of periodontal disease [30–37].

Compared to conventional treatment modalities, some of the advantages of the use of lasers in periodontal surgery include control of surgical and postsurgical bleeding, reduced bacteria in the surgical field, reduced need for anesthesia in some cases, reduced need for sutures, reduced or eliminated wound contraction and scarring, decreased postoperative edema and discomfort, and high patient acceptance and preference [26, 38, 39].

Limitations of laser use in dentistry include the relatively high cost of the instruments, the requirement of specialized training, and the strict adherence to safety precautions such as the need to protect nontarget tissues from laser exposure and the need for patients and operatory personnel to wear protective laser-specific eyewear. Optimum clinical results are achieved when proper technique and laser parameters are used, in accordance with manufacturer's directions and specified treatment protocols.

5.5 Lasers in Periodontal Treatment

The use of lasers for the treatment of periodontal disease has a lengthy history, with some reports dating from the early 1990s.

Reports of the use of erbium lasers to treat periodontal pockets began to appear in 2001, some 4 years after commercial availability in clinical dentistry. Manufacturers of erbium lasers have tried to develop protocols to treat periodontal disease but have only anecdotal reports and no human histological evidence to back up claims of regeneration. Some practitioners use erbium lasers to remove or contour osseous tissues after a flap is made. These devices can also remove calculus, but because they cannot differentiate calculus from dentin and cementum, or determine where the calculus ends and the tooth surface begins, their use in calculus removal can lead to undesirable ditching of the root surface [40, 41].

Carbon dioxide lasers are not amenable to treating periodontal disease as they have no selectivity in removing diseased tissue and can heat the bone and teeth which is not desired in the treatment of periodontal disease. Anecdotal reports of their use within the periodontal pocket exist, but their rigid delivery system tips do not readily lend themselves to accessing the full depth of the pocket without first laying a flap. In 1995, Israel et al. investigated whether de-epithelialization with a CO_2 laser at the time of flap surgery would enhance the formation of connective tissue attachment. Indeed, a 90-day postoperative assessment showed positive results in one of the two patients treated [42].

A popular use of diode lasers is sulcular debridement and bacterial reduction within the periodontal pocket, performed either by dentists or dental hygienists. The first reports of such procedures were published in 1997, 1 year after diode lasers were introduced in dentistry. Effectiveness of treatment varies, and some studies have shown that scaling and root planing (SRP) with diode laser use shows no greater benefit than SRP alone [43–47]. Human histological studies of new attachment or regeneration have not yet appeared in the literature.

The Nd:YAG laser has the longest history in periodontal pocket therapy and treating periodontitis, dating from 1991, 1 year after introduction of this laser device in clinical dentistry [5, 48, 49]. Its flexible fiber-optic delivery system facilitates minimally invasive access within periodontal pockets (Fig. 5.1). In 1994, Gold and Vilardi showed that the use of a pulsed Nd:YAG laser inside a periodontal pocket will specifically remove the diseased tissue and leave intact rete ridges to facilitate new attachment of the gingiva to the root surface [50].

Subsequent human histological investigations using one particular Nd:YAG laser (PerioLase MVP-7, Millennium Dental Technologies, Cerritos, Calif., USA) in a well-defined clinical protocol established the ability of this protocol to achieve

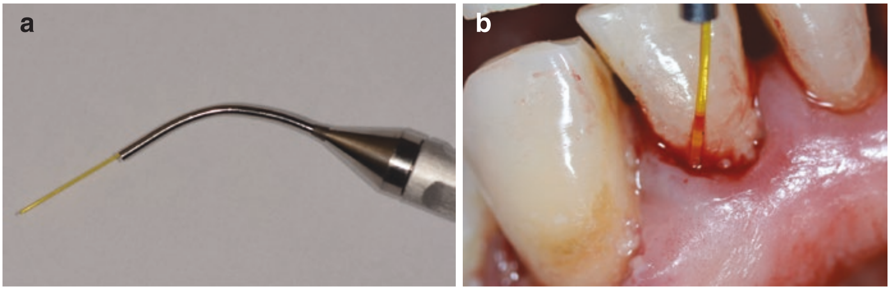

Fig. 5.1 Flexible optical fiber can be extended several millimeters past the end of the bendable cannula tip, which allows for delivery of pulsed Nd:YAG laser energy to difficult-to-access areas, such as the distal of second molars (**a**). Example of the optical fiber placed within a periodontal pocket during the LANAP protocol, removing the diseased, inflamed epithelium without removing outer gingival epithelium (**b**)

periodontal regeneration in patients presenting with moderate-to-severe periodontal disease. Based on independent studies conducted by Yukna et al. [51] and Nevins et al. [52], in March 2016, the US Food and Drug Administration granted marketing clearance to the PerioLase Nd:YAG laser for true regeneration of the attachment apparatus (new cementum, new periodontal ligament, and new alveolar bone) on a previously diseased root surface when used specifically in the LANAP® protocol.

The full-mouth LANAP procedure (Figs. 5.2 and 5.3) involves using a digitally pulsed Nd:YAG laser to remove diseased epithelium from the periodontal pocket, leaving the rete ridges intact, and reduce pathogens within the periodontal pocket. Scaling and root planing (SRP) is then performed with a piezo scaler. Osseous modification/decortication is performed to induce bleeding and release stem cells and

Fig. 5.2 Clinical application of a digitally pulsed Nd:YAG laser for periodontitis treatment. The patient was 79-year-old female who was seen for treatment of localized advanced periodontitis. Probings on the maxillary right central incisor showed severe pocketing with bleeding on probing (BOP) and suppuration (**a**). The X-ray showed vertical bone loss (**b**). Localized laser-assisted periodontal treatment (LAPT) was performed on both maxillary central incisors along with a maxillary anterior frenectomy. The frenectomy was performed due to the tension from the frenum on the interproximal tissue, which may have interfered with proper healing. After treatment she was put on 3-month periodontal maintenance. A 12.75-month post-LAPT treatment view showed decrease in pocket depths to maintainable levels, no BOP, and with minimal impact on esthetics (**c**). A follow-up X-ray showed regeneration in the vertical defect and a functional lamina dura (**d**)

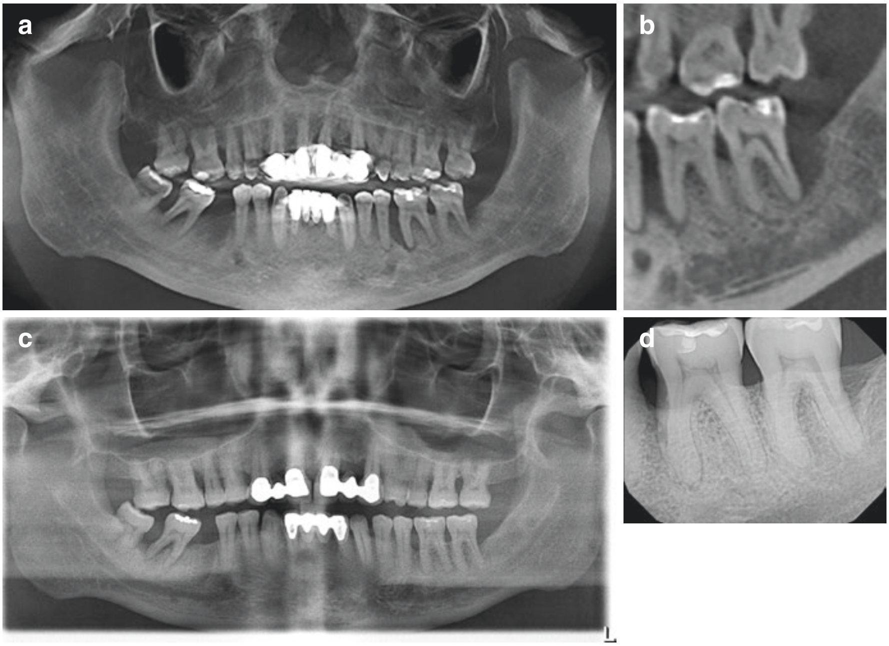

Fig. 5.3 Clinical application of digitally pulsed Nd:YAG laser for periodontitis treatment. The patient was 41-year-old male who was seen for treatment of advanced periodontitis (**a** and **b**). Probing showed generalized non-maintainable pockets. The pretreatment radiograph showed vertical bone loss and horizontal bone loss. The LANAP procedure was performed. After treatment he was put on a 3-month periodontal maintenance schedule. The 70-month post-LANAP treatment view showed no loss of any dentition. The 8.4-year follow-up showed long-term bone regeneration stability (**c** and **d**)

growth factors. The Nd:YAG is then used for hemostasis, to establish a stable fibrin clot, activate growth factors, and upregulate gene expression. The Nd:YAG laser-induced hemostasis allows patients on anticoagulants to be treated without taking them off their medications. Occlusal adjustment, essential in any regenerative procedures, is performed at the time of surgery (Fig. 5.4) and throughout periodontal maintenance during the first year post-LANAP treatment.

A study by McCawley et al., which compared periodontal bacteria reduction before and immediately after LANAP treatment and ultrasonic debridement, demonstrated that 85% of the LANAP-treated sites showed 100% reduction in the periodontal bacteria. Meanwhile, 83.3% of patients treated with ultrasonic root debridement alone remained culture-positive for most of the periodontal bacteria. Decreasing the putative periodontal bacteria is essential in the treatment of periodontitis [53].

The advantages of the LANAP protocol over conventional treatment include:

- Decrease in recession, so esthetic areas can be treated.
- Decrease in patient postoperative discomfort and sensitivity.

Fig. 5.4 Example of fibrin/thermogenic clot produced during the hemostasis part of the LANAP protocol. White powder (porcelain crown particles) shown is from the occlusal adjustment portion to decrease occlusal trauma to aid in healing and regeneration. Occlusal adjustment is performed with diamond football bur on a high-speed handpiece with no water

- Ability to treat the periodontal disease not only mechanically but at the bacterial level.
- Bone regeneration is possible without additional materials or cost to the patient or practitioner.
- Patients on blood thinners can still be treated.
- Higher patient acceptance.

5.6 Lasers in the Treatment of Periimplantitis

The prevalence of periimplantitis is recognized as a serious concern, with some estimates as high as 47% among patients with implants. Surgical treatment can entail the use of full/split thickness flaps, bone grafting with xenografts and/or allografts, resorbable/nonresorbable membranes, bone morphogenetic proteins, biomimetics, or combination of all or some of the above [54–61].

These surgical procedures require surgical skills that the practitioner may or may not have. Also, the cost to the patient may be prohibitive, and the practitioner may have to find a more cost-effective or compromised way to treat the periimplantitis. Decontamination of the implant surface seems to be essential to the treatment, but the method of decontamination is not settled [55, 62]. Even removal of the implant surface itself with drills has been advocated [63].

But there is no consensus as to which treatment gives the most consistent or predictable results. Recently, the use of lasers has also been put forward as a method of decontaminating the implant surfaces.

The two laser wavelengths that are mainly used for periimplantitis treatment are the erbium and Nd:YAG lasers.

The main use of the erbium laser is for the decontamination of the implant surface prior to bone grafting. This involves the reflection of a flap to gain access to the contaminated surfaces, degranulation either with or without the laser, and lasing the implant surface directly with simultaneous coaxial water spray to minimize heating of the implant. After decontamination, bone grafting materials with or without membranes are placed, based on the practitioner's preference, and then the suture is closed [64].

In the REPAIR implant protocol (Biolase, Irvine, Calif., USA), a closed flap procedure, the area around the implant is de-epithelialized, a collar of tissue around the implant is removed (which may cause esthetic concerns in the anterior region), and then a radial-firing tip is used to decontaminate the implant surface with Er,Cr:YSGG laser energy. Decortication of the bone follows to allow blood to fill the site; the laser is used to assist with hemostasis, followed by compression of the surgical site for 3–5 min. As mentioned previously, the Er,Cr:YSGG laser does not provide the same level of coagulation as the Nd:YAG laser to achieve a stable fibrin clot. In the REPAIR implant protocol, removal of the restoration would seem to be essential, given the non-flexibility of the laser's glass tips, as implant restorations with multiple attachments or with large convexities may not be amenable to flapless procedures. This would mean that a flapped approach with bone grafts and other regenerative materials would be indicated. The advantage of the erbium laser is that it utilizes a water spray to help cool the implant during irradiation.

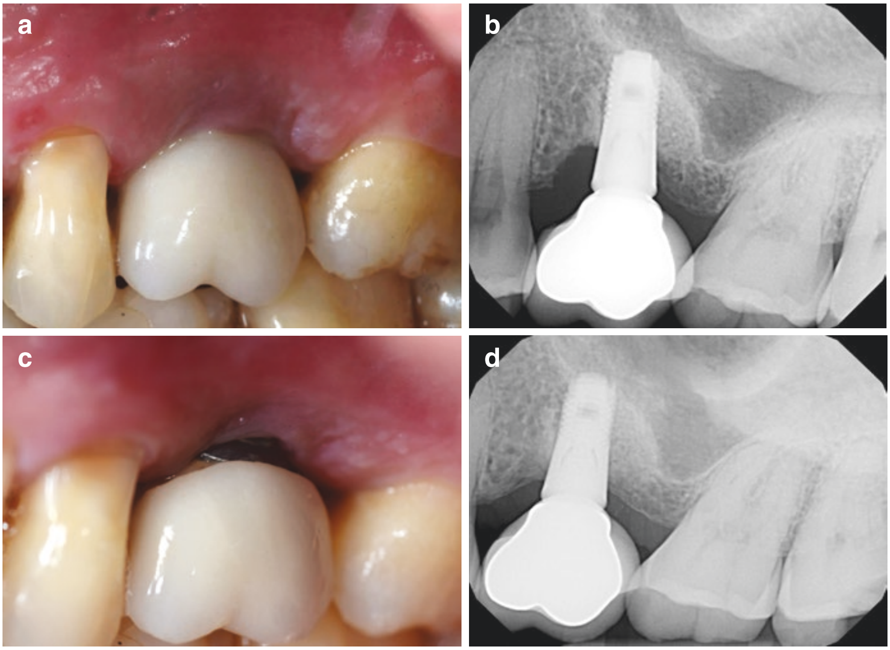

Fig. 5.5 Clinical application of digitally pulsed Nd:YAG laser in periimplantitis treatment in posterior. The patient was 47-year-old male who was seen for discomfort and suppuration on the upper left first molar (**a**). Probing showed non-maintainable pockets. The X-ray showed vertical bone loss on upper left first molar (**b**). LAPIP treatment was performed on the same day as Fig. 5.4a, b. No removal of restoration was necessary, and he was kept on a 3-month periodontal maintenance. Once inflammation and swelling of the gingiva resolved, a buccal overhang of the restoration was noted, which probably contributed to the periimplantitis (**c**). The 44-month follow-up showed decrease in pockets to maintainable levels with no suppuration or BOP. The X-ray showed stable regeneration of bone (**d**)

The Nd:YAG laser is utilized in the LAPIP protocol (Millennium Dental Technologies) for the treatment of periimplantitis. This minimally invasive surgical protocol is a modified LANAP procedure that does not require a fully reflected flap or regenerative materials. Due to the flexibility and various diameters of fibers available, removal of the implant restoration is not always necessary (Fig. 5.5). This can be particularly useful in anterior regions and in situations where there are multiple joined restorations (Fig. 5.6). Through careful fiber angulation and measuring exactly how much energy (Joules) is being produced by the Nd:YAG laser, overheating of the implant can be avoided. Aiming the laser fiber tip at the implant is not necessary to achieve disinfection of the tissues and implant surfaces. The fiber is used parallel to the implant surface, and the laser energy interacts with the implant surface via scattering from tissue. Further disruption of biofilm on the implant surface is achieved using a piezo scaler with chlorhexidine and water irrigation. As with all regenerative procedures, occlusal adjustment of the implant restoration (if not already removed) is essential to allow for nondisruption of the fibrin clot and healing of the area in the least traumatic way. In a study by Nicholson et al. on the use of the Periolase Nd:YAG laser for the LAPIP treatment of periimplantitis, the investigators reported control of the infection, reversal of bone loss, and rescue of the incumbent implant. One cited case showed a rate of bone healing of 2.097 mm^2/month [65].

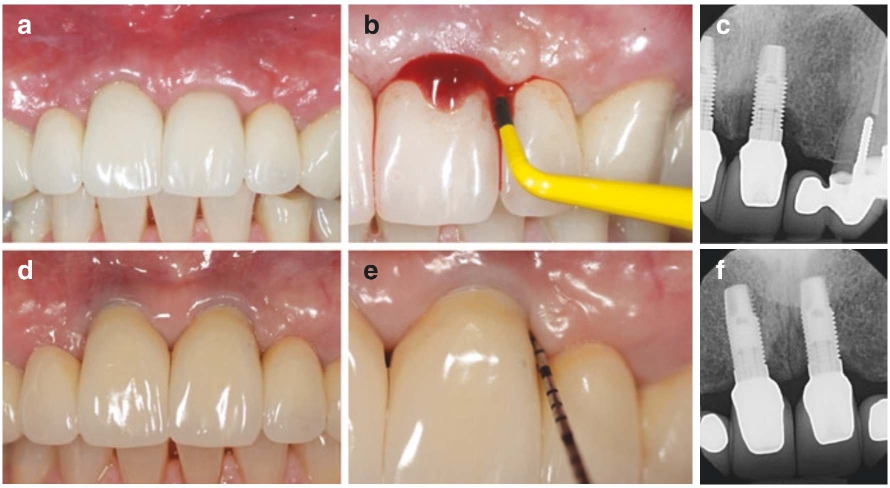

Fig. 5.6 Clinical application of digitally pulsed Nd:YAG laser in periimplantitis treatment in anterior maxilla. The patient was a 52-year-old woman who was seen for periodontal maintenance. Swelling with BOP was noted (**a**). Probings showed non-maintainable pockets on the maxillary central incisors with BOP and suppuration (**b**). The X-ray showed vertical bone loss on the distal aspect of both incisors (**c**). LAPIP treatment was performed. No removal of restoration was necessary, and she was put on a 3-month periodontal maintenance. The 49-month follow-up showed decrease in pockets to maintainable levels with no suppuration or BOP (**d** and **e**). The radiograph showed stable regeneration of the bone in defects on both teeth (**f**)

5.7 Conclusion

Overall, lasers have become essential tools in the dental practice, either as standalone or as an adjunctive instrument. It is important for the practitioner to be cognizant of the pros and cons of the different wavelengths and how those different wavelengths fit into the dental professional's practice philosophy. Completing device-specific laser training programs, studying the research available, and speaking with peers are essential to find the laser with the right fit for one's practice.

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