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Laser and Its Application in Periodontology: A Review of Literature

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Abstract

Introduction: The use of lasers is an emerging therapy in periodontology, however, controversies regarding its use. Despite the vast amount of literature that is currently available, debates regarding the use of lasers in periodontal therapy continue. This review aims to summarize and clarify the myths surrounding the use of lasers in periodontal therapy, which may offer new hope for the treatment's future. Methods: A comprehensive computer-based search was done using various databases like PubMed, Medline, and Cochrane Library. Results: Laser therapy has influenced periodontal treatment in many aspects. The advantages of laser over conventional instruments were reported, which include pain relief, inflammation reduction, tissue repair acceleration, wound healing, reduction of scar formation, removal of granulation tissue and epithelial lining, and treatment of periodontal pockets. Today, the laser starts to get more people's attention. However, an evidence-based approach to using lasers in periodontal treatment must be developed. The potential risks associated with lasers should also be considered. There must be careful and strict safety precautions implemented. Conclusion: Although laser therapy has shown promising results in the treatment of periodontal disease, further research is needed before the clinical use of lasers in evidence-based practice. Further long-term studies and clinical studies in human models are needed to generalize laser therapy in periodontology.

Keywords

Lasers, Periodontal Diseases, Low-Level Lasers, High-Level Lasers, Surgical, Non-Surgical, Soft Tissue, Hard Tissue

1. Introduction

The word LASER is an acronym that stands for light amplification by stimulated emission of radiation [1]. Although initially, laser was used for soft-tissue procedures, with the invention of the new generation of laser, it is also widely used on dental hard tissue. Hard tissue lasers may be considered an effective alternative to conventional lasers, offering clinicians a better field of work that promotes positive outcomes and better treatment outcomes. In addition, you can avoid sharp dental instruments, drilling noise, and vibration during dental procedures [2].

The laser is starting to take shape as one of the key weapons for periodontics in the coming years. Laser therapy is one of the most advanced and developing techniques in periodontology and is a highly effective treatment that makes even simple procedures more accessible and affordable. The published literature on lasers in periodontology is currently significant and growing rapidly. The current paper intends to demonstrate new possibilities for using this modern technology in routine periodontal practice.

2. Historical Background

- 1917, Albert Einstein described the theory of stimulated emission [1]. In 1959, the laser was first introduced in an article by Gordon Gould, a Columbia University graduate student. In 1960, Theodore Maiman created the first functional laser at Hughes Research Laboratories [3].
- 1961, the first gas laser and first continuously operating laser: Javan *et al.*
- In 1964, Patel created the CO_2 laser at Bell Laboratories [1].
- In 1971, Tissue reactions to laser light and wound healing: Hall and Jako *et al.*
- In 1974, Nd:YAG laser: Geusic *et al.*
- In 1977, Ar laser: Kiefhaber.
- In the1980s, the laser was used in oral surgery to remove soft-tissue lesions [4] [5].
- In 1987, the neodymium-yttrium aluminum garnet (Nd YAG) laser was specifically developed for dental procedures.
- In 1988, Er:YAG laser: Hibst and Paghdiwala.
- In 1989, Nd:YAG laser, soft tissue surgery: Midda *et al.*

3. Properties of Laser

Laser light is a single wavelength monochromatic light produced by the stimulation of synthetic material [6]. It employs light energy with a continuous uniform emission from a light chamber to target tissue for incising, cutting, and ablation [2]. A laser's active medium, which might be a gas, crystal, solid-state, or semiconductor, is what causes it to create energy-carrying photons when stimulated. The clinical applications of many lasers are determined by their wavelengths [7]. Chromophores or light-absorbing pigments are present in oral and dental hard tissue and are responsible for absorbing laser energy of a specific wavelength [8] [9] [10].

4. Laser Device Components

All lasers have the following parts [11] (**Figure 1**):

- A laser's active medium might be a gas, crystal, solid-state, or semiconductor.
- A laser tube or optical cavity with two mirrors at either end, one fully reflective or the other partially transmissive.
- A source of external mechanical, chemical, or optical energy excites or "pumps" the atoms in the laser medium to higher energy levels.

5. Laser Delivery Systems

The existing range of laser delivery systems includes the following [11]:

- Articulated arms (with 45-degree mirrors at joints), for UV, visible, and infrared lasers.
- Hollow waveguides (semi-rigid tube with reflecting internal surfaces), for middle and far-infrared lasers.
- Fiber optics\rigid tips (quartz-silica flexible fiber with quartz, sapphire tip), for visible and near-infrared lasers.
- Hand-held unit, low-power lasers.

6. Modes of Operation of the Laser

There are several emission modes for lasers (**Figure 2**):

- Continuous wave: as long as the foot switch is pressed, a single power level of a beam is released.
- Gated pulse mode (physical gating of the beam): periodic alteration for laser energy.
- Free running pulsed mode (property of the active medium): significant energy emission for a few microseconds, followed by a considerable period when the laser is turned off.

7. Laser Tissue Interaction

When laser light is applied to the target tissue, a photothermal reaction starts, which raises the tissue's internal temperature and generates heat [12]. When this temperature rises above 60˚C, the tissue's proteins coagulate [4]. However, when the temperature exceeds 100˚C, it results in the evaporation of water molecules and the ablation of soft tissue [4]. For hard-tissue procedures, however, a temperature of greater than 200˚C is necessary [10].

Four different interactions occur when laser light strikes a target tissue, depending on the optical characteristics of the tissue and the laser light's wavelength. These interactions are as follows (**Figure 3**):

- Absorption of laser light.
- Transmission of laser light.
- Reflection of laser light.
- Scattering of laser light.

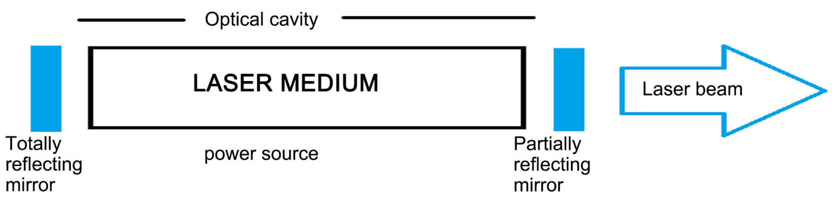

Figure 1. Laser device components.

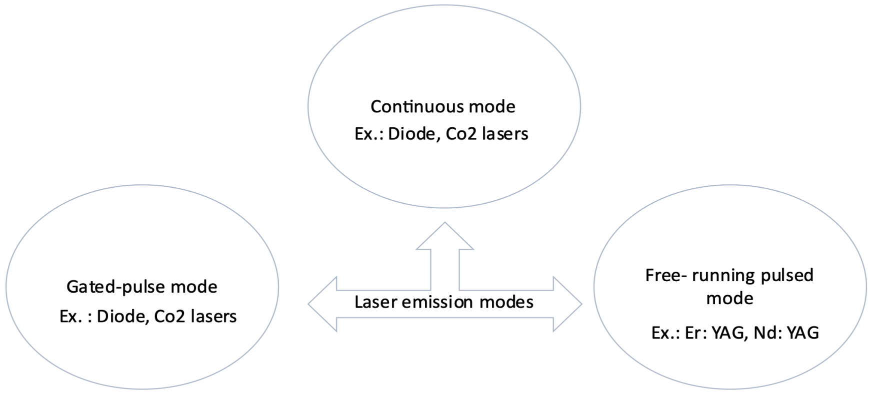

Figure 2. Laser operation modes.

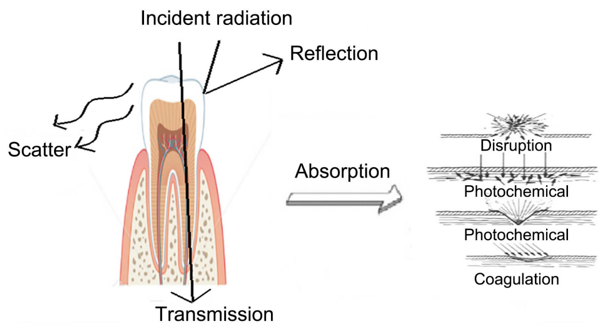

Figure 3. Laser tissue interaction.

8. Classification of Lasers

Lasers can be classified according to [13]:

- Spectrum of light.
- Material used.
- Hardness.
- Output energy.
- State of the gain medium.
- Oscillation mode.

9. Different Lasers and Their Application in the Dental Field

Nd-YAG laser, erbium:yttrium aluminum garnet (Er:YAG), CO_2, erbium chromium:yttrium scandium gallium garnet, holmium:yttrium aluminum garnet and diode laser are among the lasers that are frequently used in dentistry. In the oral cavity and orofacial regions, these are utilized for soft-tissue and hard-tissue procedures like cavity preparation, caries diagnosis, bonded restoration, root canal cleaning, periodontal surgery, treatment of peri-implantitis, and maxillofacial surgery [4]. The Nd:YAG laser, which has a pulsed mode and a wavelength of 1064 nm, is used to remove early-stage caries and ablate soft-tissue lesions. 10,600 nm is the wavelength of the gated or continuous mode of the CO_2 laser. It is recommended for soft-tissue incision, ablation, deepithelialization, and periodontal surgery due to its minimal tissue penetration of 0.03 - 0.1 mm [12]. The wavelengths of Er:YAG and Er-Cr:YSGG is 2940 nm and 2780 nm, respectively. They are mostly employed in cavity design, caries removal, and endodontic root canal preparation. Er-Cr:YSGG can vaporize bone without charring it or changing the calcium-phosphorus ratio [12]. The diode laser is frequently utilized today. Most of these gallium-arsenide lasers are utilized for soft-tissue procedures and have a wavelength of 904 nm.

10. Discussion

Laser in periodontal treatment

- Non-surgical periodontal therapy.
- Gingival soft tissue procedures.
- Hard tissue procedures.
- Surgical periodontal therapy.
- Photobiomodulation therapy.
- Antimicrobial photodynamic therapy.

10.1. High-Power Lasers in Periodontology

1) Non-surgical periodontal therapy

Nd:YAG and Diode lasers

The therapeutic application of high-power lasers has greatly advanced with the introduction of optical fibers, enabling their use in a variety of periodontal indications. Among them, the subgingival use of optical fibers, which are inserted into periodontal pockets and encourage bacterial reduction, is considered a minimally invasive technique if it is used with the right irradiation parameters [14]. The removal of the sulcular epithelium from the periodontal pocket (sulcular debridement) and the promotion of the reduction of periodontopathogenic bacteria, supra- or subgingival, are both indicated uses for the Nd:YAG laser and the diode laser. The findings of the studies are controversial. Studies evaluating the combination of the Nd:YAG laser and Er:YAG demonstrated clinical advantages only in deep pockets and additional clinical and microbiological benefits to SRP in the treatment of patients with moderate to severe periodontitis, in contrast to studies evaluating the use of the Nd:YAG laser (400 mJ/pulse; 60 s) [15] and diode laser (940 nm; 0.8 W) as adjuvants in the maintenance therapy of residual pockets that did not demonstrate additional clinical benefits [16].

Scientific evidence has shown that the use of diode laser on a root surface should be done carefully, in an interrupted mode, and with the proper parameters to prevent pulp damage. The clinical effects of a diode laser, when used as adjunctive therapy to SRP, were evaluated in several studies [17] [18] [19] [20]. The results obtained demonstrated the bacterial reduction of periodontal pathogens [18] [21] [22]. However, when comparing the use of diode lasers with standard mechanical treatment, other researchers did not support similar results. Regarding the evaluation of clinical parameters, two research papers conducted by Caruso U *et al.* and Kamma JJ *et al.* have indicated a higher reduction in probing depth and an increase in clinical attachment in areas treated with SRP combined with a diode laser, however, in other two research papers done by De Micheli G *et al.* and Alves VTE *et al.* have not demonstrated clinical benefits when a diode laser is used as an adjunct therapy to SRP.

The effects of diode laser (808 nm; 1 W, 20 PPS, 20 s/tooth, 10 J) as a monotherapy or as an adjuvant therapy to the SRP mechanical treatment in the treatment of experimental periodontitis were assessed in an animal experiment done by Theodoro LH *et al.* [17] [19]. When diode laser was utilized in conjunction with SRP, there was a larger reduction in alveolar bone loss, inflammation, and speeding up the process of repairing periodontal tissue [23]. Some studies using scanning electron microscope analysis have shown that when put on a root surface, diode laser promoted very minor morphological changes on the surface and did not affect its biocompatibility [15] [24].

A systemic review conducted by Qadri T; concluded that the diode laser is superior to SRP alone in treating probing depths higher than 5 mm [25]. However, a consensus of the evidence presented through a systematic review done by Chambrone L and other researchers showed that there is an additional clinical benefit when using diode laser combined with SRP in non-surgical periodontal treatment in patients with moderate to severe periodontitis, and the increase in clinical attachment level (CAL), although statistically significant, has only modest clinical relevance.

On the other hand, a clinical trial conducted in 2019 by Chandra S. and colleagues, has demonstrated the positive effects of the use of diode lasers (808 nm; 1.5 to 1.8 W; continuous mode) in the management of periodontal disease in patients with type 2 diabetes. It was shown that the combination of the laser and the SRP showed improvement in the periodontal clinical parameters as well as reduction of *Porphyromonas gingivallis* and *Aggregatibacter actinomycetemcomitans* bacteria, compared to treatment with the SRP alone [26]. This was accomplished by positioning the optical fiber inside the periodontal pocket and directing it to the soft tissue. A review study done by Jia L and others evaluating the use of lasers in periodontal treatment concluded that among high-power lasers, the diode laser is the second-best at promoting gain in CAL at 3 months when used in conjunction with SRP, and the best at acquiring CAL at 6 months of evaluation, reiterating these positive results [27]-[33].

Er:YAG and Er, Cr:YSGG lasers

The water molecules inside the hydroxyapatite crystals strongly absorb

Er:YAG (2940 nm) and Er, Cr; YSGG (2780 nm) lasers. Since they have a cooling system, they promote a photomechanical or photothermal action, and they do not heat nearby tissues, they have a high capacity for eliminating mineralized tissues [28] [29]. It should be noticed that hydroxyapatite greatly absorbs the Er, Cr:YSGG laser.

Several Vitro studies by Theodoro LH *et al.*, Ting CC *et al.*, and Oliveria GJ *et al.* have shown that both the Er:YAG and the Er, Cr; YSGG lasers stimulate changes in the surface that make them more uneven and rough. These surface modifications are the result of the explosive ablation process that these lasers are known for, which maintains biocompatible surfaces when employed with the proper irradiation conditions. These lasers are also recommended for dental calculus removal, non-surgical periodontitis treatment (bacterial reduction), and soft tissue ablation operations [30] [31].

A systemic review was conducted in 2019 by Agoob Elfergany M *et al.* to examine the advantages of using Er:YAG and Er, Cr:YSGG lasers to remove dental calculus and their effects on topography and root surface roughness found that the use of SRP in conjunction with Erbium lasers as an adjunctive therapy can be appropriate to remove residual debris from the root surface and have a little thermal effect on the root surface. The Er:YAG laser appears to be the most effective non-surgical periodontal therapy, according to this study's findings [28] [32] [33] [34] [35].

Despite providing better microorganism decrease, some researchers have revealed that the Er:YAG laser promotes the same therapeutic outcomes as traditional SRP therapy. Furthermore, only a few studies have assessed and looked at the therapeutic consequences of using lasers in conjunction with SRP to treat periodontitis.

Some studies have found that the Er:YAG laser is as effective as SRP alone and that it can eliminate bacteria more effectively when used as an adjuvant. For root debridement and scaling, pulse energies between 100 and 160 mJ/pulse and a repetition rate of 10 Hz were most frequently employed in clinical studies in humans [29]. The Er:YAG laser, used as an adjunct therapy to SRP, improves short-term therapeutic improvements and lessens patient pain perception, according to meta-analysis research.

The Er, Cr:YSGG laser (2780 nm), due to its thermomechanical action, has been indicated for the removal of mineralized tissues. When compared to isolated non-surgical periodontal therapy, a study showed that the Er, Cr:YSGG laser as an adjuvant therapy further reduces clinical inflammation after 1 and 3 months of treatment, although there are no changes in the reduction of IL-1B and MMP-8 [36].

2) Surgical periodontal therapy

The CO_2 (10,600 nm), Nd:YAG (1064 nm), DL (800 - 980 nm), Er:YAG (2940 nm), and Er, Cr:YSGG lasers (2780 nm), are the high-power lasers best suited for soft tissue surgery [30] [31].

The most indicated surgical procedures include subgingival curettage, excisional biopsy, excisions of pathological soft tissue (granuloma, fibroma), muscle brakes and bridles, gingivectomy/gingivoplasty, removal of melanin pigmentation, increase in the clinical crown, proximal wedge, de-epithelialization of the flap in regenerative procedures, and subgingival curettage [30] [31].

The osteotomy and osteoplasty procedure carried out with an Er, Cr:YSGG or drill laser has been examined in animal research. With the Er, Cr:YSGG laser, which is distinguished by the absence of tissue carbonization and debris, the repair was more favorable. Additionally, it was demonstrated to be a safe and accurate method, capable of controlling the depth of the cut when employed with the proper irradiation, cooling, and output beam inclination parameters [37] [38].

When doing surgical periodontal therapy with simply the Er:YAG laser, a systematic study conducted in 2018 by Chambrone lal *et al.* revealed an additional clinical increase in attachment level, however, the size of this gain is debatable.

10.2. Low-Level Laser in Periodontology

1) Photobiomodulation therapy

Non-surgical periodontal therapy

The lasers used in Photobiomodulation emit in the visible or near-infrared range (630 - 980 nm) and have significant effects on non-surgical periodontal treatment because they help to reduce gingival tissue inflammation and have a photobiomodulatory effect, which is demonstrated by a decrease in marker phenotypes linked to activated macrophages, reactive nitrogen species, and pro-inflammatory cytokines [39].

Photobiomodulation therapy has been recommended as an adjunct therapy to the SRP procedure in non-surgical periodontal therapy for the control of inflammation and for the acceleration of tissue repair in the immediate or mediate postoperative period in periodontal surgeries that affect soft and bone tissue, for the reduction of edema, postoperative pain as well as for the treatment of dentin hypersensitivity [14]. As a result, it can be utilized as an addition to surgical and non-surgical therapy for diseases of the gums that are associated or not with a plaque as well as for the treatment of periodontitis, particularly in cases where systemic problems or modifying factors, such as smoking, are present [40].

In addition to non-surgical periodontitis treatment, the efficacy of Photobiomodulation as adjuvant therapy was assessed in randomized controlled clinical studies. Currently, a lack of studies with adequate methodologies and the heterogeneity of irradiation parameters, Rem C and colleagues claimed that there is still no conclusive evidence of this therapy's effectiveness when used for this purpose. However, other authors Cobb CM *et al.* and Mokeem S *et al.* claimed that the results are encouraging because they showed this therapy's positive effects in the short term.

The efficacy of Photobiomodulation, however, was demonstrated by experimental trials that assessed this therapy as an adjuvant in the treatment of periodontal disease that was artificially produced in animals.

There is a considerable difference in the irradiation parameters and a very large divergence between the outcomes of clinical studies in people using PBM as an additional therapy. It can be challenging to determine the best treatment protocol because several studies employed Photobiomodulation in many sessions (3 to 10 sessions), with varying wavelengths (630, 632, 635, 660, 670, 780, and 830 nm), and with variable energy (0.96 to 10.5 J per tooth) [41] [42] [43].

Clinical studies have also demonstrated the positive effects of adjunctive PBM in the management of diabetic patients' periodontal disease. Using a 670 nm laser on the gingival tissue for 14 minutes each day for five days in a row resulted in a decrease in gingival inflammation. Additionally, it has been demonstrated that PBM therapy (980 nm) is useful in the nonsurgical management of chronic periodontitis in patients with uncontrolled type 2 DM [44].

Patients with periodontitis with type 2 diabetes who have periodontal pockets have shown success using Photobiomodulation. Using a laser (660 nm, 0.03 W, 22 J/cm^2, the 20s, continuous wave, 1.1 W/cm^2, total energy of 0.6 J), 79 periodontal pockets were treated locally [44].

Few reviews and meta-analysis studies on Photobiomodulation for the treatment of periodontal disease and the level of certainty varied from moderate to low. A meta-analysis conducted by Ren C *et al.* in 2017 concluded that the use of Photobiomodulation, mediated by laser associated with non-surgical periodontal therapy, gives additional benefit only in the short term.

Surgical periodontal therapy

Photobiomodulation can be used in periodontal surgical treatment to encourage gingival and mucous tissue repair; speed up bone tissue healing and lessen periodontal surgical postoperative discomfort [45].

Few studies have examined the impact of Photobiomodulation on periodontal bone repair in the bone tissue, despite the large number of studies conducted in various clinical and experimental studies on animals [45].

A meta-analysis conducted in 2018 by Yan J, on the treatment of gingival recessions revealed that while the degree of root coverage was unaffected, the association of the flap with the Photobiomodulation improved the probing depth parameters and the clinical attachment level by increasing the production of keratinized tissue [46].

2) Antimicrobial photodynamic therapy

Photodynamic therapy (PDT), also known as photo radiation, phototherapy, or photochemotherapy is a new treatment modality that has been developing rapidly within various medical specialties since the 1960s.

In this treatment modality, there is a powerful laser-initiated photochemical reaction, involving the use of photoactive dye also called photosensitizer like (Methylene Blue (MB) or ortho-Toluidine Blue (TBO)) activated by light of a specific wavelength in the presence of oxygen.

As an adjunct to the treatment of periodontitis, antimicrobial photodynamic therapy has been clinically tested in several trials. However, it is noted that the outcomes are debatable and ambiguous as a result of the variety of methods for the use of this therapy in research. It should be mentioned that several photosensitizers associated with lasers or LEDs with varying wavelengths have been utilized in the clinical investigations available in the literature. The pre-irradiation time (between 1, 3, and 5 minutes), the power used (between 60 and 280 mW), the exposure time (between 10 and 180 seconds/site), the number of sessions (single or multiple), frequency, and the interval between sessions have all been highly variable in antimicrobial photodynamic therapy in addition to the type and concentration of the photosensitizers [47].

Despite not showing benefits in CAL level after using antimicrobial photodynamic therapy, certain clinical trials by Braun A *et al.*, Christodoulides N *et al.*, Ge L *et al.*, and Petelin M *et al.* have demonstrated that this therapy can lower bleeding and manage inflammation of treated tissues. While Theodoro LH *et al.* have demonstrated how antimicrobial photodynamic therapy could encourage the reduction of bacteria, mainly periodontopathogenic bacteria. There is some scientific proof supporting the effects of repeated antimicrobial photodynamic therapy administrations in periodontal therapy [47].

The level of certainty of these reviews ranges from very low to moderate, and they have produced conflicting findings regarding the effectiveness of antimicrobial photodynamic therapy in periodontics. Regarding the early management of chronic or aggressive periodontitis, some reviews reported positive outcomes with a variety of applications, even in the short term, while others did not support greater efficacy than conventional treatment or that its impact is constrained. There is yet not enough research on the usage of antimicrobial photodynamic therapy in smokers or diabetics [48].

On the non-surgical management of periodontitis, a meta-analysis compared antimicrobial photodynamic therapy to systemic antibiotic therapy with amoxicillin + metronidazole. Even though there were only a few randomized controlled clinical studies (4) and there was significant heterogeneity among them, it was determined that antimicrobial photodynamic therapy offers comparable clinical outcomes to antibiotic therapy as adjuvants in the non-surgical treatment of periodontitis [48].

11. Contraindications of Laser Use and Its Limitations [49]

- Laser use in patients who have cardiac pacemakers should be cautious.
- It is also not advised to use in cardiac patients with a history of anginal chest pain and arrhythmia.
- It should be used with precaution in immunocompromised patients as there is a chance of disease transmission through aerosol during the laser procedure.
- Laser use in dentistry necessitates extensive training and accuracy.
- The effectiveness of laser therapy in terms of cost is debatable; also, lasers of

different wavelengths are required for different oral and dental procedures.

12. Laser Safety

Wearing protective eyewear is mandatory as it may cause eye damage. To reduce the risk of unintentional exposure to non-target tissue, the operator must be cautious about accidental exposures and the operation space should only be accessible by a small number of people. The presence of flammable materials in laser surgical rooms should be avoided as it can produce combustion hazards. When laser surgery is intended to be performed under general anesthesia, the presence of explosive anesthetic gases is contraindicated. Moreover, it must be guaranteed that the laser is in good operating order and that all safety precautions are taken [50] [51] [52].

13. Materials and Methodology

Various Databases were explored as a part of the search strategy at numerous levels. Data Bases like PubMed, Medline, and Cochrane Library were used. The articles were taken from 2015-year 2022 to for this review.

The first search was done with Medline and Cochrane Library using the following keywords "lasers application in periodontology", "lasers in periodontal treatment", "antimicrobial photodynamic therapy in periodontal treatment", and "Photobiomodulation application in periodontal treatment", "high-level lasers in periodontology", "low-level lasers in periodontology".

14. Results

The findings of nonsurgical periodontal therapy demonstrated an extra clinical benefit when scaling and root planing (SRP) is combined with the use of a diode laser (DL) in patients with moderate to severe periodontitis. The Er:YAG laser promotes the same clinical outcomes as conventional therapy and appears to be the most appropriate for nonsurgical periodontal therapy. With DL, CO_2, Nd:YAG, Er:YAG, and Er, Cr:YSGG lasers, gingival or mucosal tissue can be vaporized during periodontal surgery.

Photobiomodulation (PBM), mediated by low-level lasers associated with non-surgical periodontal therapy, promotes additional benefits in the short term, speeds up the healing of bone and gingival tissue, and lessens the side effects of periodontal surgery. In the initial reevaluation phases, the impact of photodynamic therapy on microbes is important. Studies on the use of lasers in periodontics have had mixed outcomes, and this may be because there aren't uniform irradiation parameters used across all clinical settings.

15. Conclusions

Laser therapy has influenced periodontal treatment in many aspects. The advantages of laser over conventional instruments were reported, which included pain relief, inflammation reduction, tissue repair acceleration, wound healing, reduction of scar formation, removal of granulation tissue and epithelial lining, and treatment of periodontal pockets.

Today, the laser starts to get more people's attention. However, an evidence-based approach to using lasers in periodontal treatment must be developed. The potential risks associated with lasers should also be considered. There must be careful and strict safety precautions implemented.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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