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THE CLINICAL AND MICROBIOLOGICAL EFFICACY OF ER:YAG LASERS IN THE TREATMENT OF PERI-IMPLANTITIS

| Adnane Salma [1*] | Kissi Lamia [1] | and | Azemmou Meryam [2] |

[1:] Department of Oral Surgery | Dental Consultation and Treatment Center | Ibn Rochd University Hospital Center | Casablanca | Morocco |
[2:] Private practice | Casablanca | Morocco |

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ABSTRACT

Background: Peri-implantitis represents a major biological complication following implant therapy, characterized by peri-implant inflammation and progressive bone loss. Conventional mechanical and chemical decontamination techniques have shown limited long-term success. The Er:YAG laser has emerged as a promising adjunctive modality due to its bactericidal and ablative properties. **Objective:** This review aimed to assess the clinical, microbiological, and morphological effectiveness of Er:YAG laser therapy in the treatment of peri-implantitis compared with conventional treatment modalities. **Materials and Methods:** A structured literature review was conducted in the PubMed (MEDLINE) and Google Scholar databases, following the PRISMA reporting framework. Articles published between 2015 and 2023, in English or French, evaluating Er:YAG laser therapy for peri-implantitis in human subjects, were eligible. Twenty-one studies met the inclusion criteria and were included in the qualitative synthesis. **Results:** Most studies reported significant reductions in probing depth (PD) following Er:YAG laser therapy. Some studies demonstrated improved short-term clinical outcomes when the laser was combined with regenerative surgical procedures. However, evidence regarding its long-term superiority over conventional mechanical debridement remains inconclusive. Microbiological outcomes were heterogeneous and inconsistent across the included studies. **Conclusion:** Er:YAG laser therapy appears to be effective in reducing probing depth and improving clinical parameters in the management of peri-implantitis, particularly when used as an adjunct to surgical regenerative therapy. Further studies with larger sample sizes and standardized protocols are necessary to confirm its efficacy for oral bacterial decontamination.

Keywords: *Peri-implantitis, Er:YAG laser, implant surface decontamination, regenerative therapy, laser dentistry.*

1. INTRODUCTION

Laser technology, an acronym for “Light Amplification by Stimulated Emission of Radiation,” represents a monochromatic, coherent, and collimated light source. Various laser systems have been introduced in dentistry, including the Nd:YAG, CO_2, diode, and erbium-family lasers (Tsuka et al., 2023). The Er:YAG laser (2940 nm wavelength) demonstrates high absorption in water and hydroxyapatite, making it particularly suitable for both hard and soft tissue applications. Its ability to ablate infected tissues and decontaminate implant surfaces has attracted increasing interest in the management of peri-implantitis (Macedo et al., 2016). Peri-implantitis is defined as an inflammatory condition affecting peri-implant tissues, characterized by bleeding on probing, increased probing depth, and progressive bone loss. Its prevalence reaches approximately 20% at the patient level and 11–20% at the implant level, representing a significant clinical challenge (Huang et al., 2021). The primary etiological factor of peri-implantitis is the accumulation of bacterial biofilm on implant surfaces, making effective surface decontamination the cornerstone of treatment. Conventional approaches include mechanical debridement, air-powder abrasion, antiseptic irrigation, antibiotic therapy, and resective or regenerative surgery (Diaz et al., 2022). However, complete implant surface decontamination remains difficult due to the complex morphology of implant threads. Laser-assisted therapy may offer improved decontamination without damaging titanium surfaces when properly calibrated (Saffarpour et al., 2016). The objective of this review is to assess the clinical and microbiological effectiveness of Er:YAG laser therapy in the management of peri-implantitis compared with conventional treatment modalities.

2. MATERIALS AND METHODS

This study was designed as a structured literature review conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to evaluate the clinical, microbiological, and morphological effectiveness of Er:YAG laser therapy in the treatment of peri-implantitis. Given the absence of a prospective registration, this review should be regarded as a structured (non-registered) literature review rather than a fully protocol-driven systematic review; prospective registration on PROSPERO is recommended for future updates of this work.

2.1 Focused Question and PICO Framework

The review question was formulated using the PICO framework: Population – patients diagnosed with peri-implantitis; Intervention – Er:YAG laser therapy, alone or combined with surgical/regenerative procedures; Comparison – conventional mechanical, chemical, or surgical decontamination methods (or no comparator, for single-arm studies); Outcome – clinical parameters (probing depth, bleeding on probing, clinical attachment level, radiographic bone fill), microbiological parameters (bacterial load, endotoxin/LPS levels), and morphological/thermal safety of the implant surface.

2.2 Search Strategy

A comprehensive electronic search was performed in the PubMed (MEDLINE) database and complemented by Google Scholar to identify relevant studies published between January 2015 and December 2023. The search strategy combined controlled vocabulary (MeSH terms) and free-text keywords around three core concepts: (1) Treatment (e.g., "Therapeutic," "Laser Therapy," "Treatment Outcome"), (2) Peri-implantitis, and (3) Er:YAG Laser. An illustrative Boolean search equation used in PubMed was: ("peri-implantitis"[MeSH] OR "peri-implantitis"[tiab]) AND ("Er:YAG"[tiab] OR "erbium"[tiab] OR "laser therapy"[MeSH]) AND ("treatment outcome"[MeSH] OR "decontamination"[tiab]). The reference lists of the retrieved articles and relevant systematic reviews were also hand-searched to identify additional eligible studies. Restricting the electronic search to a single bibliographic database (PubMed) supplemented only by Google Scholar is a recognized limitation, since it increases the risk of missing studies indexed exclusively in Scopus, Embase, Web of Science, or the Cochrane Central Register of Controlled Trials (CENTRAL); this limitation is acknowledged in the Discussion, and inclusion of these additional databases is recommended for future updates.

2.3 Eligibility Criteria

Studies were considered eligible if they met the following criteria: (1) published between 2015 and 2023; (2) written in English or French; (3) conducted on human subjects; and (4) evaluated the clinical, microbiological, and/or morphological outcomes of Er:YAG laser therapy in the management of peri-implantitis, reported as randomized controlled trials, prospective or retrospective cohort studies, case series, systematic reviews, or meta-analyses. In vitro studies, animal studies, isolated case reports without quantitative outcome data, conference abstracts, and publications lacking extractable clinical outcome data were excluded.

2.4 Study Selection

Titles and abstracts identified by the search strategy were independently screened by two reviewers against the eligibility criteria; full texts of potentially eligible articles were then retrieved and independently assessed for inclusion by the same two reviewers. Disagreements at either stage were resolved by discussion and, where necessary, by consulting a third reviewer. Duplicate records retrieved across the two search sources were identified and removed prior to screening. A total of 2957 records were initially identified through the electronic search. After removing 942 records published before 2015 and duplicate entries, 2,015 records were screened based on title and abstract, of which 49 full-text articles were assessed for eligibility. Ultimately, 21 studies met the inclusion criteria and were retained for qualitative synthesis (Table 1). The complete study-selection pathway, including reasons for exclusion at the full-text stage, is summarized in a PRISMA flow diagram (not reproduced here for brevity, but available on request).

2.5 Data Extraction

Data extraction was performed independently by two reviewers using a standardized, pilot-tested form based on the PICO framework, and discrepancies were cross-checked against the source articles. Extracted data included: study design and sample size; implant surface characteristics; laser parameters (wavelength, energy per pulse, frequency, water-cooling settings); comparator intervention; follow-up duration; and clinical, microbiological, and morphological outcome measures.

2.6 Quality and Risk-of-Bias Assessment

Methodological quality was appraised according to study design: the Cochrane Risk-of-Bias tool (RoB 2) was used for randomized controlled trials, the Newcastle–Ottawa Scale (NOS) for non-randomized cohort and case-series studies, and AMSTAR-2 for the systematic reviews and meta-analyses included in the synthesis. This step, together with the substantial clinical and methodological heterogeneity across the included studies (differing laser parameters, comparators, and follow-up durations), precluded a quantitative meta-analysis; findings were therefore synthesized narratively, which should be considered when interpreting the strength of the conclusions.

2.7 Data Synthesis

Given the heterogeneity of study designs, laser parameters, and outcome measures identified during data extraction, a qualitative (narrative) synthesis was adopted rather than a pooled meta-analysis. Outcomes were grouped into three domains – clinical, microbiological, and morphological/thermal safety – to allow a structured comparison of Er:YAG laser therapy with conventional decontamination modalities across the included studies.

3. RESULTS

3.1 Study Selection

The initial search identified 2,957 articles. After excluding 942 studies published before 2015, 2,015 articles were screened based on titles and abstracts, resulting in 49 full-text articles assessed for eligibility. Ultimately, 21 studies met the inclusion criteria and were included in the qualitative synthesis (Table 1). These studies included randomized controlled trials, prospective case series, systematic reviews, and meta-analyses, reflecting the diversity of current research on Er:YAG laser therapy in peri-implantitis management (Wang et al., 2021; Baima et al., 2022; Clem & Gunsolley, 2019; Huang et al., 2021; Ramanauskaite et al., 2023; Natto et al., 2015; Schwarz et al., 2017; Lei & Yingqi, 2023; Hu et al., 2021; Świder et al., 2019; Smeo et al., 2018; Li et al., 2021; Nikitas, 2019; Pisano et al., 2021; Chala et al., 2020; Lin et al., 2019; Saneja et al., 2020; Yamamoto, 2021; Komatsu et al., 2018; Norton, 2017).

Table 1: Articles Included from the Search Strategy.

No.	Author	Title	Year	Article Type
1	Chin-Wei Wang et al.	Laser-Assisted Regenerative Surgical Therapy for Peri-implantitis	2021	Randomized clinical trial (24 patients)
2	Giacomo Baima et al.	Surface decontamination protocols for surgical treatment of peri-implantitis: A systematic review with meta-analysis	2022	Systematic review of 16 articles
3	Donald Clem et al.	Peri-implantitis Treatment Using Er:YAG Laser and Bone Grafting. A Prospective Consecutive Case Series Evaluation: 1 Year Posttherapy	2019	Prospective case series
4	Peijun Huang et al.	Efficacy of Er:YAG laser irradiation for decontamination and its effect on biocompatibility of different titanium surfaces	2021	Experimental in vivo study
5	Ausra Ramanauskaite et al.	Photo/mechanical and physical implant surface decontamination approaches in conjunction with surgical peri-implantitis treatment: A systematic review	2023	Systematic review of 6 articles
5*	Zuhair S. Natto et al.	Comparison of the Efficacy of Different Types of Lasers for the Treatment of Peri-Implantitis: A Systematic Review	2015	Systematic review of 13 articles
6	Schwarz Frank et al.	Combined surgical therapy of advanced peri-implantitis evaluating two methods of surface decontamination: a 7-year follow-up observation	2016	Randomized clinical trial (15 patients)
7	Lei Li et al.	Efficacy of Er:YAG Laser as a Debridement Method in Surgical Treatment for Peri-Implantitis: A Systematic Review	2023	Systematic review of 5 randomized clinical trials
8	Meng-Long Hu et al.	Network meta-analysis of the treatment efficacy of different lasers for peri-implantitis	2021	Meta-analysis
9	Katarzyna Świder et al.	Effect of Different Laser Wavelengths on Periodontopathogens in Peri-Implantitis: A Review of In Vivo Studies	2019	Literature review of 7 articles
10	Khaled Smeo et al.	Antibacterial effect of Er:YAG laser in the treatment of peri-implantitis and their effect on implant surfaces: a literature review	2018	Literature review of 29 articles
11	Lu Li et al.	The clinical efficacy of Er:YAG lasers in the treatment of peri-implantitis: a systematic review and meta-analysis	2021	Meta-analysis of 10 articles
12	Alexandros Nikitas	Er:YAG and Diode Lasers in Treatment of Peri-Implantitis–A Case Report	2019	Case report
13	Massimo Pisano et al.	Laser Therapy in the Treatment of Peri-Implantitis: State-of-the-Art, Literature Review and Meta-Analysis	2021	Meta-analysis of 14 articles

14	Marianna Chala et al.	Adjunctive Use of Lasers in Peri-Implant Mucositis and Peri-Implantitis Treatment: A Systematic Review	2020	Systematic review of 9 randomized clinical trials
15	Taichen Lin	Clinical evaluation of multiple peri-implant bony defect management by Er:YAG laser-assisted bone regenerative therapy	2019	Case report
16	Ritu Saneja et al.	Efficacy of different lasers of various wavelengths in treatment of peri-implantitis and peri-implant mucositis: A systematic review and meta-analysis	2020	Systematic review of 11 randomized clinical trials
17	Atsuhiko Yamamoto et al.	Efficacy of Erbium:YAG Laser for Regenerative Surgical Treatment of Peri-implantitis: Clinical, Microbiological, and Biomarker Analyses	2021	Clinical trial
18	Komatsu Y et al.	Effectiveness of an erbium-doped: yttrium, aluminum and garnet laser for treatment of peri-implant disease: Clinical, microbiological, and biochemical marker analyses	2018	Randomized clinical trial (20 patients)
19	Michael R. Norton	Efficacy of Er:YAG Laser in the Decontamination of Peri-implant Disease: A One-Year Prospective Closed Cohort Study	2017	Cohort study

3.2 Clinical Outcomes

Most studies reported improvements in key clinical parameters following Er:YAG laser therapy:
Probing Pocket Depth (PPD): A prospective cohort study reported a reduction in mean PPD from 5.9 mm at baseline to 3.1 mm at the one-year follow-up. Deep pockets (≥6 mm) were reduced to a mean of 3.5 mm at 12 months.
Bleeding and Suppuration: Spontaneous bleeding decreased from 50% at baseline to 10% after one year, while spontaneous suppuration was reduced from 60% to 30% over the same period.
Clinical Attachment Level (CAL) and Bone Fill: A significant gain in CAL was observed following treatment. When combined with bone grafting, Er:YAG laser therapy resulted in a mean radiographic bone fill ranging from 1.34 mm (mesial) to 1.52 mm (distal) in infra-osseous defects.
Despite these favorable findings, some studies reported outcomes comparable to those obtained with conventional mechanical debridement, suggesting that the clinical superiority of Er:YAG laser therapy remains inconclusive.

3.3 Microbiological Outcomes

The Er:YAG laser demonstrated superior bactericidal efficacy for decontaminating various implant surfaces:
Bacterial Reduction: At an energy setting of 100 mJ/pulse, Er:YAG laser irradiation achieved a bacterial reduction of 84.1% on sandblasted large-area (SLA) titanium surfaces and approximately 77.85% on hydroxyapatite (HA)-coated surfaces.
Endotoxin Elimination: Laser irradiation was associated with a significant reduction in lipopolysaccharide (LPS) levels, which are bacterial endotoxins adhering to contaminated implant surfaces and known to impair re-osseointegration.

3.4 Morphological and Thermal Safety

Morphological studies using Scanning Electron Microscopy (SEM) confirm that the Er:YAG laser preserves implant integrity when optimal parameters are respected:
Optimal Settings: A configuration of 100 mJ/pulse, 1 W, and 10 Hz combined with continuous water spray, achieves effective decontamination without inducing surface alterations or significant temperature increases.
Damage Thresholds: Energy levels ≥180 mJ/pulse were associated with noticeable surface damage, including melting of sandblasted large-area (SLA) titanium surfaces and detachment of hydroxyapatite (HA) coatings.
Reflective Properties: Titanium reflects approximately 71% of Er:YAG laser radiation, limiting direct energy absorption by the implant and thereby reducing the risk of thermal damage to surrounding bone tissues when appropriate clinical parameters are used.

4. DISCUSSION

Laser technology (Light Amplification by Stimulated Emission of Radiation) produces a monochromatic, coherent, and collimated beam of high-energy light. In dentistry, several laser systems have been introduced, including Er:YAG, Nd:YAG, diode, CO_2, and argon lasers. Their clinical applications depend on wavelength and tissue interaction properties, allowing use in both hard- and soft-tissue procedures (Tsuka et al., 2023). Among these systems, the erbium-doped yttrium aluminum garnet (Er:YAG) laser, operating at a wavelength of 2940 nm, has attracted significant attention due to its selective interaction with biological tissues. Its high absorption in water and hydroxyapatite, major components of hard and soft oral tissues, enables rapid energy transfer and localized thermomechanical tissue removal while minimizing thermal diffusion to surrounding structures. The pulsed emission mode, combined with water spray, further regulates temperature and enhances clinical safety (Macedo et al., 2016). In implant dentistry, these properties have prompted growing interest in the use of Er:YAG lasers for the management of peri-implant diseases. Peri-implantitis is primarily a biofilm-induced inflammatory condition characterized by progressive bone loss around dental implants, making effective implant surface decontamination a critical component of its management (Schwarz et al., 2017; Lei & Yingqi, 2023). Conventional approaches include mechanical debridement, air-powder abrasion, antiseptic irrigation, antibiotic therapy, and resective or regenerative surgery; however, these methods often provide limited long-term clinical and microbiological improvements and may alter implant surface characteristics. In this context, the Er:YAG laser has been proposed as a promising adjunctive or alternative therapeutic approach (Renvert & Polyzois, 2015).

This structured literature review aimed to evaluate the effectiveness of Er:YAG laser therapy in managing peri-implantitis, with a focus on clinical, microbiological, and morphological outcomes. Overall, most studies reported improvements in clinical parameters such as probing depth (PD), bleeding on probing (BOP), and clinical attachment level (CAL) following Er:YAG laser therapy. Several trials demonstrated a significant short-term reduction in PD (up to 6 months), likely due to the laser's ability to remove granulation tissue and decontaminate implant surfaces without inducing thermal damage (Li et al., 2021). Nevertheless, when compared to conventional mechanical debridement, results are inconsistent. Multiple systematic reviews and meta-analyses found no statistically significant differences between Er:YAG laser therapy and traditional treatments regarding CAL gain, BOP reduction, or plaque index improvement. These findings suggest that, although effective, the laser may not provide substantial additional benefits as a standalone treatment (Natto et al., 2015; Chala et al., 2020). Interestingly, some studies indicate that adjunctive use of the Er:YAG laser in surgical or regenerative procedures can enhance outcomes (Wang et al., 2021; Lin et al., 2019). In particular, its combination with bone grafting has shown promising results in terms of defect fill and pocket depth reduction, highlighting the laser's potential role as part of a combined therapeutic strategy rather than as an isolated intervention (Clem & Gunsolley, 2019).

However, from a microbiological standpoint, the antibacterial effects of Er:YAG laser remain controversial. While some studies have reported a significant reduction in bacterial load, others observed only limited or transient microbiological effects. These discrepancies may be attributed to variations in laser parameters, treatment protocols, and study designs (Świder et al., 2019; Smeo et al., 2018). In fact, Huang et al. reported bacterial reductions of 84.1% on SLA titanium surfaces and approximately 77.85% on hydroxyapatite-coated surfaces at an energy setting of 100 mJ/pulse. Furthermore, Yamamoto and Komatsu et al. reported significant reductions in lipopolysaccharide (LPS) levels following laser irradiation, suggesting an important role in detoxifying contaminated implant surfaces (Yamamoto, 2021; Komatsu et al., 2018). However, despite these promising short-term antimicrobial effects, Świder et al. found no significant long-term impact on peri-implant microbiota (Świder et al., 2019). Similarly, Komatsu et al. reported no significant reduction in specific peri-implant pathogens despite clinical improvements (Komatsu et al., 2018). These findings suggest that bacterial recolonization and host-related factors may limit the long-term microbiological efficacy of the laser (Świder et al., 2019; Komatsu et al., 2018). Morphological analyses using scanning electron microscopy have confirmed that the Er:YAG laser can effectively decontaminate implant surfaces without causing structural damage when appropriate parameters are applied (Smeo et al., 2018). Optimal settings, typically around 100 mJ/pulse with water cooling, preserve surface integrity and prevent thermal injury. In contrast, higher energy levels have been associated with surface alterations, including titanium melting and detachment of hydroxyapatite coatings (Smeo et al., 2018). These findings underscore the importance of strict parameter control to ensure both safety and efficacy (Ramanauskaite et al., 2023). The heterogeneity observed across studies represents a major limitation in interpreting the available evidence (Baima et al., 2022; Ramanauskaite et al., 2023; Pisano et al., 2021). Variations in study design, laser parameters, treatment protocols, follow-up durations, and outcome measures make direct comparisons challenging (Baima et al., 2022; Pisano et al., 2021). In addition, the inclusion of different implant surface types and defect morphologies further contributes to variability in outcomes (Ramanauskaite et al., 2023). Another important limitation is the relatively short follow-up period in most studies. Given the chronic and progressive nature of peri-implantitis, long-term data are essential to determine the true effectiveness and stability of treatment outcomes (Schwarz et al., 2017). The lack of standardized protocols also limits the reproducibility and clinical applicability of the findings (Baima et al., 2022; Pisano et al., 2021). Despite these limitations, the Er:YAG laser presents several advantages, including its minimally invasive nature, reduced patient discomfort, effective decontamination capacity, and ability to preserve the integrity of the implant surface (Pisano et al., 2021). These properties make it a valuable adjunct in the management of peri-implantitis (Pisano et al., 2021).

5. CONCLUSION

Er:YAG laser therapy appears to be an effective adjunct in the management of peri-implantitis, providing clinical outcomes comparable to conventional treatments while offering advantages in precision and tissue preservation.

Although short-term results are promising, further well-designed studies with standardized protocols are required to confirm its long-term efficacy and optimize its clinical application.

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