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LASERS : A RAY TOWARDS PERIODONTICS

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ABSTRACT: Theodore maiman in 1960 invented the ruby laser, since then lasers technology has holded the attention in dental practice and has revolutionised dental treatment. Lasers have been used in initial periodontal therapy, surgery, and also in implant treatment. Lasers have various periodontal applications including calculus removal; for removal of the pocket epithelium; soft tissue excision, incision and ablation; decontamination of root and implant surfaces; biostimulation; bacteria reduction; and osseous surgery. Further research is necessary on lasers so that it can become a part of the dental procedures. This paper gives an acuity to laser in Periodontics.

KEYWORDS: Laser, periodontics, LLLT, PDT

INTRODUCTION

The word LASER is an acronym for light amplification by stimulated emission of radiation[1]. The use of laser technology and its advancements in the field of medicine and dentistry is playing a major role in patient care and well-being. There has been a continuous acceleration in the development of laser-based dental devices based on photomechanical interactions, from the end of the 20th century until now[5].While their ability to penetrate soft tissue and remove soft tissue lesions is well established[6,7], the effectiveness of their use in periodontics and implantology remains a topic of debate[8,9]. The aim of this paper is to present innovative opportunities for using lasers in periodontal and peri‐implant surgery and to present new challenging indications of this modern technology for the daily practice

History

Based on Albert Einstein's theory of spontaneous and stimulated emission of radiation, the search for lasers began as an extension of stimulated amplification techniques employed in the microwave region. In 1954 the first Microwave Amplification by Stimulated Emission of Radiation (MASER) was built by C. Townes an American physicist who proposed extending the maser principle to optical frequencies but they did not find a suitable material or the means of exciting it to the required degree of population inversion[5]. In 1960, Theodore Maiman was the first scientist who developed a working laser device "known as ruby laser," made of aluminum oxide, that emitted a deep red-colored beam. it was T. Maiman who had given the name LASER (**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.) and demonstrated the laser function also[2]. Shortly thereafter, in 1961, Snitzer published the prototype for the Nd:YAG laser[10].The first application of a laser to dental tissue was reported by Goldman et al. and Stern and Sognnaes, each article describing the effects of the ruby laser on enamel and dentin, with a disappointing result[11,12]. In 1970's, researchers began to find the clinical oral soft tissue uses of medical CO_2 and neodymium doped: yttrium aluminium garnet (Nd:YAG) lasers. The first laser that had truly both hard and soft tissue application was the CO_2 laser, invented by Patel in 1964[13]. The first pulsed Nd:YAG laser was released which is thought to have a better interaction with dental hard tissues[2].

In 1985, Myers and Myers[14] described the in vivo removal of dental caries using a modified ophthalmic Nd:YAG laser[12]. Four years later, it was suggested that the Nd:YAG laser could be used for oral soft tissue surgery[62], which ultimately lead to the present relationship between lasers and clinical periodontics[15,16,17].

The first dental lasers approved by the US Food and Drug Administration, namely the CO_2, the Nd:YAG and the diode lasers were accepted for use only for oral soft tissue procedures in periodontics[4]. In 1997, the Food and Drug Administration cleared the first Er:YAG laser system, then in use for preparing dental cavities, for incisions, excisions, vaporization, ablation and hemostasis of soft and hard tissues in the oral cavity[18].

Principal of working of lasers:

Laser light is a man-made single photon wavelength. The process of lasing occurs when an excited atom is stimulated to emit a photon before the process occurs spontaneously. Spontaneous emission of a photon by one atom stimulates the release of a subsequent photon and so on[4].

Laser is a type of electromagnetic wave generator[19]. The emitted laser has three characteristic features.

1. Monochromatic: in which all waves have the same frequency and energy.
2. Coherent: all waves are in a certain phase and are related to each other, both in speed and time.
3. Collimated: all the emitted waves are nearly parallel and the beam divergence is very low[20].

Lasers can concentrate light energy and exert a strong effect on targeting tissue at an energy level that is much lower than that of natural light. The photon emitted has a specific wavelength which depends on the state of the electron's energy when the photon is released[6].

When a laser is directed at and absorbed by living tissue, the target tissue is directly impacted. The laser's light energy can also be reflected, scattered, or move through the tissue without any effect, however, individual laser wavelengths have varying abilities to affect living tissue.

Light energy which is absorbed gets converted to heat and can lead to warming, coagulation, or excision and incision of the target tissue. Energy absorbed by the target tissue depends on the wavelength of the laser, optical properties of the tissue, such as pigmentation, water content, and mineral content, can also influence the extent of energy absorbed[21]. The term 'waveform' describes the manner in which laser power is delivered over time, when activated, lasers can work on a continuous basis or on a pulsed setting. Continuous wave lasers deliver large amounts of energy in an uninterrupted steady stream potentially resulting in increased heat production on the other hand pulsed wave lasers deliver smaller amount of energy that enables countering the build-up of heat in surrounding tissues between intense pulse[22].

The most important determinant of a laser's potential effects on living tissue is the beam's wavelength .Wavelengths are measured in nanometers (nm) or microns.

Generally, laser wavelengths cannot be changed — they are fixed. The most common range of wavelengths used in periodontics and implantology spans from 400 nm to 10,600 nm. This range includes both the invisible and visible portions of the electromagnetic spectrum.

More than 95% of the lasers used in dentistry — including those used to treat periodontitis and peri-implantitis — produce invisible energy. The range of the electromagnetic spectrum includes[7]: the visible wavelengths (390 nm to 700 nm), the invisible range, also known as infrared and far-infrared portions of the electromagnetic spectrum (700 nm+) and wavelengths below 450 nm. Ionizing radiation (e.g., X-rays and gamma rays) is also part of the invisible range. Depending on exposure duration, it is generally harmful to human tissue. Dental lasers do not produce this type of radiation.

Tissue Effects of Laser Radiation[5]

Lasers are sometimes referred to as soft or hard tissue lasers. When a laser is activated and the energy is absorbed into the target tissue[7], four basic types of interactions or responses may occur:

1. Photochemical interaction: Photo chemical interaction include Bio-stimulation, which describes the stimulatory effects of laser light on biochemical and molecular processes that normally occur in tissues such as healing and repair[5].

The therapy performed with low-level lasers is called as LLLT or therapeutic laser therapy, and this therapy has been referred as biostimulation and biomodulation[23]. The low-level lasers do not cut or ablate and do not cause temperature elevation within the tissue, but rather produce their effects from photobiostimulation effect within the tissues. Laser enhanced biostimulation has been reported to induce intracellular metabolic changes, resulting in faster cell division, proliferation rate, migration of fibroblasts and rapid matrix production[24,25]. The first commercialized biostimulative laser was a heliumneon (HeNe) laser of <1 mW but it's use for biostimulation is limited. It has generally been replaced by the indium-gallium-aluminum-phosphide laser. The most frequently used laser for LLLT in dentistry is the gallium-aluminum arsenide laser, a diode laser.

LLLT has been shown to stimulate the production of basic fibroblast growth factor (bFGF), a multifunctional polypeptide which supports fibroblast proliferation and differentiation. Fibroblasts irradiated with low dose LLLT show both increased cell proliferation and enhanced production of bFGF, while high dose LLLT suppresses both parameters.

A further effect of LLLT on fibroblasts that can influence the wound healing process is the transformation of fibroblasts into myofibroblasts, which are responsible for wound contraction[26].

2. Photo thermal interaction: Photo thermal interactions include Photo ablation, or the removal of tissue by vaporization and superheating of tissue fluids, coagulation and hemostasis.

3.Photo mechanical interaction: Photomechanical interaction include Photo-disruption or photo-disassociation, which is the breaking apart of structures by laser light.

4.Photo electrical interaction: Photoelectrical interactions include Photo plasmolysis which describes how tissue is removed through the formation of electrically charged ions and particles that exist in a semi-gasseous high energy state.

Classification of Lasers: Lasers can be classified according to its spectrum of light, material used and hardness etc. They are also classified as soft lasers and hard lasers[4].

- **Classification based on light spectrum:**

1) UV Light: 100 nm – 400 nm (Not Used in Dentistry)
2) Visible Light: 400 nm – 750 nm [Most commonly used in dentistry (Argon & Diagnodent Laser)]
3) Infrared light: 750 nm – 10000 nm(Most Dental Lasers are in this spectrum)

- **Classification According to material used:**

1) Gas: Carbon Dioxide
2) Liquid: Not so far in clinical use
3) Solid: Diodes, Nd:YAG, Er:YAG, Er:Cr:YSGG, Ho:YAG

I. Soft and Hard tissue lasers:

1. **Soft laser;** Soft lasers are of cold (athermic) energy emitted as wavelengths; those are thought to stimulate cellular activity. These soft lasers generally utilize diodes and the manufacturers claim that these lasers can aid healing of the tissue, reduces inflammation, edema, and pain. The current soft lasers in clinical use are the:

- Helium-neon (He-N)
- Gallium- arsenide (Ga-As)

2. **Hard lasers (surgical);** Hard lasers can cut both soft and hard tissues. Newer variety can transmit their energy via a flexible fiber optic cable. Presently more common type clinically used, under this category are:

- Argon lasers (Ar)
- Carbon-dioxide lasers (CO2)
- Neodymium-doped yttrium aluminum garnet (Nd:YAG)
- Holmiumyttrium-aluminum-garnet (Ho:YAG)
- Erbium,chromiummyttrium-slenium-gallium-garnet (Er,Cr:YSGG)
- Neodymiummyttrium-aluminum-perovskite (Nd:YAP)

II. On the basis of output energy

1) Low output, soft or therapeutic eg. Low-output diodes
2) High output, hard, or surgical eg. CO2,Nd:YAG,Er:YAG

III. On the basis of oscillation mode

1) Continous wave eg. CO2, Diodes
2) 2)Pulsed wave eg. Nd:YAG, Er:YAG

Application in Periodontics:

Lasers have various periodontal applications including calculus removal (Er: YAG, Er, Cr: YSGG lasers); soft tissue excision, incision and ablation; decontamination of root and implant surfaces; biostimulation; bacteria reduction; and last but not least bone removal (osseous surgery)[1]. Different lasers penetrate to different tissue depths, depending on their wavelength and the type of tissue at which they are directed. For instance, when applied to soft tissues, Nd: YAG lasers (1064 nm) have a penetration depth of approximately 2–3 mm, compared to CO2 lasers (10,600 nm), which affect the tissue only superficially (0.1–0.3 mm). In addition, CO2 lasers have a high absorption from the water. Certain laser wavelengths (i.e. Er: YAG, Er, Cr: YSGG) are highly absorbed by hydroxyapatite and can be used for bone removal more efficiently than others[1]. In contrast, diode and Nd: YAG lasers are more highly absorbed by hemoglobin and thus should be used when coagulation is desirable. In addition, due to the effect that these wavelengths (diode and Nd: YAG lasers) have on pigmented tissues, they can be used for removal of gingival pigmentation and/or reduction of periodontopathogenic black pigmented bacteria[1].

Initial Periodontal Therapy Scaling And Root Planing: The Er: YAG laser is able to remove calculus at a level similar to ultrasonic scaler , an increased loss of cementum and dentin which should be taken into account in clinical situations[27]. There is potential for clinical application of the Er: YAG laser in subgingival scaling[28]. These lasers are effective in removing lipopolysaccharides and other root surface endotoxins and are highly bactericidal against certain periodontal pathogens including *P. gingivalis* and *Actinobacillus actinomycetemcomitans*[2]

Laser Curettage: Both the Nd:YAG and diode lasers are indicated for curettage. Laser assisted curettage significantly improves outcomes in mild to moderate periodontitis. The treatment is not invasive and comfortable to the patients. The beneficial effects of these lasers are due to the bacterial properties particularly against periodontal pathogens such as *A. actinomycetemcomitans* and *P. gingivalis*. However, recent studies have shown that there are no added advantages of these lasers as compared with the conventional debridement[2].

Removal of the pocket epithelium: The Nd: YAG was used for treating periodontal pockets[29] and controlling bacteremia and gingival bleeding[29,30]. The probing pocket depth and bleeding index scores were reduced using the pulsed Nd: YAG laser. Furthermore, clinical evaluation of soft tissue biopsies taken from human subjects using the Nd: YAG laser presented a complete removal of the epithelium of the pocket after use of the pulsed Nd: YAG laser[31].

When deep periodontal pockets are present, removal of the pocket epithelium using a glass laser fiberoptic offers benefits. With or without flap elevation and a conventional periodontal access flap procedure, the pocket epithelium will be removed from the inner and the outer part of the pocket. Later the epithelium can be ablated every 7–10 days from the outer part of the pocket, usually under the use of topical anesthesia, in order to control apical migration. This can result in long‐term, stable connective tissue attachment, without gingival recession . The principle underlying this approach is guided tissue regeneration; it has been called “laser‐assisted guided tissue regeneration”[32].

Laser root conditioning: Barone et al.[33] showed that a defocused, pulsed CO2 laser can be used for root conditioning with a better fibroblastic activity, cellular proliferation, and greater fibroblast attachment[35], thus able to create smooth and clean root surface

Laser Assisted Incisional and Excisional Biopsy: These procedures are accomplished at 100°C. The lasers are placed in cutting or focused mode, held perpendicular to the tissue and follow the surgical outline. When laser light interact with the soft tissue, there is vaporization of intra and extracellular water content resulting in ablation or removal of biological tissue. However, when the temperature exceeds 200°C, there is heat generated within the tissues during the results in carbonization and irreversible tissue necrosis[2].
In addition, there are specific soft tissue indications for the clinical use of lasers, including gingival depigmentation, gingivectomy/gingivoplasty, operculectomy, sulcus debridement, pre-impression sulcular retraction, laser assisted new attachment procedures, removal of granulation tissue. Pulp capping, pulpotomy and pulpectomy, incisions and draining of abscesses, removal of hyperplastic tissues, frenectomy, vestibuloplasty, and treatment of herpetic and recurrent aphthous ulcers. Other excisional procedures that can be easily performed using lasers are the removal of benign growths such as fibromas or papillomas. In addition, LLLT is indicated for oral soft tissue lesions such as frictional keratosis, nicotinic stomatitis, leukoplakia, erythroplakia, verrucous carcinoma[35].

It has been shown that Er-Cr:YSGG (Waterlase C-100) system is used to release the fibrotic bands of oral submucous fibrosis. It works on “hydro-photonic process” in which the energy from the Er-Cr: YSGG laser interacts with water droplets on the tissue to create water molecule excitation, micro expansion and propulsion giving a clean and precise hard-tissue cutting.

Bacterial reduction: A laser is applied for the reduction of bacteria in pockets, due to the high absorption of specific laser wavelengths by the chromophores. Initially, the use of an Nd: YAG laser was shown to reduce the load of *Porphyromonas gingivalis* and *Prevotella intermedia*[36]. A study by Assaf et al.[37] suggested that diode lasers should be used to prevent bacteremia, especially in immuno-compromised patients. Using a 980nm‐diode laser to reduce periodonto‐pathogenic bacteria in patients with aggressive periodontitis has also been investigated. Kamma et al.[38] confirmed that it was possible to reduce the total bacterial load in pockets without use of any systemic antibiotic therapy.

Due to the bacteria reduction, and the reduced bleeding on probing provided by the PDT, the PDT was recommended for periodontal patients especially for the maintenance appointments

Laser And Implant Gingival enlargement is relatively common around implants when they are loaded with removable prosthesis. Lasers can be used for the hyperplasia removal as well as in the treatment for peri-implantitisand in second stage implant exposure. Er:YAG laser due to its bactericidal and decontamination effect, can be used in the maintenance of implants. It has bacterial effect without heat generation around implants[39]. Some researchers have suggested using the Er:YAG laser to prepare fixture holes in the bone tissue in order to achieve faster osseointegration of the placed implants and to produce less tissue damage in comparison to conventional bur drilling.

Previous clinical case series were able to demonstrate new bone fill and long‐term success of failing implants that were decontaminated with a CO2 laser[40,41,42,43]. The main advantage of using CO2 laser irradiation on implant surfaces is that this wavelength does not pose the risk of overheating[44], unlike other wavelengths, such as that of diode, Nd: YAG, and Er: YAG lasers[45,46]. Although information is limited about the clinical application of CO2 (10.6 μm) lasers in the surgical treatment of peri‐implantitis, its use appears promising[47].

Laser assisted new attachment procedure (LANAP):): Initial reports suggest that LANAP can be associated with cementum-mediated new connective tissue attachment and apparent periodontal regeneration of diseased root surface in humans[4].

Bone Surgery: The YSGG laser was first cleared for bone, including cutting, shaving, contouring and resecting oral osseous tissues. The laser was later cleared for osteoplasty, ostectomy, and osseous recontouring to correct defects and create physiologic osseous contours necessary for ideal clinical results[2].

Osseous Crown Lengthening: In 2003, the YSGG laser was the first laser device cleared for osseous crown lengthening to achieve biologic width which can be completed without laying a flap, suturing, or damage to the bone (Wang, 2002)[2].

Low-level laser therapy: Applications of LLLT in dental and periodontal treatments represent the subject of many in vivo and in vitro studies, which recommend the use of laser therapy after gingivectomy and gingivoplasty procedures due to its ability to speed up the healing process[48,49]. The low-level lasers facilitate fibroblast and keratinocyte motility, collagen synthesis, angiogenesis and growth factors release, thus facilitating the healing process. This therapy has been used in pain management protocols following gingivectomies, and as an adjunct treatment in nonsurgical periodontal procedures[50]. A study done by Lui et al. suggested that the combined course of photodynamic therapy with LLLT could be a beneficial adjunct to nonsurgical treatment of chronic periodontitis on a short term basis[51]. Regeneration of new bone is of major importance in several surgical procedures and also in periodontal therapy. LLLT should be used in the surgical site after suturing and during the initial healing period when the proliferative activity is high. Repeated irradiation for 2-weeks needed for a pronounced effect[52,53]. The use of LLLT at a range of doses between 1.5 and 3 J/cm2 may modulate the activity of cells interacting with an implant thereby enhancing tissue healing and ultimate implant success[54].

Advantages of using lasers in the periodontal therapy include

1. Less pain
2. Less need for anesthetics (an advantage for medically compromised patients)
3. No risk of bacteremia
4. Excellent wound healing; no scar tissue formation
5. Bleeding control (dependent on the wavelength and power settings);
6. Usually no need for sutures
7. Use of fewer instruments and materials and no need for autoclaving (economic advantages)
8. Ability to remove both hard and soft tissues
9. Lasers can be used in combination with scalpels (however, the laser is a tool and not a panacea).
10. Greater hemostasis, bactericidal effect, and minimal wound contraction[55,56,57].
11. Lasers can cut, ablate and reshape the oral soft tissue more easily, with no or minimal bleeding and little pain as well as no or only a few sutures[4]

Disadvantages of using lasers in periodontal therapy include :

1. Relatively high cost of the devices
2. A need for additional education (especially in basic physics)
3. Every wavelength has different properties
4. The need for implementation of safety measures (i.e. goggle use, etc.)
5. Laser irradiation can interact with tissues even in the noncontact mode, which means that laser beams may reach the patients eyes and other tissues surrounding the target in the oral cavity[4]
6. Laser beams can be reflected by shiny surfaces of metal dental instruments[4]
7. Laser systems have strong thermal side effects, leading to melting, cracking, and carbonization of hard tissues[4].

Recent Advances:

Waterlase system is a revolutionary dental device that uses laser energized water to cut or ablate soft and hard tissue[1].

Periowave, a photodynamic disinfection system utilizes nontoxic dye (photosensitizer) in combination with low intensity lasers enabling singlet oxygen molecules to destroy bacteria[33].

Photodynamic Therapy: A more powerful laser-initiated photochemical reaction is photodynamic therapy (PDT). As in photo - activated dye, laser-activation of a sensitizing dye in PDT generates reactive oxygen species. These in turn directly damage cells and the associated blood vascular network, triggering both necrosis, and apoptosis[58].

PDT can be used in non-surgical treatment of aggressive periodontitis, treating periodontal pockets, plaque-infected cervical regions of teeth and implants, disinfecting oral tissues prior to and during surgery, treating oral candidiasis in immunocompromised patients[59], guided bone regeneration (as an adjunct in minimizing any bacterial contamination) success enhanced following Photodynamic antimicrobial chemotherapy (PACT)[60]. Laser PDT can also be used in implantology to promote osseointegration and to prevent peri- implantitis. One of the most interesting developments over the last years has been the introduction of the 9.6-μm CO2 laser. It has been shown in the recent literature that the use of this new device can preserve tissue, with almost no adverse effects at the light microscopic level.

Types of Photosensitizers:

First generation sensitizers: Photofrin and hematophyrin derivatives

Second generation photosensitizers include 5–aminolevulinic acid (ALA), benzoporphyrin derivative, texaphyrin, and temoporfin (mTHPC).

Third generation include Biologic conjugates (e.g. Antibody conjugate, liposome conjugate)[61]

Limitations of Lasers

- It requires additional training and education for various clinical applications and types of lasers[2].
- High cost required to purchase equipment, implement technology and invest in required education[2].
- More than one laser may be needed since different wavelengths are required for various procedures[2].

CONCLUSION

With introduction of laser in the field of periodontics for last several years, it has emerged and witnessed several wonderful experiences by clinicians and the patients. Lasers are expected to serve as an alternative or adjunctive to conventional mechanical periodontal treatment and thus shows a promising future in periodontics. Laser treatments are in continuous evolution and.; possibly in the upcoming years our scope will be to have equipments combining different photonic properties allowing us to choose the most adequate system for each necessity.

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