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LASERS IN THE MANAGEMENT AND PREVENTION OF PERI-IMPLANTITIS: A NARRATIVE REVIEW OF CURRENT EVIDENCE AND FUTURE DIRECTIONS

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ABSTRACT

Current laser systems used in the management and prevention of peri-implantitis, recognizing that despite multiple therapeutic strategies, no gold-standard treatment exists. The aim also addresses the limitations of traditional mechanical debridement, which may damage implant surfaces, and highlights the potential advantages of laser-assisted decontamination. A narrative review approach examining existing literature on various laser modalities used in peri-implantitis therapy. The review focuses on commonly employed laser systems, their mechanisms, clinical applications, and the rationale behind their use as adjunctive or alternative treatment options to conventional mechanical debridement. Findings indicate that multiple laser systems demonstrate effective implant surface decontamination with minimal surface alteration compared to traditional mechanical instruments. Evidence supports their utility in both non-surgical and surgical peri-implantitis management, though variability exists in clinical outcomes due to differences in laser parameters, implant surface types, and disease severity. The extensive variation in laser types, operational parameters, and clinical methodologies across the literature complicates comparative analysis and hinders the development of standardized treatment protocols. This underscores the urgent need for robust, controlled clinical trials to facilitate evidence-based guidelines and enhance the predictability of laser-based interventions for peri-implantitis.

INTRODUCTION

Dental implants are well recognized for their high rates of long-term success and survival; however, they are still vulnerable to biological complications that may undermine their stability over time. One of the most common complications is peri-implantitis, a plaque-induced inflammatory condition that, if left untreated, can lead to progressive bone loss and eventual implant failure. Effective debridement and surface decontamination are crucial to both preventing and managing this condition. Nonetheless, conventional mechanical methods are often insufficient and may even alter or damage the surface of the implant.[1,2]

To overcome these limitations, lasers have been introduced as adjunctive tools in peri-implant disease management. Implant surfaces are engineered with varying levels of roughness — including macro-, micro-, and nano-scale modifications — to promote osseointegration. Preserving these features during non-surgical peri-implantitis therapy is considered essential, as they may support bone regeneration in peri-implant defects. This differs from surgical approaches, where procedures like implantoplasty are sometimes employed to intentionally alter the surface and facilitate cleaning.[3,4]

Numerous studies have evaluated the potential of laser systems in preserving implant surface integrity while achieving microbial decontamination. However, wide variability in the types of lasers, power settings, exposure times, and implant designs makes the existing literature difficult to interpret. Moreover, since laser energy can interact with both the titanium substrate and the microbial biofilm, there is a concern that the beneficial surface characteristics of the implant may be compromised.[5,6]

Although implants exhibit excellent survival rates — between 95.2% and 96.8% at five years, and 86.7% to

92.8% at ten years — peri-implant diseases remain a substantial clinical challenge. These biological complications stem from infections affecting the peri-implant tissues and are often linked to factors such as poor oral hygiene, a history of periodontitis, smoking, or systemic conditions like diabetes. Peri-implantitis shares its microbial etiology with periodontitis, with bacterial colonization triggering inflammation and subsequent tissue destruction.[7,8]

As such, routine monitoring and maintenance, along with effective surface decontamination, are essential for the long-term success of implant therapy. Owing to the similarity in disease mechanisms, treatment strategies for peri-implantitis often parallel those used in periodontitis, with the goal of thoroughly removing biofilm and calculus from both supra- and subgingival regions.[9]

When initial non-surgical debridement proves ineffective, surgical intervention may be required, often combined with adjunctive antiseptics or antibiotics. Mechanical debridement techniques typically involve plastic or carbon-fiber instruments, air-abrasive devices, or localized delivery of antimicrobial agents. Despite the range of available methods, no single protocol has emerged as superior. Consequently, there is increasing interest in whether laser therapy could achieve comparable or better results while preserving implant surface properties.[10,11]

In one comparative study, the use of an Er: YAG laser, chitosan brushes, and titanium curettes was evaluated for decontaminating biofilm from implant surfaces. While all three methods effectively reduced the bacterial load, titanium curettes resulted in notable surface alterations, whereas the Er:YAG laser and chitosan brushes maintained surface integrity.[12]

Lasers in the Management of Peri-implantitis

Various laser systems have been studied for their potential role in treating periodontal and peri-implant diseases. These devices operate across a broad electromagnetic spectrum, including visible light (400–700 nm), near-infrared (700–1500 nm), and mid-to-far-infrared wavelengths (1500–11,000 nm), each with distinct tissue interactions.[13,14]

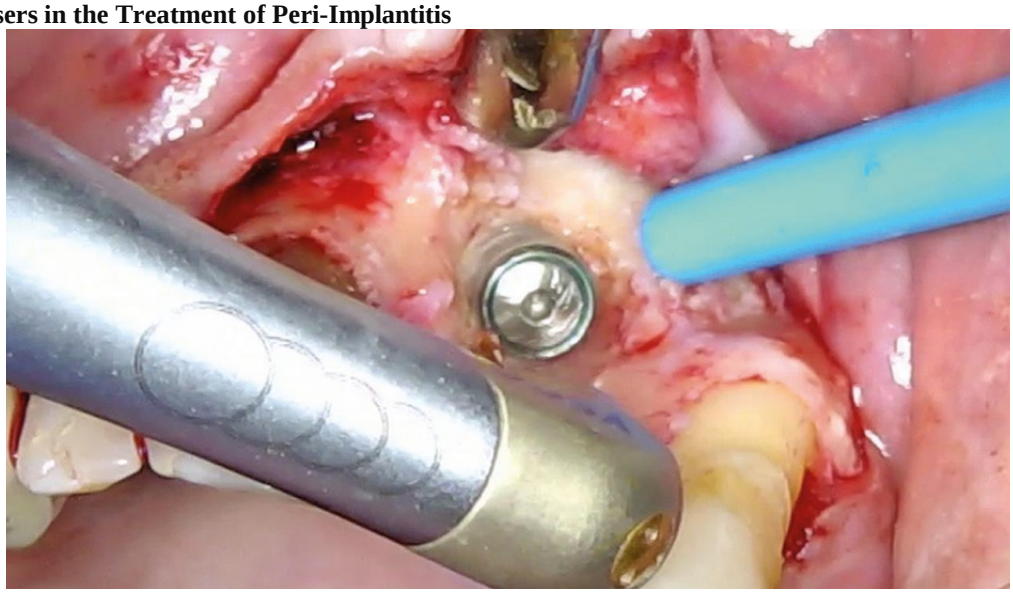
Infrared lasers are of particular interest in dental applications. Among these, the most frequently investigated types include.

- Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) laser at 1064 nm.
- Erbium-doped Yttrium Aluminium Garnet (Er:YAG) laser at 2940 nm.
- Erbium, Chromium-doped Yttrium Scandium Gallium Garnet (Er,Cr:YSGG) laser at 2780 nm.
- Carbon Dioxide (CO_2) lasers at 9300 and 10,600 nm
- Diode lasers operating between 810 and 980 nm.

Among these systems, Er:YAG lasers have gained significant attention for non-surgical periodontal therapy. Several clinical trials have demonstrated that Er:YAG lasers can yield clinical outcomes comparable to those achieved through conventional mechanical debridement.[15,16] Their capacity for effective biofilm disruption, combined with their minimally invasive nature, supports their use as a safe and efficient adjunctive treatment modality.

The selection of an appropriate laser type depends on multiple factors, including tissue composition, target pathogens, and the anatomical complexity of the treatment site. Each wavelength interacts uniquely with tissue components such as water, hemoglobin, and hydroxyapatite, influencing both efficacy and safety outcomes.[17] As such, clinicians must consider both the optical and thermal properties of the laser when integrating it into peri-implantitis treatment protocols.

Erbium Lasers in the Treatment of Peri-Implantitis



Erbium lasers, specifically Er:YAG (2940 nm) and Er,Cr:YSGG (2780 nm), have been extensively researched for their application in peri-implantitis management. Their wavelengths are strongly absorbed by water, producing high-frequency micro-explosions and cavitation effects that disrupt biofilm and provide bactericidal effects. This mechanism is beneficial for implant surface decontamination while preserving structural integrity.[18,19]

Studies indicate that Er:YAG lasers can effectively remove dental plaque and calculus without causing thermal damage or altering the implant's micro-topography, as long as the energy settings are optimized. For instance, pulse energies ranging from 60 to 180 mJ/pulse and longer pulse durations (250–300 µs) have shown minimal surface damage.[20] However, excessive energy levels or prolonged irradiation can adversely affect implant surfaces and hinder osteoblast attachment.[21]

To mitigate risks, the use of concurrent water irrigation during irradiation is recommended, as dry laser applications tend to generate higher heat and surface changes. Custom-designed fiber tips—such as chisel- or conical-shaped—enhance precision, allowing targeted delivery and reduced energy dispersion to adjacent tissues.[22]

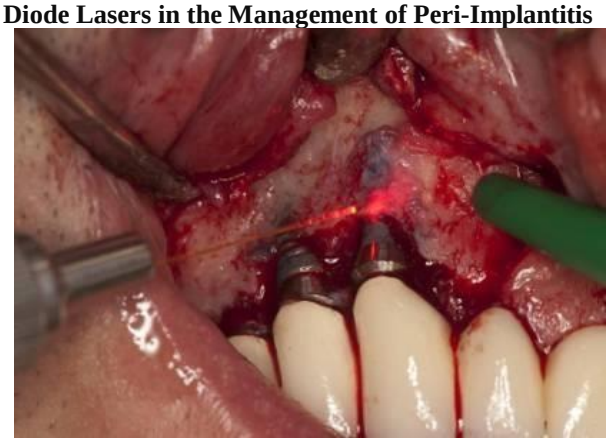
Surface roughness also influences laser-tissue interaction. Implants with moderately rough surfaces (Sa 1–2 µm) are more susceptible to surface modifications compared to machined surfaces, which are smoother and exhibit higher resistance to laser-induced topographic changes.[23] Additionally, the design of the handpiece and the fiber tip geometry can affect energy density and distribution, with focusing tips generating higher power densities that may increase surface alteration risk.[24]

Nd:YAG Laser in the Treatment of Peri-Implantitis

The Nd:YAG laser (1064 nm) is recognized for its deep tissue penetration and bactericidal effects but poses challenges in implant decontamination. Its energy is poorly absorbed by water but readily absorbed by titanium, increasing the risk of thermal damage.[25] Early studies have shown significant surface alterations to titanium implants when using Nd:YAG lasers at conventional power levels.[26]
Recent efforts have focused on reducing power output and using longer pulse durations with cooling techniques to minimize thermal injury. Despite these adjustments, repeated pulses can cause cumulative surface damage, especially on roughened titanium surfaces which absorb more energy.[27,28]

Dry conditions exacerbate these effects, producing distinctive spindle-shaped ablation patterns. Use of conical tips can help distribute energy and reduce localized fluence, minimizing surface degradation risks.[29]

Diode Lasers in the Management of Peri-Implantitis



Diode lasers, particularly those operating at 810–980 nm, are popular in peri-implantitis treatment due to their compact design and strong bactericidal effects. Studies using 980 nm and 809 nm diode lasers report significant bacterial reduction on titanium surfaces without causing visible damage, particularly at power levels below 3 W.[30]

However, full bacterial eradication on complex implant surfaces, such as SLA (sand-blasted, large-grit acid-etched), remains inconsistent. These surfaces contain intricate micro- and nano-structures that may harbor microbes beyond the laser's reach.[31]

The wavelength of diode lasers affects how energy interacts with blood and tissue. For example, blue and green wavelengths exhibit high absorption in blood, increasing localized temperature. To avoid thermal side effects, pulsed modes and low average power settings are advised.[32]

Carbon Dioxide (CO_2) Lasers in the Management of Peri-Implantitis

CO_2 lasers (10,600 nm) are highly absorbed by water, making them effective for soft tissue ablation and bacterial decontamination. They reflect off titanium surfaces, minimizing the risk of physical damage during use.[33]

Typically employed in open flap surgical procedures, CO_2 lasers are effective for granulation tissue removal and exposure of implant surfaces. However, their use in closed debridement is limited by technical challenges in subgingival energy delivery and lack of lateral energy dispersion.[34]

Past attempts to adapt CO_2 lasers for preventive or non-invasive therapy faced limitations due to impractical settings and inadequate control. Thus, their primary utility remains confined to visual access surgical procedures.[35]

Influence of the Laser Delivery System

The efficacy and safety of laser treatment depend heavily on the laser delivery system. Different systems utilize optical fibers, articulated arms, or hollow waveguides to transmit laser energy to target tissues. Fiber tip geometry, emission pattern, and rigidity all affect beam divergence, energy density, and operator control.[36,37]

Standard fiber tips emit a narrow, forward-directed beam that may not adequately reach subgingival implant threads. Therefore, innovations such as side-firing and conical tips have been developed to improve lateral emission and precision.[38] Mechanically or chemically modified fiber tips with honeycomb patterns have been shown to improve subgingival laser application and reduce collateral tissue exposure.[39]

DISCUSSION

This review highlights the diverse laser systems used in peri-implantitis management and their specific interactions with implant surfaces. Among them, Er:YAG and Er,Cr:YSGG lasers demonstrate the most favorable balance between decontamination efficacy and preservation of implant integrity.[40] In contrast, Nd:YAG and diode lasers carry a higher risk of surface damage, particularly if not carefully calibrated. CO_2 lasers are valuable in open procedures but are limited in closed contexts.

Challenges in tip design, laser wavelength selection, and energy control hinder standardization of laser therapy in clinical practice. Moreover, the majority of available evidence stems from in vitro or animal studies, emphasizing the need for human-based randomized trials. Future research must focus on long-term clinical endpoints such as probing depth reduction, bone stability, and implant survival to validate these technologies.[41]

CONCLUSION

Lasers present a promising adjunctive approach in peri-implantitis management, offering effective biofilm removal while minimizing surface damage. Er:YAG lasers, in particular, stand out for their favorable safety and efficacy profiles in non-surgical applications.[42]

However, the lack of standardized treatment parameters, variability in clinical outcomes, and limited long-term evidence prevent conclusive recommendations. Well-designed clinical trials and clear operational guidelines are essential to integrate laser therapies reliably into routine peri-implant care.

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