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Review

Evaluating the Efficacy of Various Laser Types in Periodontal Treatment: A Narrative Review

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Abstract

Objectives: This review examines the efficacy of each laser type in the field of periodontal surgery and analyzes published articles that focus on the use of lasers in periodontal surgery. **Methods:** Automatic and manual searches were made in 3 separate databases (PubMed, Embase, and Cochrane) with the aim of finding all published articles of the last 15 years up until December 2023 that describe the clinical manipulation of diode, erbium:yttrium-aluminum-garnet (Er:YAG), erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG), neodymium yttrium-aluminum-garnet (Nd:YAG), and carbon dioxide (CO_2) lasers for periodontal surgical procedures in humans. Results: A total of 18 studies were selected for inclusion, all of which compared the usage of a laser type to conventional periodontal surgical techniques with their main follow-ups being in 3, 6, or 9 months. **Conclusions:** There are a variety of laser types, each with different settings and wavelengths, that can be applied to the established aspects of resective and regenerative periodontal surgeries. A significant majority of the publications, 10 of the 12 studies, that include diode lasers as an adjunctive show an improvement in clinical results compared to traditional surgical techniques alone, while 2 articles studied the Er:YAG laser and 1 article studied the Er,Cr:YSGG laser, with all 3 of them failing to completely test their therapeutic capabilities and indicating similar results to conventional surgery. The Nd:YAG laser was featured in 3 studies, with 1 study showing superior results for the laser group, another study showing the negative influence of the laser, and the 3rd study being inconclusive. The CO_2 laser was used in 1 study and showed better clinical results for the laser group. Diode lasers have been proven to produce additional therapeutic results, but there is a need for further investigation of erbium family lasers along with the Nd:YAG and CO_2 lasers, as the current provided literature contradicts their potential healing capabilities.

Keywords: laser; periodontal surgical therapy; periodontitis; resective surgery; regenerative surgery; diode laser; Er:YAG laser; Er,Cr:YSGG laser; Nd:YAG laser; CO_2 laser

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1. Introduction

The periodontium is an intricate structure that is comprised of four distinct components. These are the cementum, which is a type of mineralized tissue surrounding the dentin of the root of the tooth; the gingiva, which is comprised of mucosal and connective tissue that connects the tooth with the adjacent bone; the alveolar bone, which is the surrounding bone of the tooth; and finally the periodontal ligament (PDL), which is a fibrous tissue that is located between the tooth and alveolar bone [1] and whose fibers anchor the tooth to the surrounding bone [2]. These constructs have important roles in enabling the periodontium to support the tooth by withstanding the mechanical forces and functional loads that are constantly applied on it [3], as well as defending against various oral bacteria [4].

The disruption of the normal structure and function of the periodontium can be caused by both hereditary and acquired factors and leads to periodontal disease, which can affect all aspects of the periodontium and is divided into two main categories: gingivitis, the milder form, and periodontitis, which in turn damages the deeper connective tissues and alveolar bone of the periodontium of the tooth [5]. Gingivitis is limited to the upper level of soft tissues of the periodontium, appearing with the typical signs of inflammation, with an extremely high prevalence among the general population [6] and leading to the presence of dental plaque, along with its accompanying microbial biomass [7].

It is estimated that 7.4% of the global population is affected by a severe form of periodontal disease [8], with high-income countries having the highest recorded percentage of a type of periodontitis [9].

A connection between periodontitis and other medical conditions has also been described [10], with some studies, among others, showing a two-way relationship between the disease and diabetes [11] and an association with cardiovascular diseases [12]. Periodontitis is thus a highly prevalent disease globally, which requires extra caution from medical authorities and establishments worldwide [13].

Light is a type of electromagnetic energy that behaves both as a wave and a particle, with its fundamental unit being the photon. The acronym "LASER" stands for "light amplification by stimulated emission of radiation." Laser light differs by conventional light sources in that it is monochromatic. Monochromaticity means the generation of a light beam of a single color, which can be both visible and invisible, depending on whether the wavelength falls inside or outside of the visible spectrum [14].

1.1. Laser Light Properties

Laser light possesses unique attributes not found in conventional light sources, making it highly suitable for a variety of scientific and technological fields. These characteristics include collimation, coherency, and efficiency, all of which are crucial for various material processing and characterization purposes.

Collimation ensures the laser beam maintains consistent spatial size and shape [14].

Coherence indicates that the light waves have an identical amplitude and frequency, which creates a distinctive type of focused electromagnetic energy [15].

Finally, efficiency is maybe the most crucial aspect of laser light in clinical applications. While a standard 100 watt bulb generates about 20 watts of visible light, with the remaining 80 watts transformed into heat energy, a mere 2 watts of Nd:YAG laser light can precisely cut through gingival tissue, demonstrating its efficient use of energy [16].

1.2. Laser Setup

The basic core of the laser setup is the optical cavity. Inside it lies an active medium, which is situated inside the optical resonator [17]. An optical resonator is an arrangement of two optically parallel mirrors, with one being highly reflective and the other partially transparent. The active medium, be it a solid, a liquid, or a gas, is pumped by an energy source, either electrical or optical in nature, to stimulate emission. Each laser type is typically named after the material constituting this active medium. In the field of dentistry, two types of lasers with gaseous active mediums are commonly used: argon and CO_2 lasers.

The other prevalent types are solid-state semiconductor lasers, constructed using multiple layers of metals like gallium, aluminum, indium, and arsenic, or solid garnet crystal rods infused with different combinations of yttrium, aluminum, scandium, and gallium. These crystals are then further enhanced with doping elements such as chromium, neodymium, or erbium [18].

The setup amplifies the light wave's amplitude as it passes through the active medium. The active medium, positioned between the mirrors, ensures that the oscillating light repeatedly traverses the medium, therefore being amplified greatly before being emitted through the partially reflective mirror (Figure 1).

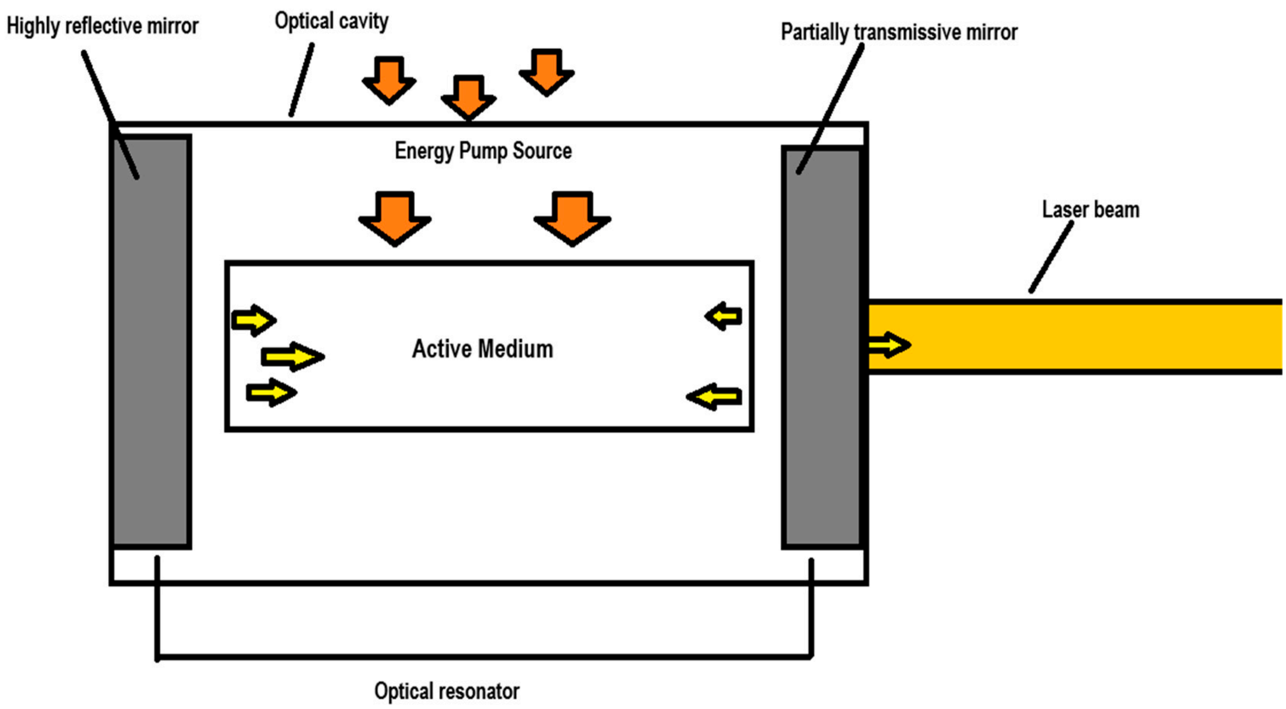

Figure 1. A laser setup consisting of its basic parts inside the optical cavity.

Uses of Lasers in Dentistry

The various uses of lasers in dentistry are as follows [19]:

- Gingivectomy/gingivoplasty
- Treatment of periodontal disease
- Removal of hyperplastic/granulation tissue
- Frenectomy/frenotomy
- Second-stage recovery of implants
- Excision of tumors/lesions
- Incision/excision biopsies
- Caries diagnosis and removal
- Curing of composites
- Activation of tooth-bleaching solutions, etc.

1.3. Effects on Tissue Related to Temperature Changes Generated by Laser Energy

The main effect of lasers on tissues in the field of dentistry is photothermal, which means the changing of laser light energy to thermal energy [20]. The thermal effect of laser energy depends on the degree of heat generated, and thus temperature elevation, within the targeted hard and soft tissues. Based on the temperature, the following tissue effects are observed: 37 °C (normal), 45 °C (hyperthermia), 50 °C (lowering of enzymatic activity and loss of cell mobility), 60 °C (coagulation, protein and collagen denaturation), 80 °C (cell membranes become permeable), 100 °C (vaporization, ablation), >100 °C (carbonization), and >300 °C (melting).

Alteration Effects in Tissue by Laser Application

(1) Photothermal: This refers to the generation of heat in the operative area by the conversion of light energy to thermal energy and is the primary effect observed when a laser reaches the targeted tissues, usually soft tissues [20]. This type of effect is usually observed when chromophores absorb laser energy, generating heat used for tasks such as cutting tissue or coagulating blood. Vaporization is an interaction that involves evaporation and homogeneous bubble nucleation and takes places at temperatures lower than the material's critical point, limiting the amount of energy that can be exploited [21]. Naturally, it is important to manage this heat generation with extreme care in order to prevent unwanted damage to the tissues.

(2) Photodisruptive Ablation: Photodisruption produced by a laser can be used with the intent to precisely disrupt or break down tissues, such as calculus or infected tissues on periodontally afflicted root surfaces. The deliverance of energy is typically very short, with intense pulses. It creates mechanical waves and a rapid expansion of gas and fluid matter within the tissue targeted, leading to its disintegration. In hard tissues, their removal typically involves high-powered laser bursts interacting with water, which may originate from both the working hand piece and the targeted tissue and leads to rapid expansion of the water molecules [22]. An example is the efficiency of erbium laser ablation, which is largely due to micro-explosions in overheated tissue water, where the laser energy is intensely absorbed. Consequently, dental and bone tissue are not vaporized but rather broken down through a photomechanical ablation process. This generates a distinctive popping sound during the use of the erbium laser and minimizes thermal damage because of thermal energy residue, especially when the concept of thermal relaxation is applied.

(3) Plasma-induced Ablation: Distinguished from the photodisruptive type, this type of ablation works by high power density, which forms local ionized plasma at a focal point. It was reported using a neodymium-doped yttrium lithium fluoride (Nd:YLF) laser [23].

(4) Photochemical: Photons have the ability to initiate chemical responses in tissues, creating photochemical reactions. These reactions can contribute to some beneficial effects in biostimulation and antimicrobial photodynamic therapy (aPDT).

    (a) Photobiomodulation or biostimulation involves using non-ionizing light sources that interact with endogenous chromophores to stimulate biological responses. Several signaling pathways that are activated via reactive oxygen species, cyclic AMP, NO, and Ca^{2+} lead to activation of transcription factors, which in turn increases the expression of genes related to cell migration, proliferation, anti-inflammatory signaling, and anti-apoptotic proteins, thus accelerating healing, enhancing circulation, reducing edema, and alleviating pain [24].

    (b) The application of aPDT is another use of lasers in periodontal nonsurgical therapy that involves the use of light-sensitive substances, known as photosensitizers, in conjunction with light energy from a laser. During this process, the photosensitizer is first inserted into the periodontal pocket and activated by a laser. It absorbs the energy from photons and transfers it to nearby molecules [25]. This transfer leads to the creation of reactive oxygen species and free radicals, which are oxidative agents capable of damaging bacterial cells. They target key bacterial components such as proteins, lipids, and nucleic acids, leading to the inactivation and potential destruction of bacteria [26]. A significant advantage of aPDT over traditional antibiotic treatments is its ability to avoid the development of resistant bacterial strains [27].

(5) Fluorescence: It has been proven that exposure of tooth structures to the 655 nm visible wavelength produced by diode lasers can reveal their potential carious lesions. The degree of fluorescence correlates with the lesion size and assists in diagnosing early carious lesions [28], as seen in devices like Diagnodent [29]. The idea behind it is that the fluorescence is excited from the carious tooth structure by the light energy, which is reflected back to the laser detector, which analyzes and quantifies the degree of caries [14].

In general, the high functionality of lasers achieves effects in dental tissues through absorption by basic biological molecules like water, proteins, and pigments. Each laser wavelength has different absorption coefficients by these typical periodontal and dental tissue components, meaning that depending on the wavelength, laser energy can be absorbed, transmitted, scattered, or reflected from each type of molecule in a tissue [20].

The absorption coefficients for water, hydroxyapatite, melanin, and hemoglobin are of the outmost importance because of their abundance and how commonly they are encountered in dental tissues. Water is the main absorber of the infrared part of the spectrum and reaches maximum absorption of the wavelengths of the two erbium lasers, with the wavelength of CO_2 lasers coming right behind them. On the contrary, lasers with shorter wavelengths, like diode and Nd:YAG lasers, can only reach a few millimeters deep into tissues. Pigments and proteins absorb mainly in the ultraviolet (UV) and visible light spectrum. Melanin is the primary pigment in skin and the most significant chromophore in the epidermis, showing an increasing absorption coefficient from the visible spectrum to the UV range. Hemoglobin is prevalent in vascular tissues and plays a key role in absorption during laser coagulation of blood [20]. Proteins exhibit a notable absorption peak at about 280 nm [30], while hydroxyapatite reaches that peak at 10,600 nm, which is the wavelength of CO_2 lasers.

The absorption met at this level is greater than any other laser that is used in dentistry and about 1000 times greater than by erbium lasers, which produce the second greatest absorption coefficient. That is why when the operating field includes soft tissues with hard dental tissues in the vicinity, extreme care and measures must be taken so that a laser beam does not unintentionally target the tooth. A metal object is occasionally placed into the gingival sulcus so that the tooth surface becomes shielded from laser light [14].

Most biomolecules exhibit a complex band structure in the 400 nm to 600 nm range. Since neither macromolecules nor water have strong absorption in the near-infrared spectrum, a therapeutic window is established between approximately 600 nm and 1200 nm. Within this range, radiation can penetrate biological tissues with reduced loss, facilitating the treatment of deeper tissue layers [20].

Hemoglobin and other blood components and pigments such as melanin have very high absorption of the wavelengths at which diode and Nd:YAG lasers operate. Especially, the diode laser is an excellent soft tissue surgical laser and is highly indicated for cutting and coagulating gingiva and mucosa, expanding its use in various fields of dentistry through sulcular debridement, biopsy, frenectomy, gingivectomy, and impression troughing.

Erbium lasers, such as Er:YAG and Er,Cr:YSGG lasers, exhibit the highest absorption rates in water among all dental laser wavelengths and show a strong affinity toward hydroxyapatite. These lasers interact both with the hydroxyl radicals in apatite crystals and the water attached to a tooth's crystalline structure. This is an interaction that leads to the vaporization of water in the tooth's mineral components, resulting in significant volume expansion that disintegrates with high effect on the surrounding areas. Particularly useful in removing carious lesions and any overlapping soft tissue, erbium lasers, when used with the correct settings, can achieve this with high efficiency. Moreover, erbium and CO_2 lasers, highly effective in absorbing tissue with substantial water content like mucosa, penetrate only a few microns into the targeted tissue, enabling high precision.

This review's aim is to examine the use of lasers in periodontal surgery and whether there is a difference in treatment results between the various laser types that can be used in the periodontal surgical field. With the therapeutic effects of the combination of laser and nonsurgical periodontal therapy having been long well established [31,32], articles have been published during the last decade that have started to show the potential beneficial effects of lasers in synergy with various periodontal surgical techniques [33–35]. The distinction, however, in surgical results based on the type of laser applied has remained obscure in the published literature, creating a need for further research, which is why this is the goal of this review. One hypothesis is that some laser types do indeed show a clinical superiority in results against other types. Another hypothesis is that each laser type shows an improved efficacy with different surgical techniques.

2. Materials and Methods

2.1. Main Focused Question

Is there any difference in therapeutic effectiveness regarding the type of laser?

The selection process was based on the patient, intervention, comparison, and outcome (PICO) [36].

P: Dentate patients with periodontal disease (including all stages and grades).

I: Diode, Er:YAG, Er,Cr:YSGG, Nd:YAG, and CO_2 lasers applied in periodontal surgical therapy.

C: Any type of periodontal surgical therapy, which uses techniques and materials other than a laser.

O: Positive results, lack of them, or negative influence in the outcomes of probing depth, clinical attachment level, bleeding on probing, or gingival recession.

2.2. Eligibility Criteria

Regarding the inclusion criteria that must be met for the selection of articles:

Case studies could be both randomized and not, prospective and retrospective, cohort or case–control series, and which investigate in adult humans the application of lasers in periodontal surgical therapy in the last fifteen years.

Special attention and analysis were given to studies in which patients had any systemic disease which hindered healing and regeneration. Whenever they were included, they were mentioned as well.

2.3. Exclusion Criteria

(i) Non-human species, (ii) systematic reviews and literature reviews, (iii) underage patients, (iv) pregnant/lactating women, (v) laser application in periodontal nonsurgical therapy, and vii) articles published before 2008.

2.4. Screening Process

Three databases (PubMed, Embase, and Cochrane) were used. The articles selected were in English and were published between January 2008 and December 2023. In PubMed, the search sequence was the following: (laser*[MeSH Terms] OR diode laser* OR Er:YAG laser* OR erbium YAG laser* OR CO_2 laser* OR carbon dioxide laser* OR Nd:YAG laser* OR Er,Cr:YSGG laser* OR neodymium doped yttrium aluminum garnet laser*) AND (periodontal[Other Term] OR periodontal flap[Other Term] OR periodontal surgery OR periodontal surgical therapy OR periodontal debridement) AND English [filter] AND humans[filter] AND (2008:2023[pdat]). The keywords used for the search in Embase were the following: laser* AND ('periodontal surgery' OR "bone loss" OR (periodontal AND disease) OR (periodontal AND treatment)) AND human, while for the Cochrane library were: laser AND ("periodontal surgery" OR "periodontal therapy") AND ("bone loss" OR "bone gain" OR "surgical flap" OR "open flap") (Figure 2).

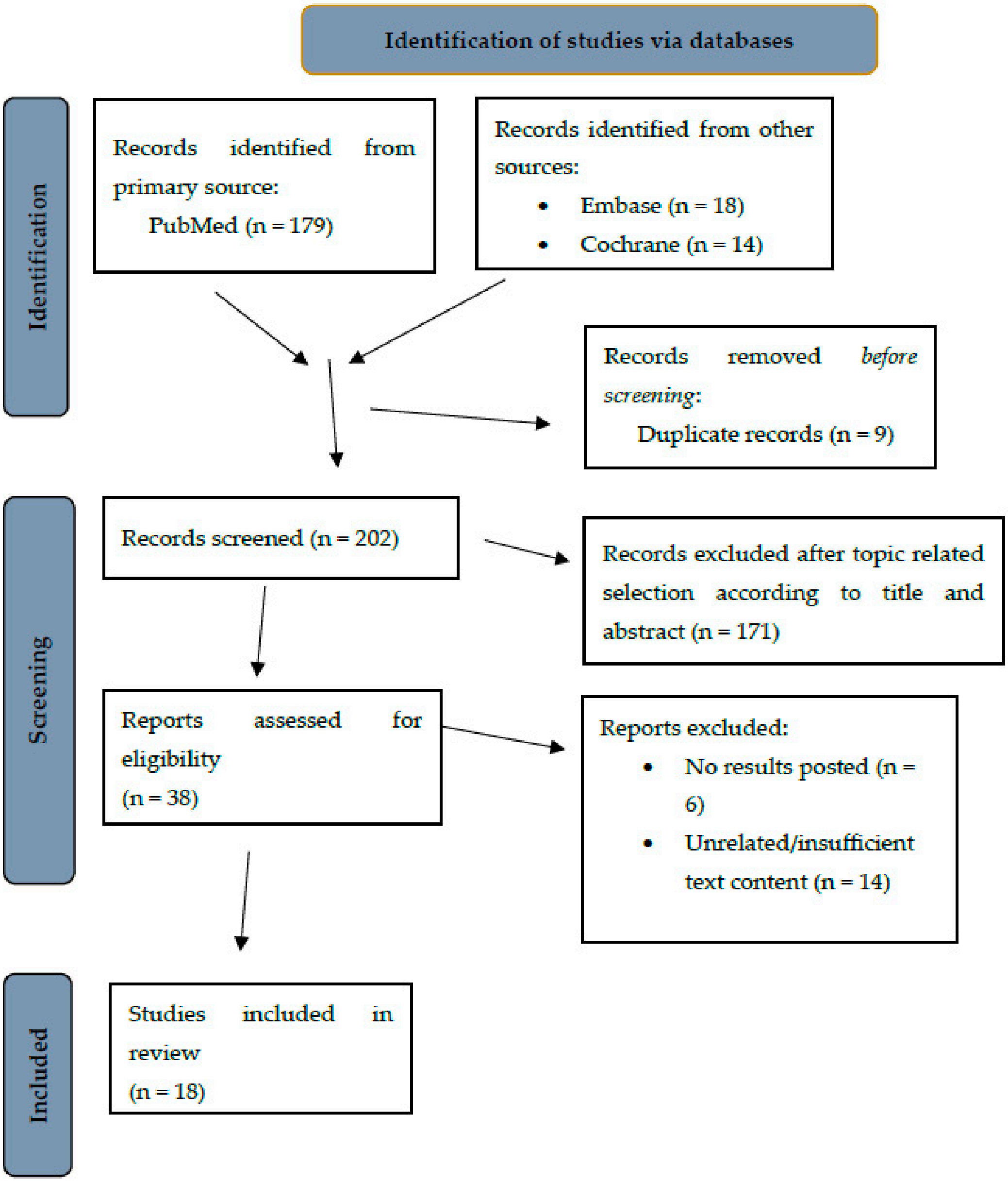

Figure 2. Flow chart of screening process [37].

3. Results

Study Selection

Initially, 218 articles were selected from across all platforms, with 9 of them being removed as duplicates and another 171 removed because of unrelated abstracts and/or titles. Of the 38 articles selected based on the eligibility criteria, 20 of them had unrelated or insufficient data and/or results. The result was 18 articles for analysis (Table 1) (Figure 2).

Table 1. Studies selected after screening.

Reference	Type of Laser	Clinical Findings	Laser Parameters	Last Follow-Up
[38]	Diode	Improved clinical parameters for laser group	810 nm, 1 W, 4 J/cm^2	9 months
[39]	Diode	Similar findings between test and control groups	No data, wavelength, 1.5 W	6 months
[40]	CO_2	Improved clinical parameters for laser group	No data	15 years
[41]	Nd:YAG	Improved clinical parameters for control group	1064 nm, 1 W, 10 Hz,	6 months
[42]	Er:YAG	Similar findings between test and control groups	2940 nm 2 Hz, 60 mJ/pulse	6 months
[43]	Nd:YAG	Similar findings between test and control groups	1064 nm 1 W, 10 Hz, 100 mJ, 141.54 J/cm^2	12 months
[44]	Nd:YAG	Improved clinical parameters for laser group	1064 nm, 100 mW, 10 Hz, 100 mJ, 4 J/cm^2	6 months
[45,46]	Diode	Initially improved results for test group, followed by results similar to both groups	660 nm	6 months + 2 years
[47]	Diode	Improved clinical parameters for laser group	980 nm, 2.5 W, 50 J/cm^2	3 months
[48]	Diode	Improved clinical parameters for laser group	970 nm, 7 W, 50 J/cm^2	6 months
[49]	Diode	Improved clinical parameters for laser group	980 nm, 2 W	6 months
[50]	Diode	Improved clinical parameters for laser group	588 nm, 4 J/cm^2	12 months
[51]	Er,Cr:YSGG	Similar findings between test and control groups	2780 nm, 25–50 Hz, 2–3.5 W	3 months
[52]	Diode	Improved clinical parameters for laser group	810 nm, 1 W, 4 J/cm^2	1 week
[53]	Diode	Improved clinical parameters for laser group	980 nm, 2.5 W	6 months
[54]	Er:YAG	Similar findings between test and control groups	2940 nm 3 W, 300 mJ, 10 Hz, 1000 µs/1.20 W, 120 mJ, 10 Hz, and 100 µs	3 months
[55]	Diode	Improved aesthetic parameters for laser group	810 nm, 0.8 W	6 months

4. Discussion

Laser introduction in the last decade in the field of periodontal dentistry has led to a variety of laser types being developed, with their functionality and advantages studied not only in nonsurgical treatment but in the surgical phase of therapy as well. The main concept by which they can contribute is the restriction of epithelial proliferation from the marginal gingiva toward the periodontal pocket and thus the promotion of connective tissue attachment within through their ability to remodel and contour the gingiva and bony structures [56]. However, depending on the type, each laser operates at a specific wavelength, which is different from the others. This means that the variety of lasers can have a plethora of different tissue depth penetrations and thereby different results when applied in periodontal surgery.

The diode laser was the most commonly used laser in the studies included in this article, as not only was it more often selected compared to the other types, but it was also included in most of the studies, specifically in 11 [38,39,45–50,52,53,55] out of a total of 18. This fact could be potentially attributed to its relatively low, more affordable price and smaller and easier to relocate units compared to other lasers. As a laser type operating at wavelengths absorbed by pigments like hemoglobin and melanin, when applied in periodontal surgery, it is focused on the soft tissues of the periodontium, with the targeted granulation tissue being found in the operative area being the most important. Its use has been observed to enable the incising of flap margins with high precision and promoting hemostasis and wound healing [57]. Except for two [39,46] articles in which both the control and test groups provided the same therapeutic results, all of the rest of the studies [38,45,47–50,52,53] reported that the diode laser provided some additional benefit(s) to the surgery in which it was applied, indicating a high efficacy and usefulness for this type of laser in periodontal surgical therapy. Lastly, the correlation between different wavelength usages of the diode laser must also be noted. Three studies [47,49,53] used the same 980 nm wavelength function, one study [48] used a similar wavelength of 970 nm, and two studies [38,55] used the diode laser at a wavelength of 810 nm, all of which showed clinical improvements in their respective measurements.

Regarding the Er:YAG laser, a total of two articles [42,54] studied its use in periodontal surgery, with both comparing its effects in combination with soft tissue graft placement. The first article [42] used the laser parameters 2940 nm, 2 Hz, and 60 mJ/pulse only for root surface biomodification. It was concluded that the adjunctive use of the Er:YAG laser did not provide additional effects in soft tissue graft transplantation. The second study [54] used the Er:YAG laser with parameters 2940 nm, 3 W, 300 mJ, 10 Hz, and a very long pulse (1000 µs) mode for preparation of the recipient area of the graft, while for root surface biomodification, the parameters 1.20 W, 120 mJ, 10 Hz, and a medium short pulse (100 µs) mode were used. It was shown that the laser versus scalpel and convention surgery usages indicating similar clinical results in the graft area, implementation at the surgical site, and, hence, improvements in gingival recession. There was, however, published literature that showed high advantages and suggested that the Er:YAG laser's full potential may have not be yet discovered. For example, through its thermomechanical changing of the microstructure of the tooth's dentin surface [58], there was reported in vivo enhancement of initial cell and collagen attachment in addition to improved fibrin and blood clot formation in the laser's targeted area [59–61]. As mentioned in a previous section, the high absorption by water molecules of the operative wavelength of the Er:YAG laser enables it to ablate hard tissues with ease and without complications [62]. Several studies indicated that laser application led to a significant improvement in wound healing through improved fibroblast growth and adhesion rate on root surfaces compared to conventional mechanical debridement [63–65]. Delayed topical gingival fibroblast proliferation was reported when the laser was used at high energy levels, with effective absorption by the irradiated root surface during the healing period, which led to successful connective tissue reattachment [63]. New connective tissue formation along with disease progression was also reported in the laser's application in nonsurgical periodontal therapy [66]. However, on the other hand, it was also reported that root surfaces irradiated in vitro by the Er:YAG laser could obtain microirregularities [59,61]. Decreased biocompatibility potential and restricted early PDL cell attachment [67] because of this microarchitecture formation along with a possible break down of the surface's collagen fiber structures were also reported [61]. These provoke a confusion of results and effects regarding Er:YAG laser use and more so in periodontal surgery, since the literature on this subject remains limited.

In the same manner, another laser from the erbium family, the Er,Cr:YSGG laser, was found to be used with the parameters 2780 nm, 25–50 Hz, and 2–3.5 W only in one study [51] for open flap debridement and was compared with the conventional method. The study found the two methods to be of equal measure and concluded that Er,Cr:YSGG laser use is a safe and viable alternative. This was backed by another study [68], which observed the effect of this type of laser in soft and hard tissues of rats and found the soft tissue healing in both the laser and conventional surgical approaches to be similar. The new bone formation was, however, statistically better where the laser was applied compared to the surgical approach with a diamond bur. It was reported that when the Er,Cr:YSGG laser was used for treating intrabony defects with a closed approach, it had benefits of the same level as a minimally invasive surgical technique [69] (MIST), as described by Cortellini (2015). Further research regarding the efficacy of erbium lasers in bone recontouring of bone craters and defects along with root biomodification would surely help to improve our understanding of these lasers in the clinical field.

Results stemming from the articles that were included in this review and used the Nd:YAG laser were mixed. All three studies that examined its use [41,43,44] used a similar wavelength of 1064 nm at 10 Hz, with two studies [41,43] applying it with a power of 1 W, while the third study [44] applied it with a power of 100 mW. The latter [44] found the laser to be beneficial in the form of LLLT application to bone defects along with guided bone augmentation compared to conventional bone augmentation. The second [41] study used the laser for root conditioning of the recipient area before the placement of a soft tissue graft for the treatment of gingival recession. The clinical results found that the Nd:YAG laser with these parameters to be a negative addition for root conditioning. In the third study [43], the laser was used also for root surface biomodification, but the graft area was enhanced with enamel matrix proteins (EMD). The results showed similar clinical outcomes in both the test and control groups. Similarly, results for the CO_2 laser were limited. It was used only in one study [40], where a CAF was made in the test group, while a modified Widman flap was made in the control group. A monitoring of 15 years showed that CO_2 + CAF produced superior results compared to MWF.

5. Conclusions

The diode laser remains the most frequently utilized and effective laser in periodontal surgery among the studies reviewed, consistently demonstrating benefits such as precise incision, enhanced hemostasis, and improved wound healing. Its widespread use may be attributed to its affordability, portability, and efficacy in targeting soft tissues. By contrast, the Er:YAG laser, examined in two studies, shows potential as a viable alternative to conventional techniques, particularly in hard tissue ablation and wound healing, although its benefits remain inconsistent and its full potential remains underexplored due to mixed outcomes, including microirregularities on treated surfaces. Similarly, the Er,Cr:YSGG laser proved to be a safe and comparable alternative to traditional methods, with some evidence of superior bone formation, yet further research is needed to solidify its role in clinical applications. The Nd:YAG and CO_2 lasers present mixed and limited results, with the Nd:YAG laser showing varied efficacy across three studies and the CO_2 laser demonstrating superiority in one long-term study. Collectively, while diode lasers exhibit clear advantages, erbium family lasers and other lasers like Nd:YAG and CO_2 lasers require additional investigation to clarify their efficacy and optimize their use in periodontal therapy.

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