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Laser-Assisted Non-Surgical Treatments of Periodontitis

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Definition: This entry explores the innovative use of lasers in the non-surgical treatment of periodontitis, shedding light on the advantages, effectiveness, and limitations of this approach. There has been a massive eruption of innovations and technologies to assist in the treatment of periodontal diseases over the past 30 years. The use of lasers has opened new horizons and possibilities that can enhance periodontal treatments. However, their use is not always based on validated concepts and evidence-based protocols. Hence, this entry aims to describe, summarize, and assess the available evidence on the current laser-assisted protocols in the non-surgical treatment of periodontitis. Four distinct laser-assisted approaches are addressed: (1) the use of lasers for the removal of subgingival calculus, (2) the use of lasers in photodynamic therapy/photoactivated disinfection, (3) the use of lasers in photobiomodulation therapy, and (4) the use of high-power lasers. Based on the available studies and on the current guidelines and recommendations, the use of lasers exhibits several advantages, such as the increased disinfection of periodontal pockets and the junctional epithelium and connective tissue, the removal of calculus and biofilm, and the bactericidal effect on periodontal pathogens. Moreover, photobiomodulation therapy seems to play a positive role in the management of the inflammatory process of periodontitis. Although promising, the use of lasers in the non-surgical treatment of periodontitis needs to be further investigated.

Keywords: periodontitis; lasers; periodontal treatment; disinfection; periodontal pathogens

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1. Introduction

Periodontitis is a chronic inflammation induced by the biofilm affecting the integrity of the periodontium and ultimately resulting in its destruction [1–3]. Periodontitis depends mainly on the action of specific periodontal pathogens [3,4]. These specific pathogens or periodontal pathogens were described by Marsh et al. [5] as red complexes, including: *Porphyromonas gingivalis* (*P.g.*), *Aggregatibacter actinomycetemcomitans* (*A.a.*), *Tannerella forsythia* (*T.f*), and *Prevotella intermedia* (*P.i.*) [5]. Moreover, Hajishengallis et al. [3] discussed the concept of keystone pathogens and defined *P.g.* as one of these. The keystone-pathogen hypothesis suggests that the presence of *P.g.* can orchestrate the inflammatory process and periodontitis progression [3].

Treatment of periodontal pathologies, notably periodontitis, consists primarily of the elimination of the primary etiology that is the biofilm [6,7]. The aim of the non-surgical management of periodontitis is ultimately to eradicate the supragingival and subgingival biofilm, leading to an attenuation of the inflammation [6–8]. Hence, mechanical debridement consisting of manual instrumentation or ultrasonic instrumentation is currently the standard of care [6]. Clinically, this manifests in an absence of bleeding on periodontal probing, a reduction of pocket depth (PD), and an increase in clinical attachment level (CAL). However, mechanical removal of subgingival calculus and biofilm is limited, in some cases, because of some systematic and local limitations, such as the presence of a deep probing pocket or furcation involvement. This can lead to an unresolved inflammation, with the risk of further progression of periodontitis [9–11].

Laser-assisted protocols are increasingly indicated in dentistry, with various treatment modalities [12–14]. In fact, lasers have been shown to be efficient in eradicating periodontal pathogens. For instance, the energy of the laser absorbed by the bacteria will result in the overheating, disruption of the bacterial cell and membrane, hence destruction of the bacteria [12–14]. In addition to photothermal therapy, lasers can be used in combination with photosensitizing agents in a process called photodynamic therapy leading to the production and activation of reactive oxygen species that can have a bactericidal effect on the periodontal pathogens.

The enormous development of lasers has led to uncertainty among clinicians about the scientific indications and the evidence of their use [15]. The question of what is considered professionally right and what is deemed professionally wrong has become harder to determine. On the other hand, education on the use of the laser in different fields of dentistry, notably in periodontology, is not well established in the majority of undergraduate and postgraduate studies at worldwide faculties of dentistry. Hence, the aim of this entry is to explain the evidence-based data available in the literature on laser-assisted approaches in the non-surgical treatment of periodontitis. It is important to note that this entry aims to help readers understand the available literature, but do not serve as a guideline. In this context, readers are advised to consult the European Federation of Periodontology (EFP) [6] and the American Academy of Periodontology (AAP) [7] for evidence-based and guidelines for the treatment of periodontitis.

2. Current Laser-Assisted Approaches

Based on the literature and a multitude of reporting guidelines, it is established that the use of lasers can be considered as a promising adjunct to the gold standard non-surgical treatment of periodontitis [13,14]. In fact, lasers [16,17], probiotics [18], antimicrobial peptides [19], antibiotics [20], antiseptics [21], photodynamic therapy [22], and other approaches are used to enhance the results of the conventional treatment of periodontitis, but not to replace it. Based on available studies, the desired clinical effects of the lasers in the treatment of periodontitis seem to be its disinfection and bactericidal properties, root planing and removal of calculus, coagulation and hemostasis, and the stimulation of the living tissues [14–17]. In this entry, a summary of the laser-assisted protocols in the non-surgical management of periodontitis and their results will be illustrated. These protocols will be divided into: (1) removal of subgingival calculus, (2) photodynamic therapy or photoactivated disinfection, (3) photobiomodulation therapy, and (4) laser assisted periodontal regeneration protocols.

2.1. Removal of Subgingival Calculus

In the non-surgical treatment of periodontitis, the standard of care is still considered scaling and root planing debridement (SRP), which can be performed manually and/or by ultrasonic instruments, with no significant difference in terms of effectiveness between both manual and ultrasonic methods [6]. Erbium-doped yttrium-aluminum-garnet (Er: YAG) and erbium, chromium-doped yttrium, scandium, gallium, and garnet (Er, Cr: YSGG) are the lasers of choice when it comes to SRP, since the erbium laser is highly absorbed in the main components of subgingival calculus, calcium and phosphorus, with minor components of carbonate, sodium, and magnesium [23]. In fact, Er: YAG and Er, Cr: YSGG have a water absorption coefficient that is 10 times superior to that of the CO_2 laser and 10,000 to 20,000 times superior compared to that of the Nd: YAG laser [24,25]. The laser energy is therefore absorbed by the water molecules in the calculus, causing it to heat up and explode, which can help to break down the calculus and make it easier to remove.

This has led researchers to investigate the effectiveness of erbium lasers for scaling and root planing. In this context, in a histological study, Eick S. et al. [26,27] showed that the Er: YAG laser is effective in plaque and calculus ablation. In fact, the Er: YAG laser presents similar results to that of the manual instrumentation. Erbium lasers do not lead to morphological damage to the irradiated cementum with an increase in temperature, which is comparable to that obtained with ultrasonic instrumentation [28,29]. However, Agoob et al. [29] showed in their study that the Er: YAG laser, with a 2940 nm wavelength and under specific irradiation parameters, led to better removal of cementum compared to SRP alone. To conclude, introducing lasers as a tool for the elimination of subgingival biofilm is beneficial only if used as an adjunct to the conventional debridement. A meta-analysis systematically evaluated the available evidence concerning the clinical effectiveness of Er, Cr: YSGG lasers in the non-surgical treatment of chronic periodontitis from 2000 and until 2020. Pocket depth and clinical attachment level were assessed. Out of 1321 studies, 16 randomized clinical trials were included in the meta-analysis. The meta-analysis concluded that Er, Cr: YSGG, when used as an adjunct to SRP provided significantly better clinical effectiveness in PD reduction and CAL gain than the conventional SRP method at a 3-month follow-up, but with no significant difference at a 6-month follow-up [30]. Based on their study [30], at the 3-month follow-up, an additional reduction of 0.342 mm in PD was obtained with erbium + SRP, with a 95% confidence interval (CI) [−0.552, −0.132] and a 0.001 of p value. CAL gain at the 3-month follow-up was 0.17 mm for erbium + SRP, with a 95% CI [−0.31, 0.03] and a p value of 0.017 [30].

The EFP's clinical practice guideline suggests that lasers not be used as adjuncts to subgingival instrumentation in the surgical and non-surgical treatment of periodontitis [6]. The EFP's decision was based on five randomized clinical trials with single laser application, reporting 6-month outcomes in which only two of the randomized clinical trials reported a significant periodontal pocket reduction. On the other hand, the AAP suggests the presence of some evidence showing that the adjunctive use of the Er: YAG laser is superior to conventional periodontal therapy alone in deep periodontal pockets with a probing depth $\geq$7 mm. However, the current evidence is inadequate to conclude that laser therapy alone is either superior or comparable to conventional periodontal therapy in terms of clinical improvement in PD and CAL in the treatment of moderate to severe chronic and aggressive forms of periodontitis [7]. Hence, lasers should not be used for the removal of subgingival calculus prior to further investigations.

2.2. Activated Photodynamic Therapy/Photoactivated Disinfection with Lasers

Activated photodynamic therapy (aPDT) is a medical treatment that uses a photosensitizing agent and light to destroy targeted tissue [30,31]. The photosensitizing agent is typically a drug that is injected or administrated to the patient and afterwards activated by a light source [31]. The light activates the drug, which then generates reactive oxygen species that exclusively kill cells that absorb the photosensitizer [32]. On the other hand, activated photodynamic therapy is a process that uses light energy to activate a photosensitizing agent, which in turn generates reactive oxygen species that can kill or inactivate microorganisms [33]. The process involves applying a solution containing a photosensitizing agent, such as a porphyrin, in the gingival pocket to be disinfected [33]. The photosensitizer is absorbed by the targeted organisms [33]. The exposition to a specific wavelength of light, usually in the blue or near-ultraviolet range, activates the photosensitizing agent and induces the release of reactive oxygen species, such as singlet oxygen, which can kill or inactivate the microorganisms in the pocket [33,34].

Today, a growing body of evidence shows that activated photodynamic therapy (aPDT) and/or photoactivated disinfection (PAD), once used as additional approach to periodontitis treatment, can be effective [34–36]. In fact, since periodontitis is primordially induced by biofilm, the use of antimicrobial methods such as aPDT/PAD may shows promising outcomes. In this context, studies have shown that *P.g.* and *A.a.* can infiltrate through the epithelial barrier and into the depth of the periodontal tissues [37,38]. Here, it can be supposed that conventional mechanical debridement will not be able to penetrate effectively into the depth of the tissues, nor will it disinfect or decontaminate the damaged infiltrated connective tissues. Consequently, if photodynamic therapy can have a bactericidal effect on the periodontal pathogens, its use will be rational. In the literature, there is growing evidence suggesting that periodontal pathogens, including *P*.g, *F.n.*, *P.i.*, and *P.m.*, are sensitive to some type of aPDT/PAD treatment [39,40]. Moreover, evidence indicates that the use of aPDT as an adjunctive to SRP promotes significant improvement in BOP, CAL, and PPD, with little or no reported side effects, and that this improvement seems to be more prominent when the periodontal pockets are initially deeper (>5 mm) [37–41]. For instance, in a systematic review using meta-analysis (SR-MA), Ramanauskaite et al. [42] concluded and that there is a significant improvement in mean values of CAL and PPD when using PDT rather than SRP alone. However, no significant difference in BOP was observed [42]. In their SR-MT [42], the overall effect of the adjunctive use of PDT was statistically significant for the reduction in probing depth (PD), with a mean of 0.376 mm improved reduction compared to SRP alone, and a significant reduction in CAL, with a mean value of 0.207 mm of gain compared to SRP alone; however, no significant difference was observed for bleeding upon probing.

Despite the moderate body of evidence on the effectiveness of aPDT/PAD, the EFP's clinical practice guideline is against the use of activated photodynamic therapy in patients with periodontitis [6]. The conclusion by the EFP was based on five randomized clinical trials with a total of 121 patients, with a follow-up of an average of six months and a single session of application. However, the AAP concluded that the evidence demonstrates that appropriate aPDT/PDT as an adjunct to conventional therapy may provide modest (<1 mm) improvements in probing depths and clinical attachment levels when compared to conventional periodontal therapy for periodontitis [7]. Based on the available literature, a protocol will be suggested to be used as PDT/PAD. This protocol is only a suggestion made for further studies, and not a treatment recommendation. The protocol is as follow:

First session, or the session of the conventional mechanical debridement:

- Invite patient to disinfect the oral cavity with a prepared 0.12% chlorhexidine mouthwash.
- Optional: apply local anesthesia for zones with a pocket depth greater than 5 mm.
- Perform scaling root planning for the full-mouth in one session, the full-arch per session, or one quadrant per session. There is no significant difference between different approaches, and the determination is patient and operator dependent.
- Perform manual instrumentation and root debridement with Gracey curettes for the sites with a pocket depth greater than 5 mm.
- Perform a pocket irrigation with 0.12% chlorhexidine for 5 s per pocket using an endodontic needle.
- Apply tolonium chloride as a photosensitizer (Smart M, Lasotronix, Warsaw, Poland) inside the pocket depth.
- Remove the excess tolonium chloride, which will float outside the sulcus.
- Wait for 1.5 min.
- Activate the laser while moving it from the apical to the coronal direction with a speed of 1 mm per second, using the parameters described in Table 1.
- Repeat the exact same procedure 2 to 3 times in the same session.

Table 1. Suggested parameters for the photoactivated disinfection/photodynamic therapy protocol.

Parameters	
Wavelength	635 nm
Irradiation mode	Continuous
Power	400 mW
Irradiation speed	1 mm/s
Fluency	6 J/cm^2 per point
Points of irradiations	2 points per pocket
Number of sessions	2–4 session
Total energy of irradiation	24–48 J per pocket

2.3. Photobiomodulation Therapy

Photobiomodulation therapy (PBMT) is a form of therapy that uses light to stimulate healing and tissue repair [43,44]. This can be done using lasers, LEDs, or other lighting sources. PBMT is used to manage various conditions, such as pain, inflammation, and wounds [45]. The mechanism of action of PBMT is not fully understood, but it is thought to involve the activation of cellular processes that promote healing and reduce inflammation [45,46]. A large amount of data shows that the use of PBMT is effective in the treatment of multiple clinical complications, such as the management of chronic inflammation, inflammation of the oral mucosa (oral mucositis), recovery of the muscles, management of pain, etc. PBMT has been shown to primarily activate cytochrome C oxidase (CCO), an enzyme that converts energy in the form of electrons. This activation of CCO increases the activity of the mitochondria and the production of ATP and the energy stimulating cellular activities. In addition, the high level of reactive oxygen species blocking the respiratory chain of stressed cells can be reduced and modulated by PBMT [45–47].

There are still relatively few studies that assess the effectiveness of PBMT in the management of periodontitis. Among the available studies, a randomized controlled, split-mouth clinical trial by Özberk et al. [48] studied the effectiveness of PBM therapy in non-surgical periodontal treatment in patients with type 2 diabetes mellitus [48]. Özberk et al. suggested that PBMT, as an adjunct to SRP, led to a significant improvement in data regarding CAL and PD when compared to SRP alone at six months of follow-up [48]. Özberk et al. stated that at 6 months, the mean value of PD was 2.6 $\pm$ 0.3 vs. 2.6 2.9 $\pm$ 0.4 for PBM + SRP and SRP, respectively. As for CAL, the values were 2.79 $\pm$ 0.32 mm vs. 3.00 $\pm$ 0.39 mm for PBM + SRP vs. SRP only, respectively. Moreover, Pereira SRA et al. [49] performed a histological study on PBMT + SRP in a rat model of ligature-induced periodontitis and observed less bone loss and greater alveolar bone margin values 14 days after treatment with the 660 nm diode laser + SRP when compared to treatment with SRP alone [49]. The use of PBMT for the management of periodontal disease seems to be promising; however, investigations are necessary to confirm its effectiveness. Hence, there is not yet enough evidence to suggest the use of PBMT in periodontology.

2.4. High Power Laser Protocols

Several studies show that laser-assisted periodontitis treatment protocols, with relatively high power (>1 W), may be interesting in periodontal therapy [50,51]. In this particular indication of the laser, a large number of studies were conducted showing promising results, but with some controversy. The aim of using the laser in high power is to disinfect, ablate, or coagulate [52–55].

It was suggested that the use of the Nd: YAG laser in some particular applications for periodontitis can lead to bone regeneration and an improvement of the overall clinical periodontal parameters [56]. Several studies were conducted afterwards regarding the concept known as "laser-assisted periodontal regeneration" (LAR) [54–56]. A histological study performed by Yukna et al. [57] on 6 teeth managed with a laser-assisted regeneration (LAR) procedure demonstrated that it is possible to achieve new attachment formation, as well as the regeneration of cementum tissue and periodontal ligaments after 12 weeks of follow-up [57]. In addition, Nevins et al. [58] stated that LAR treatment was effective in 10 samples studied, in which 5 of them showed evidence of periodontal regeneration, but only one tooth presented new attachment with new cementum and collagen fibers. The other four samples that were included showed healing in the long junctional epithelium [58]. Different from the previous study by Yukna et al. [57], the healing was observed after 9 months, which is more consistent with the normally observed period of 6 months to 2 years for optimal regeneration. This report provides proof that LAR protocols can induce periodontal regeneration. The minimally invasive nature and expendable surgical materials required make this laser-assisted periodontal regeneration approach very promising and is therefore worth trying before moving on to a more complex, complicated, and expensive approaches.

In general, the goal of this procedure is to add to the conventional mechanical instrumentation used for scaling root planning (SRP), providing further disinfection (laser light) that penetrates beyond the limit of mechanical debridement obtained with manual and ultrasonic instrumentation. Irradiation with lasers, such as the diode laser and Nd: YAP, are generally the choice for this kind of protocols [53,59]. This is because these wavelengths can, if used properly, generate thermal and photo-disruptive energy leading to an injury or damage to the bacteria that are available in the site or in the nearby region [59]. The energy that the laser provides can penetrate deeply, which can theoretically result in a deep detoxification and disinfection of the periodontium with the potential to eradicate the periodontal pathogens found deep in the junctional epithelium and the epithelial cells [58,59]. Hence, the photo-disruptive energy of the laser and the heating that it provides are able to reach areas that the conventional mechanical instrumentation cannot [58,59]. This will lead to an enhanced disinfection of the junctional epithelium, the connective tissue, and the periodontal ligaments. In addition, the direct absorption of wavelengths, emitting in the near infrared light, is able to kill and destroy a large range of pathogens with pigmentation that presents protoporphyrin IX like *A.a* [60]. The positive outcome obtained with LAR studies has encouraged other researchers to use the laser in the same way. In this context, a clinical and bacteriological study by Nammour et al. [61] revealed that a 980 nm diode laser, coupled with 3% hydrogen peroxide, can be used in deep periodontal pockets (greater than 5 mm), and if a certain procedure was employed, result in a significant increase in the mean values of CAL, a decrease in the mean values of pocket depth, and an improvement in the mean values of clinical parameters (Table 2) [61]. Moreover, a retrospective study by El Mobadder et al. [17] revealed that after scaling and root planing (SRP), irrigation with 3% hydrogen peroxide, coupled with a 980 nm diode laser irradiation, if used within certain protocols, can result in an increased disinfection due to the overall decrease in total bacterial count when used as an additional approach to conventional SRP in periodontal pockets >5 mm [17]. Additionally, a significant improvement of the periodontal parameters was observed when sodium 0.5% hypochlorite was coupled with a 980 nm diode laser [16]. In this context, the AAP stated that human histologic evidence is consistent with the potential for periodontal regeneration following laser-assisted therapy in patients with moderate to severe periodontitis [7].

In this entry, a protocol for the use of high-power lasers will be suggested based on the available literature. The protocol of Nammour et al. [61] requires that the pockets be greater than 5 mm, have 2 or 3 walls, and that treatment consists of two sessions. The non-surgical protocol is as follow:

First session, or the session of the conventional mechanical debridement:

- Invite patient to disinfect the oral cavity with a prepared 0.12% chlorhexidine mouthwash.
- Optional: apply local anesthesia for zones with a pocket depth greater than 5 mm.
- Perform scaling and root planning (SRP) for the full-mouth in one session, a full-arch per session, or one quadrant per session. There is no significant difference between different approaches, so the determination is patient and operator dependent.
- Perform manual instrumentation and root debridement using Gracey curettes for the sites with a pocket depth greater than 5 mm.
- Perform a pocket reduction with 0.12% chlorhexidine for 5 s per pocket using an endodontic needle.
- After 4 weeks, re-evaluate the sites. The sites with a vertical bony defect and a PPD > 5 mm can benefit from the LAR therapy.

Second session, session of the LAR therapy made with a 980 nm diode laser [61]:

- After an SRP, dispose H_2O_2 diluted solution (3%) in the pocket using a syringe with a needle.
- After a 1 min wait, treat the inside of the pocket with a 980 nm diode laser (Lazon 980 nm Dental Diode Laser, Lazon Medical Laser Co., Ltd., Liaoning, China) 1 mm above the bottom of the pocket.
- Irradiate the pocket with a back and forth movement from the apical to the cervical sides and parallel to the longitudinal axis of the tooth. The laser must be used in contact mode in order to de-epithelize the sulcular and junctional epithelium (internal side of the pocket), with a frequency of 10 kHz, an irradiation speed of ± 1 mm/s, a pulse duration of 10 µs, a pick power of 10 W, an average power of 1 W, and a fiber

diameter of 400 µm (Table 3). The end of the treatment corresponds to the complete de-epithelialization of the internal side of the pocket.

- The de-epithelization of 4–5 mm of the external epithelium of the pocket must be carried out with the aim of delaying epithelial migration, allowing more time for the pocket to initiate its ossification process, and avoiding the formation of a long junctional epithelium attachment.
- Bleeding must be provoked inside the pocket. This can be achieved with a sterile manual periodontal curette. Afterwards, the coagulation and stabilization of the blood inside the pocket must be achieved with several passages of the laser fiber inside and at the entrance of the pocket. The patient is advised to avoid excessive fluid intake for the first 24 h to preserve the blood clot. Gentle brushing over the treated site can prevent injury to the treated pocket.
- In case of failure observed 6 weeks after the first treatment, the same procedure can be repeated twice, at 6-week intervals between sessions. If failure persists after 3 treatment sessions, other therapeutic approaches may be considered.

Table 2. Mean value and standard deviation of pocket depth and clinical attachment level for laser + SRP vs. SRP alone [61].

Groups	Baseline	6-Month Follow-Up	12-Month Follow-Up	Statistical Significance T0 vs. T3 within the Same Group
Pocket depth (mm)				
SRP only	6.92 ± 0.93^{a}	5.06 ± 0.81^{b}	5.00 ± 0.83^{b}	<0.01
Laser + SRP	7.67 ± 0.59^{a}	1.59 ± 0.49^{c}	1.77 ± 0.46^{c}	<0.0001
Clinical attachment level (mm)				
SRP only	7.74 ± 0.58^{a}	6.59 ± 0.37^{c}	6.22 ± 0.76^{c}	<0.0001
Laser + SRP	8.91 ± 0.52^{b}	3.46 ± 0.48^{d}	3.61 ± 0.41^{d}	<0.0001

The significant difference between different groups is indicated in letters as a, b, c, etc. Similar letters indicate a nonsignificant difference, and the difference between letters indicates a significant difference [61].

Table 3. Parameters suggested for the high-power laser protocol with a 980 nm diode laser [61].

Parameters	
Pick power	10 W
Average power	1 W
Pulse duration	10 µs
Frequency	10 kHz
Fiber diameter	400 µm

3. Prospects

The use of lasers as an additional tool in the non-surgical treatment of periodontitis seems promising, offering numerous advantages. However, its use remains an additional treatment to conventional mechanical debridement, and is not suggested as a replacement. Hence, we encourage further studies on the effectiveness of different laser-assisted periodontitis treatment approaches.

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