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ADVANCEMENTS IN LASER TECHNOLOGY FOR PERIODONTAL THERAPY: A COMPREHENSIVE REVIEW

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ABSTRACT

Periodontal disease, a prevalent oral health issue, has traditionally been treated using invasive surgical methods. In recent years, laser technology has emerged as a promising alternative in Periodontics. This comprehensive review examines various laser types, their mechanisms of action, and clinical applications. It assesses advantages and disadvantages, patient outcomes, and safety considerations. Furthermore, the article explores future directions, including emerging laser technologies and integration with digital dentistry. Understanding these advancements is crucial for enhancing Periodontal care and patient outcomes.

Keywords: Periodontics, laser technology, minimally invasive, clinical applications, patient outcomes, photothermal effects, photobiomodulation, digital dentistry.

INTRODUCTION

Periodontal disease, characterized by the inflammation and deterioration of the supporting structures of teeth, remains a significant global concern for oral health. It can affect people of all age groups and, if left untreated, may result in tooth loss[1]. Traditional treatment methods for periodontal disease have mainly involved surgical operations, mechanical cleaning, and the use of additional medications. While these approaches have been proven effective, they often come with drawbacks such as discomfort, extended recovery periods, and varying levels of invasiveness[2]. In recent decades, the field of periodontics has undergone a profound transformation with the introduction of laser technology. LASER, an acronym standing for "light amplification by stimulated emission of radiation," which was once considered a concept from science fiction, has now become a valuable tool for conducting minimally invasive and efficient therapeutic procedures in dentistry[3]. These lasers possess distinctive features, including precision, the ability to selectively interact with tissues, and the capacity to sterilize, all of which have opened up new possibilities for innovative treatment approaches in periodontics. The justification for integrating lasers into Periodontics is clarified, emphasizing the demand for less invasive and more patient-friendly alternatives to the conventional treatment methods. An essential aspect of harnessing the potential of lasers in Periodontics is understanding how they work, as this knowledge serves as the foundation for their practical applications. These clinical applications encompass a wide range of procedures, including both nonsurgical and surgical interventions for periodontal issues, as well as the management of soft tissues and the treatment of peri-implantitis[4]. Furthermore, the role of lasers in addressing pain and inflammation in the context of periodontal care is thoroughly explored. Although lasers offer numerous advantages, such as enhanced precision, reduced bleeding, and improved patient comfort, it's important to acknowledge that they are not without limitations and potential disadvantages. This review provides a comprehensive examination of both the benefits and drawbacks associated with laser therapy in, aiming to offer a balanced perspective for both clinicians and researchers. Additionally, the article evaluates patient outcomes and safety considerations linked to laser therapy, including the effectiveness of treatment, patient comfort levels, and safety precautions. In conclusion, the discussion extends to the future directions of the field, highlighting emerging laser technologies and the integration of lasers with digital dentistry, which have the potential to redefine the landscape of periodontal care.

CLASSIFICATION AND TYPES OF LASER

Classification of lasers is based on several factors, including the state of the medium, output energy, and oscillation mode[4][5]:

Based on the state of the medium:

1. Solid-state lasers: These lasers use a solid crystalline or glass medium to generate laser light. Examples include Nd:YAG and Er:YAG lasers.

2. Gas lasers: Gas lasers employ a gas mixture as the active medium to produce laser emissions. The CO2 laser is a prominent example in dentistry.

3. Excimer lasers: Excimer lasers use reactive gases, typically a combination of noble gases and halogens, as the active medium. They are known for their use in refractive eye surgery (e.g., LASIK).

4. Diode lasers: Diode lasers use semiconductor materials as the active medium. They are commonly used in soft tissue procedures and photobiomodulation therapy.

Based on output energy:

1. Low output, soft, or therapeutic lasers: These lasers produce relatively low energy levels and are often used for therapeutic purposes. Examples include the He-Ne laser, Ga-As laser, and Ga-Al-As laser.

2. High output, hard, or surgical lasers: These lasers generate high-energy laser beams and are suitable for surgical and cutting applications. Examples include the CO2 laser and Nd:YAG laser.

Based on oscillation mode:

1. Continuous wave lasers: Continuous wave lasers emit a continuous stream of laser energy. They are commonly used in surgical settings when a continuous and consistent laser beam is needed.

2. Pulsed wave lasers: Pulsed wave lasers emit laser energy in pulses, with brief bursts of high energy followed by periods of no output. These lasers are versatile and are used in various applications, including both surgical and non-surgical procedures.

LASER DELIVERY SYSTEMS

1. Articulated Arm Delivery Systems:

Articulated arm delivery systems consist of a series of rigid hollow tubes equipped with mirrors at each joint (referred to as knuckles). These mirrors reflect the laser energy down the length of the tube.

However, these systems have some drawbacks, including their bulkiness and non-contact nature. They are not well-suited for precise procedures within the oral cavity.

2. Flexible Hollow Waveguide or Tube:

A flexible hollow waveguide or tube features an interior mirror finish, allowing laser energy to be reflected along its length. The energy exits through a hand piece located at the surgical end, interacting with the tissue in a non-contact manner. An accessory tip made of sapphire or hollow metal can be attached to the end of the waveguide for contact with the surgical site[6].

3. Glass Fiberoptic Cable:

Glass fiberoptic cables are more flexible, lightweight, and offer less resistance to movement compared to waveguides. They have a smaller diameter and are often encased in a protective sheath. However, glass fibers can be fragile and may not bend sharply. They fit snugly into a handpiece and can be used for both contact and non-contact laser procedures[6].

The dental laser device can emit light energy in two main modalities over time:

Continuous Wave (CW): In this mode, the laser beam is emitted at a constant power level for as long as the operator presses the foot switch. It provides a continuous output of laser energy.

Pulsed Mode: Pulsed mode emission includes variations in laser energy output as a function of time. There are two subcategories:

Gated-Pulse Mode: Laser energy is emitted periodically, similar to a blinking light, with regular on-off cycles.

Free-Running Pulsed Mode (True Pulsed): In this mode, the laser emits large peak energies of laser light for a very short duration, typically in microseconds, followed by a relatively long period during which the laser is off.

The choice of laser emission mode is crucial as it affects how laser energy interacts with tissue. In pulsed modes, tissue has time to cool between laser pulses, reducing the risk of overheating. In contrast, continuous wave mode requires the operator to manually control the laser emission to allow tissue thermal relaxation. For hard-tissue laser procedures, the use of a water spray can prevent micro fracturing of crystalline structures and reduce the likelihood of carbonization[7].

SALIENT FEATURES OF LASERS USED IN DENTISTRY:

1. Diode Lasers (810-980 nm):

Diode lasers are commonly used for soft tissue procedures in periodontics. They are effective for procedures such as gingival contouring, crown lengthening, and pocket disinfection. They provide good hemostasis and coagulation and are often used for aesthetic procedures due to their precise cutting ability in soft tissues.

2. Nd:YAG Lasers (1064 nm):

Nd:YAG lasers have applications in both soft and hard tissue treatments. In periodontics, they are used for pocket decontamination, bacterial reduction, and soft tissue procedures. Their longer wavelength allows for deeper penetration into tissues, making them effective for debriding periodontal pockets

3. Er:YAG and Er,Cr:YSGG Lasers (2780 and 2940 nm):

These lasers are primarily used for hard tissue applications, such as calculus and plaque removal. They are also used in periodontics for non-surgical and surgical procedures, including scaling and root planing, as they can efficiently remove hard deposits from tooth surfaces.

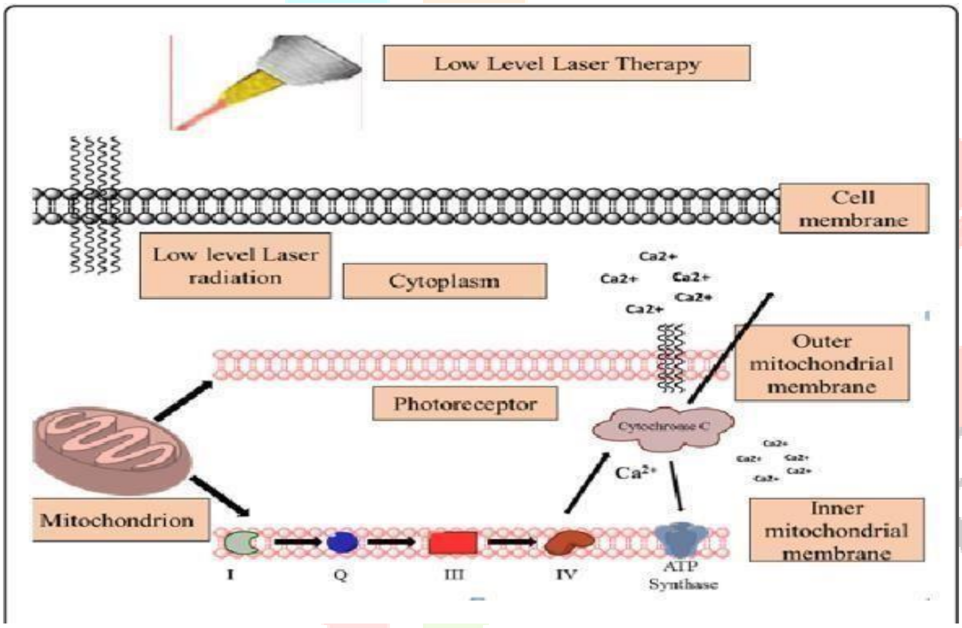
4. CO2 Lasers (10,600 nm):

CO2 lasers are versatile and can be used for both soft and hard tissue procedures. In periodontics, they are employed for soft tissue contouring, incisions, and pocket sterilization. Their precise cutting and ablative capabilities make them valuable tools in various periodontal treatments.

5. Er:YAG/Er,Cr:YSGG Lasers (Waterlase):

- **Clinical Applications:** These lasers are specifically designed for minimally invasive dental treatments. They are used in periodontics for procedures such as periodontal pocket debridement, crown lengthening, and soft tissue surgery. They offer the advantage of reduced discomfort and faster healing times[8].

MECHANISMS OF ACTION:



1. Photothermal Effects:

When laser energy is directed at dental tissues, it is absorbed by pigments within the tissues, such as melanin, haemoglobin, and water. These pigments absorb specific wavelengths of laser light. The absorbed laser energy causes localized heating of the tissue. The extent of heating depends on the laser's wavelength and the tissue's composition. In soft tissues, photothermal effects can lead to tissue vaporization, coagulation, and cutting. Laser-induced coagulation reduces bleeding during surgical procedures. In hard tissues like teeth, laser energy can ablate (remove) tooth structure by vaporization or melting. Different lasers are suited for specific hard tissue procedures.

2. Photoacoustic Effects

Laser Energy Absorption Laser energy can be absorbed by dental tissues, leading to rapid heating and expansion of tissue fluids, creating acoustic shockwaves. These shockwaves can disrupt calcified tissue structures, such as dental calculus (tartar) or dentin, without causing excessive thermal damage to surrounding tissues. Photoacoustic effects are utilized in some lasers for periodontal procedures, contributing to efficient removal of calcified deposits[9].

3. Photomechanical Effects

Pulse-Induced Mechanical Forces: Some lasers produce high-intensity, short-duration laser pulses. When these pulses interact with dental tissues, they create shockwaves and micro-explosions. These shockwaves can ablate hard tissues and remove unwanted deposits, such as dental calculus or carious lesions. The photomechanical effects of lasers allow for precise tissue removal with minimal damage to adjacent tissues, making them valuable in periodontal and restorative procedures.

APPLICATIONS OF LASERS IN DENTISTRY

Laser technology has a wide range of applications in dentistry, offering precision, reduced discomfort, and enhanced treatment outcomes. Lasers are commonly used for various soft tissue procedures, including: Gingivectomy and gingivoplasty, Frenectomy and frenotomy, Operculectomy , Vestibuloplasty. Erbium lasers (Er:YAG and Er,Cr:YSGG) can selectively remove dental caries without the need for traditional drills. Laser-assisted teeth whitening procedures activate whitening agents, leading to faster and more effective results. Lasers enable precise removal of soft tissue lesions, aiding in diagnostic biopsies and lesion management. Low-level laser therapy (LLLT) can help alleviate pain, reduce inflammation, and manage conditions like temporomandibular joint (TMJ) disorders. Laser therapy can also be used for dentinal hypersensitivity management. Lasers aid in cleaning and disinfecting root canals, reducing the risk of reinfection. Lasers assist in tissue modification and contouring for better denture and prosthesis fit. Lasers can be employed for the management of oral ulcers, cold sores, and aphthous stomatitis. Laser-assisted uvulopalatoplasty (LAUP) can be used to treat snoring and mild obstructive sleep apnea.

APPLICATIONS OF LASERS IN PERIODONTICS

NON-SURGICAL APPLICATIONS:

LASER THERAPY IN NONSURGICAL POCKET THERAPY:

Laser Bacterial Reduction (LBR)

LBR is a non-surgical procedure aimed at eliminating or reducing the number of viable bacteria within the gingival sulcus. Diode lasers are commonly used with thin fiber-optic fibers to emit photonic laser energy into the sulcus, reducing the microbial load and periodontal pathogens[10].

Calculus Removal

Effective removal of diseased tissue and calculus from the surgical site is crucial for successful periodontal therapy. Lasers are increasingly used for calculus removal. They not only eliminate calculus on the root surface but also alter the cementum surface to enhance fibroblast attachment. While diode and Nd:YAG lasers can be used for initial periodontal therapy, erbium:yttrium-aluminumgarnet (Er:YAG) lasers are preferred as they leave no craters on the root surface. Er:YAG lasers offer selective subgingival calculus removal comparable to traditional scaling and root planing. They are effective in removing lipopolysaccharides, smear layer, and calculus, while creating a biocompatible surface for soft tissue attachment. The American Academy of Periodontology recognizes Er:YAG lasers as having the best application for laser use on hard tissue due to minimal thermal damage and improved soft tissue compatibility[11][12].

SURGICAL APPLICATIONS:

LASERS IN AESTHETIC DENTAL PROCEDURES:

Depigmentation:

Laser technology is employed for depigmentation of gingiva, addressing issues of gum discoloration. A CO_2 laser is typically utilized in continuous wave mode with a defocused beam. This technique creates blisters that separate the epithelium from the underlying connective tissue. Since melanocytes are located in the basement membrane of the epithelium, they are permanently eliminated along with the tissue removed, resulting in long-lasting depigmentation[13].

Crown Lengthening:

Lasers are utilized for crown lengthening procedures or soft-tissue management around dental abutments. The precise action of lasers allows for the controlled removal of excess gum tissue, improving the appearance of teeth and enhancing their proportion in the smile[13].

LASER-ASSISTED SURGICAL THERAPIES IN PERIODONTICS LANAP (Laser-Assisted New Attachment Procedure)

In LANAP, a laser is utilized to remove the epithelial lining of the gingival sulcus and the junctional epithelium. Laser treatment has been found to slow down the downgrowth of epithelial tissue, providing more time for connective tissue to attach to the root surface.

Subgingival Curettage

Subgingival curettage involves the removal of granulation tissue within the periodontal sulcus and pocket area using a soft-tissue laser. This procedure can be performed without raising a flap, contributing to reduced patient discomfort.

Minor Surgeries

Soft-tissue lasers enable the performance of non-osseous gingival surgeries, including frenectomy, frenotomy, gingivectomy, gingivoplasty, operculectomy, and vestibuloplasty.

Biopsy and Excision

Soft-tissue pathologies can be biopsied and excised precisely using lasers, ensuring minimal damage to surrounding healthy tissue.

De-epithelialization

CO_2 lasers have been employed to delay epithelial downgrowth. By irradiating with CO_2 lasers, epithelialization on the treated side is delayed, allowing for new connective tissue growth. This technique can promote new clinical attachment with bone fill in previously diseased sites.

Osseous Recontouring

For osseous surgery, the FDA has approved the use of erbium family lasers, including Er:YAG and Er,Cr:YSGG. These lasers can safely ablate osseous tissue, facilitating precise osseous recontouring procedures.

Removal of Granulation Tissue

Soft-tissue lasers, such as argon, diode, and Nd:YAG lasers, are effective for removing granulation tissue in periodontally involved sulci and pockets. These lasers are absorbed by pigments like melanin and hemoglobin, commonly found in inflamed periodontal tissues.

Periodontal Regeneration Surgery

Lasers are employed in periodontal regenerative procedures. A double-wavelength technique is often used, combining Er:YAG for debridement and root surface preparation with CO_2 laser for epithelial removal. This approach fosters fibroblast adhesion and proliferation, promoting new attachment in previously diseased sites[14].

LASER THERAPY FOR BONE HEALING

Accelerated Bone Repair: laser photo therapy (LPT) has shown the potential to speed up the bone repair process and increase callus volume, particularly during the early stages of hematoma absorption and bone remodeling.

Pre- and Post-Extraction Applications: LPT can be beneficial when used both before and after tooth extraction. Before extraction, it can facilitate quicker onset of local anesthesia and reduce bleeding. After extraction, it helps control swelling and inflammation, resulting in reduced postoperative pain and improved healing. This accelerated healing is attributed to the stimulation of osteogenesis and bone morphogenetic proteins by LPT [15].

Influence on Bone Cell Activity: LPT influences the expression of various factors involved in bone health, including osteoprotegerin, receptor activator of nuclear factor κB ligand, and receptor activator of nuclear factor κB. This influence enhances bone cell metabolic activity and promote bone healing.

LASERS IN DENTAL IMPLANTS Implant Uncovering

CO2 lasers are employed to remove tissue overlying dental implants. Due to the small surgical area, a char layer often forms quickly during the procedure. It is essential to remove this char layer during surgery to ensure continued laser energy absorption and prevent scattering of the laser beam, which could potentially damage the implant. After exposing the implant, the cover screw can be removed, and a healing abutment is placed. This approach avoids the need for an incision extending through the interproximal papillae, resulting in a more favourable cosmetic outcome[16].

Peri-Implantitis Management

Er-YAG lasers are well-suited for both hard and soft tissue treatment, making them valuable in managing peri-implantitis, a condition characterized by inflammation and infection around dental implants. The goal in peri-implantitis management is to achieve a "surgically clean" interface, akin to the sterile condition when the implant was originally placed. Ablative lasers, such as Er-YAG and even CO2 lasers, are effective in removing infected tissue and microbial pathogens, leaving the area free from infection. Importantly, the laser treatment does not typically lead to overheating of the implant when operated within reasonable time and power settings[17].

ADVANCES

PHOTODYNAMIC ANTIMICROBIAL CHEMOTHERAPY IN PERIODONTITIS

Photodynamic antimicrobial chemotherapy is a technique used in periodontics that involves the use of low-intensity lasers and light-activated compounds that specifically target and destroy microbial pathogens, thereby eliminating disease symptoms. The process is noninvasive and convenient for patients and can be conducted in outpatient or day-care settings. This therapy can be accurately and selectively applied to localized diseases, and repeated doses are suitable without total dose limitations[18][19].

Applications of Photodynamic Antimicrobial Chemotherapy in Periodontics

Nonsurgical Treatment of Aggressive Periodontitis: Photodynamic antimicrobial chemotherapy can be used as a nonsurgical approach to treat aggressive forms of periodontitis effectively.

Adjunct to Nonsurgical Periodontal Treatment: It can serve as an adjunct to conventional nonsurgical periodontal therapy, enhancing its effectiveness.

Destruction of Periodontopathogenic Bacteria: Photodynamic therapy (PDT) involving the application of photosensitizers followed by light exposure can effectively target and kill oral bacteria associated with periodontal diseases.

In PDT, a photosensitizer is applied to the treatment area, and upon exposure to light, it sensitizes the organisms to visible light, leading to damage. This process generates cytotoxic free oxygen radicals due to light application, contributing to bacterial cell death. One example of such a system is PeriowaveTM, which utilizes low-intensity lasers and light-activated compounds to precisely target and eliminate microorganisms. Antimicrobial photodynamic therapy has gained popularity due to its technical simplicity and high effectiveness in killing bacteria associated with periodontal and periimplant diseases[20].

Low-Level Laser Therapy (LLLT), also known as soft laser therapy, has shown promise in improving clinical outcomes in periodontics, especially when used in conjunction with surgical lasers. LLLT employs lower-energy lasers over larger tissue areas, resulting in photochemical and photobiological effects that selectively increase cellular activity[21].

PDT is a photochemical reaction that requires molecular oxygen, a photosensitizer like dihematoporphyrin ether (DHE), and laser light. This process produces highly reactive singlet oxygen radicals, leading to tissue necrosis. PDT can be used to treat malignancies and aid in surgical excisions.

LLLT in periodontics stimulates fibroblasts, promotes soft tissue regeneration, provides analgesia, and modulates inflammatory chemicals. It has shown promise when used alongside surgical lasers for procedures such as gingivectomies, periodontitis treatment, and periodontal surgery, leading to improved clinical outcomes. LLLT stimulates intense cellular metabolic activity, the proliferation of odontoblasts, and the production of dentin, contributing to the long-term reduction of dentin hypersensitivity[22][23]. LLLT interferes with peripheral nerve signal transmission to the central nervous system, leading to reduced pain perception. It also plays a role in sealing dentinal tubules, preventing external oral fluid communication with the pulp, which helps maintain an analgesic dentin state. Additionally, LLLT can induce the coagulation of hydroxyapatite crystals and stimulate reparative dentin formation[24]

DISCUSSION

Utilizing lasers in periodontal therapy offers several distinct advantages. These include diminished patient discomfort, reducing the necessity for anesthetics, which is particularly beneficial for individuals with underlying medical conditions[25]. Laser treatments entail no risk of bacteremia, enhance wound healing without scar tissue formation, and provide effective bleeding control, contingent upon the chosen wavelength and power settings. Furthermore, sutures are often unnecessary, leading to streamlined procedures and cost savings by requiring fewer instruments and materials, as well as eliminating the need for autoclaving. Lasers exhibit versatility in addressing both hard and soft tissue concerns, and they can complement traditional scalpel-based approaches. However, it is essential to acknowledge certain drawbacks, such as the relatively high cost of laser devices, the prerequisite for additional education, especially in the domain of basic physics, and the necessity for stringent safety measures like protective goggles due to the varying properties of different laser wavelengths[26].

CONCLUSION

In conclusion, laser dentistry has already revolutionized the practice of periodontics and holds immense potential for the future. Its ability to provide minimally invasive, precise, and patient-friendly treatments is reshaping the way periodontal conditions are managed. While challenges such as cost and education remain, ongoing advancements are likely to address these issues. As laser technology continues to evolve, it will undoubtedly contribute to better periodontal health outcomes and improved patient experiences in the years to come. Dental professionals embracing laser technology will be at the forefront of these exciting developments in the field of periodontics.

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