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Alternative Treatment Approaches in Chronic Periodontitis: Laser Applications

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1. Introduction

Periodontal disease is initiated by pathogenic plaque biofilm and characterized by bacteria-induced inflammatory destruction of tooth-supporting structures and alveolar bone (Lui & Corbet, 2011). With a constant bacterial challenge, the periodontal tissues are continuously exposed to specific bacterial components that have the ability to alter many local functions. The role of the inflammatory process is to protect the host and limit the pathogenic effect of biofilm, thus determining some tissue destruction as a collateral effect of the defence. The extent and severity of damage vary among individuals and over time (Offenbacher, 1996;Kinane et al., 2005; Karlsson et al., 2008), mainly influenced by individual's immune and inflammatory responses to microbial challenge. In some patients gingivitis progresses to periodontitis, with a slower or faster progression, that is characterized by the destruction of the supporting structures of the teeth, including periodontal ligament and bone, and cementum alterations, that may in turn ultimately cause tooth loss (Kinane, 2001). Unfortunately, little and still uncertain is the possibility to interfere with individual response, to redirect inflammatory and immune defences or, as it is commonly defined, to perform a "host modulation". The rationale behind this approach is to aid the host in its fight against infectious agents by supplementing the natural defence mechanism or to modify its responses by changing the course of inflammatory systems. Therefore, pharmaceutical inhibition of host response with an anti-inflammatory mechanism may prove to be an effective strategy for treating periodontal diseases. Current research has focused on the use of subantimicrobial dose of doxycycline (SDD) as a treatment modality, and SDD is the only systemically used host modulatory drug approved by the United States Food and Drug Administration. (Deo et al., 2010) (Figure 1).

At present state, an effective and widely accepted treatment approach for periodontal disease is the mechanical removal of the bacterial biofilm and their toxins from the tooth surface by scaling and root planing, making it compatible with biologic reattachment that is the basis of any eventual adjunctive therapy (Sigusch et al., 2010). Traditionally, scaling and root planing procedures can be performed by hand and/or powered instruments. However, complete removal of bacterial deposits within the periodontal pockets is not necessarily achieved with conventional mechanical therapy. In addition, access to areas such as furcations, concavities, grooves, and distal sites of molars is limited (Aoki et al., 2004).

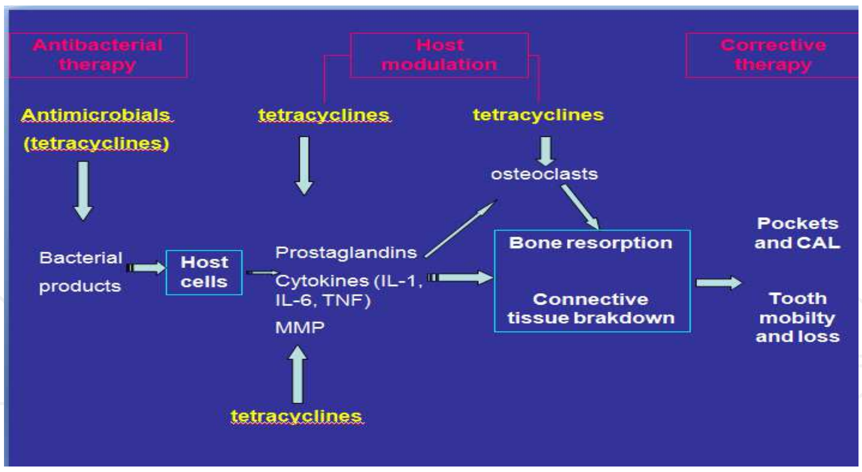

Fig. 1. Scheme of pathogenesis of periodontal disease; role of tetracycline in different phases.

Currently, efficient anti-infective treatments with reduced side effects are being searched for. Local and systemic antibiotics may lead to bacterial resistance, allergies, gastrointestinal disorders and others, reducing patient compliance or advising against the prescription (Quirynen et al., 2003; Rodrigues et al., 2004).

Therefore, development of novel systems for scaling and root planing, as well as further improvement of currently used mechanical instruments, is required.

For its various characteristics, such as ablation or vaporization, haemostasis and sterilization effect, the use of laser may serve as an adjunct or alternative treatment to conventional periodontal therapy (Aoki et al., 2004).

2. Characteristics of lasers

The word LASER is the acronym for Light Amplification by Stimulated Emission of Radiation. A laser is a device that emits light through a process called stimulated emission, featuring collimated (parallel) and coherent (temporally and spatially constant) electromagnetic radiation of a single wavelength. Laser light is produced by pumping (energizing) a certain substance, or gain medium, within a resonating chamber (Figure 2).

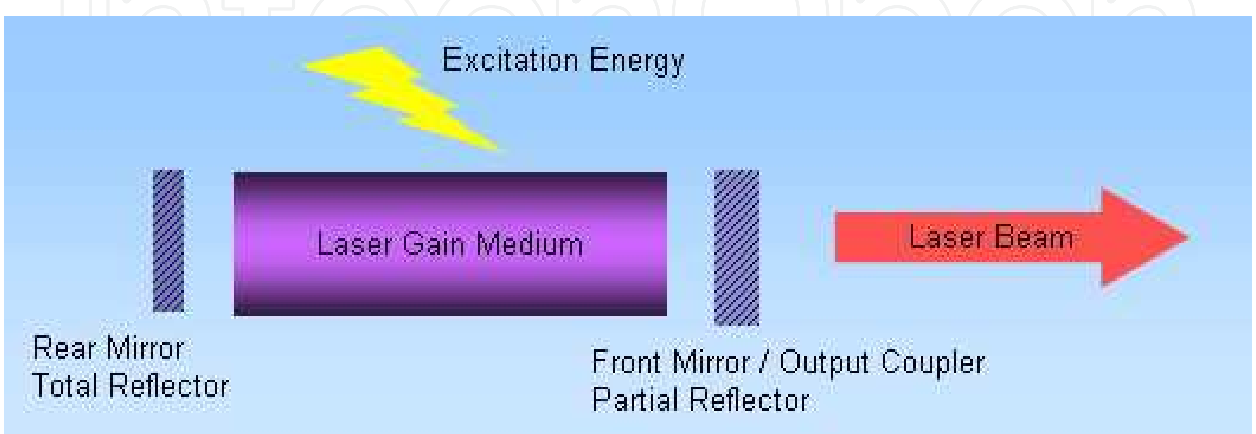

Fig. 2. Schematic drawing of the main component of a laser system.

The process of lasing occurs when an exited 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. This stimulated emission generates a very coherent and synchronous wave, of a single wavelength and in a collimated form (parallel rays) of light that is found nowhere else in nature. The various laser systems are usually named after the ingredients of the gain medium, but three factors are important to the final characteristics of the laser light: as said before, gain medium, source of pump energy, design of resonating chamber. Clinically, that is for medical applications, both the laser-delivery system (e.g. optical fiber or articulated arm with mirrors) and the application tip are of paramount importance, as they may condition the ease of use, range of applications and energy efficiency of a laser system. The most common classifications of lasers are those related to the type of gain medium and characteristics of the laser light.

The characteristics of lasers depend on their wavelength (table 1 and figure 3).

Laser type		Wavelength	Color
Excimer lasers	Argon Fluoride (ArF)	193 nm	Ultraviolet
	Xenon Chloride (XeCl)	308 nm	Ultraviolet
Gas lasers	Argon	488 nm	Blue
		514 nm	Blue-green
	Helium Neon (HeNe)	637 nm	Red
	Carbon Dioxide (CO_2)	10,600 nm	Infrared
Diode lasers	Indium Gallium Arsenide Phosphorus (InGaAsP)	655 nm	Red
	Gallium Aluminum Arsenide (GaAlAs)	670–830 nm	Red-infrared
	Gallium Arsenide (GaAs)	840 nm	Infrared
	Indium Gallium Arsenide (InGaAs)	980 nm	Infrared
Solid state lasers	Frequency-doubled Alexandrite	337 nm	Ultraviolet
	Potassium Titanyl Phosphate (KTP)	532 nm	Green
	Neodymium:YAG (Nd:YAG)	1,064 nm	Infrared
	Holmium:YAG (Ho:YAG)	2,100 nm	Infrared
	Erbium, chromium:YSGG (Er,Cr:YSGG)	2,780 nm	Infrared
	Erbium:YSGG (Er:YSGG)	2,790 nm	Infrared
	Erbium:YAG (Er:YAG)	2,940 nm	Infrared

Table 1. Type and wavelength of lasers (from Aoki et al. 2004)

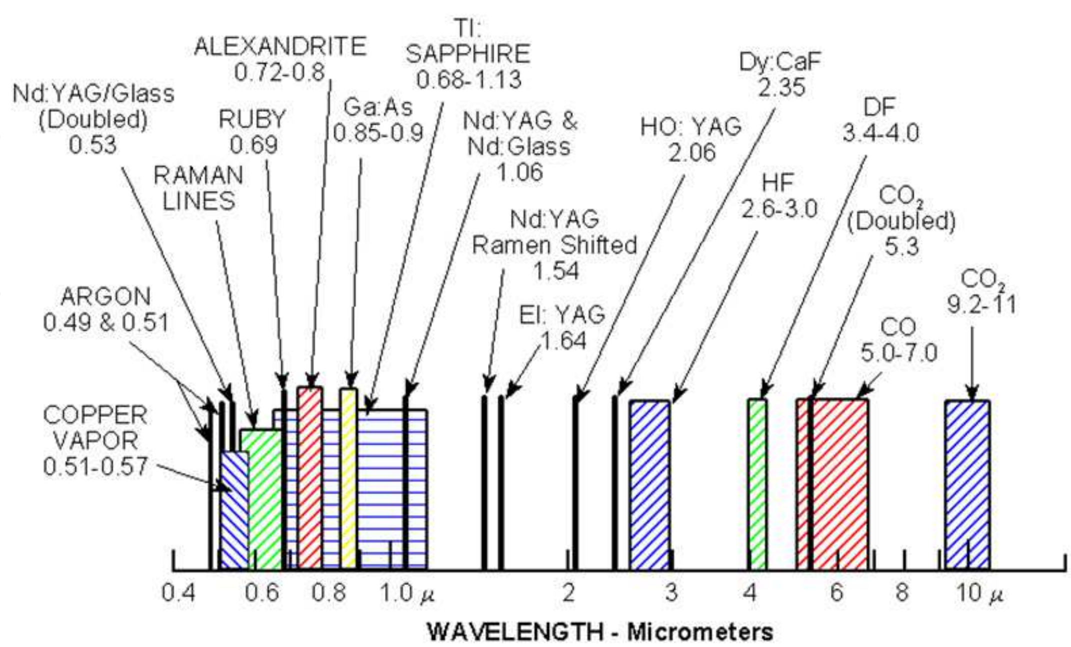

Fig. 3. Electromagnetic spectrum and wavelengths of lasers.

The term "waveform" describes the way of laser delivery over time, either as a continuous or as a pulsed beam emission (table 2). A continuous wave laser beam emits an uninterrupted beam at the output power set for as long as the switch is turned on. The pulsed beam may be delivered in two different modalities: a free-running pulse, in which pulsation is stored for a certain time and the emission has a peak power greater than the power selected on the panel, or gated pulse, in which a continuous wave beam is interrupted at various rates by a shutter, having the laser the same power set.

Criteria	Types	Examples
Output Energy	Low-output, soft, or therapeutic High-output, hard, or surgical	Low-output diodes Diodes, CO_2, Nd:YAG, Er:YAG, Er,Cr,:YSGG
State of the gain medium	Solid-state Gas Excimer Diode	Nd:YAG, Er:YAG, Er,Cr,:YSGG, KTP HeNe, Argon, CO_2 F_2,ArF, KrCl, XeCl GaAlAs, InGaAs
Oscillation mode	Continous-wave Pulsed- wave	CO_2, Diodes CO_2, Diodes, Nd:YAG, Er:YAG, Er,Cr,:YSGG, KTP

Table 2. Mode of irradiation and laser denomination.

The first prototype of laser was developed by Maiman in 1960, using a crystal medium of ruby that emitted a coherent radiant light from the crystal when stimulated by energy. The first application of laser in dental field was reported by Goldman et al. (1964), describing the effect of the ruby laser on enamel and dentin while attempting to remove caries in vitro using the ruby laser. Since then, many researchers investigated the effects of various laser types on dental hard tissue and caries. However, previous laser systems where basically not indicated for hard tissue procedures due to major thermal damage (Frentzen et al., 2002).

The effect of the laser on a tissue depends on its behaviour within it. It can reflect, scatter, be absorbed or transmitted to surrounding tissues (Figure 4).

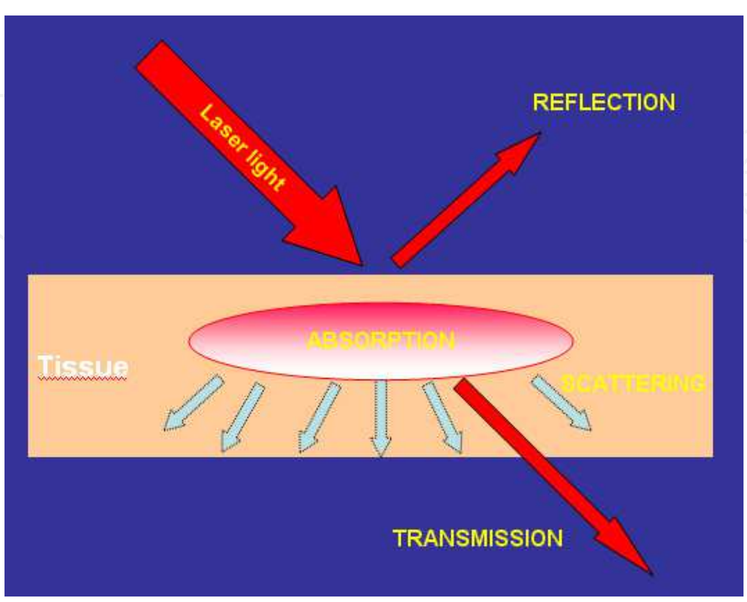

Fig. 4. Possible effects of laser irradiation on tissue.

Basically, as the absorption increases, the reflection, scattering and transmission decrease. For most biological tissues, higher absorption occurs in wavelengths with greater absorbance in water. The more absorbance occurs, the less the laser light penetrates the surrounding tissues with a shallower layer of laser-affected tissue (Ishikawa et al. 2009).

Since the periodontium is composed of gingiva, periodontal ligament, cementum and alveolar bone, both soft and hard tissues are involved in a lasering process. The high power carbon dioxide (CO_2) and neodymium-doped yttrium aluminium garnet (Nd:YAG) lasers are capable of excellent soft tissue ablation with a good haemostatic effect. As such, these lasers have been generally proposed for periodontal surgery and oral surgery (Aoki et al. 2004). However, these lasers are not suitable for treatment of root surface or alveolar bone, due to carbonization of these tissues and major thermal side-effects on the target and surrounding tissues, with a limitation of employment indications to gingivectomy and frenectomy.

In the late eighties Keller and Hibst (1989) and Kayano et al. (1991) reported the possibility of dental hard tissue ablation by erbium yttrium aluminium garnet (Er:YAG) laser irradiation, which is highly absorbed by water, without producing major thermal side-effects. Er:YAG laser was then proved for periodontal hard tissue procedures such as dental calculus removal and decontamination of the diseased root surface.

Diode and Nd:YAG lasers are also currently under investigation and used by clinicians because of their flexible fiber delivery system, which is suitable for pocket insertion. Nd.YAG, CO2, Diodes, Er:YAG, erbium chromium-doped yttrium scandium gallium and garnet (Er,Cr:YSGG), Argon, excimer and alexandrite lasers are being studied in vitro or are in clinical use (table 3).

Laser type		Current/Potential dental application
Excimer lasers	Argon Fluoride (ArF) Xenon Chloride (XeCl)	Hard tissue ablation, Dental calculus removal
Gas lasers	Argon (Ar)	Curing of composite materials, Tooth whitening, Intraoral soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis)
	Helium Neon (HeNe)	Analgesia, Treatment of dentin hypersensitivity, Aphthous ulcer treatment
	Carbon Dioxide (CO_2)	Intraoral and implant soft tissue surgery, Aphthous ulcer treatment, Removal of gingival melanin pigmentation, Treatment of dentin hypersensitivity, Analgesia
Diode lasers	Indium Gallium Arsenide Phosphorus (InGaAsP)	Caries and calculus detection
	Galium Aluminum Arsenide (GaAlAs) and Galium Arsenide (GaAs)	Intraoral general and implant soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis), Analgesia, Treatment of dentin hypersensitivity, Pulpotomy, Root canal disinfection, Aphthous ulcer treatment, Removal of gingival melanin pigmentation
Solid state lasers	Frequency-doubled Alexandrite	Selective ablation of dental plaque and calculus
	Neodymium:YAG (Nd:YAG)	Intraoral soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis), Analgesia, Treatment of dentin hypersensitivity, Pulpotomy, Root canal disinfection, Removal of enamel caries, Aphthous ulcer treatment, Removal of gingival melanin pigmentation
	Erbium group Erbium:YAG (Er:YAG), Erbium:YSGG (Er:YSGG), Erbium,chromium:YSGG (Er,Cr:YSGG)	Caries removal and cavity preparation, Modification of enamel and dentin surfaces, Intraoral general and implant soft tissue surgery, Sulcular debridement (subgingival curettage in periodontitis and peri-implantitis), Scaling of root surfaces, Osseous surgery, Treatment of dentin hypersensitivity, Analgesia, Pulpotomy, Root canal treatment and disinfection, Aphthous ulcer treatment, Removal of gingival melanin/metal-tattoo pigmentation

Table 3. Characteristics and actual or potential clinical use of different laser lights (from Aoki et al. 2004)

Characteristics, possible development and actual studies will be analyzed for different laser types.

2.1 CO_2 laser

The CO_2 laser has a wavelength of 10.600 nm and can be used in either pulsed-wave or continuous-wave modes. Because of an excellent capacity for soft tissue ablation, CO_2 lasers have been successfully used as an adjunctive tool to de-epithelialize the mucoperiosteal flap during traditional flap surgery (Centty et al. 1997). The scattering of laser energy within the surrounding tissues is low and the layer of heat-altered tissue that remains after vaporization is relatively shallow; however the vaporization temperature is high and the irradiated surface is easily carbonized. With the CO2 laser, the performance advantages are the rapid and simple vaporization of soft tissues with strong haemostasis, which produces a clear operating field and requires no suturing (Pick et al., 1995). Gingival hyperplasia is a typical indication for CO2 laser treatment. Inorganic components of hard tissues, like bone and cementum (and also dental calculus), can reach very high temperatures, due to their content in apatite, especially phosphate ions (-PO_4), that absorb CO_2 laser wavelength much more than water (Featherston, 2000).

2.1.1 Periodontal applications of CO_2 laser

Several studies reported major thermal side effects, such as melting, cracking or carbonization when CO_2 lasers were used directly on root surface (Aoki et al. 2004). However, these negative effects were avoided when irradiation was performed in a pulsed mode with a de-focused beam (Barone et al., 2002). The defocused mode of the CO2 laser has root conditioning effects, such as smear layer removal, decontamination and the preparation of a surface favourable to fibroblast attachment (Crespi et al., 2002).

Transmission of the CO2 laser through optical fibers was very difficult and therefore the system previously employed mirror systems using articulated arms for laser beam delivery. In the case of the CO2 laser, because of the lack of an appropriate flexible delivery system with suitable contact tips for periodontal pocket therapy, only a few clinical studies have been reported on the effects of this laser in the non surgical treatment of periodontitis (Miyazaki et al., 2003; Mullins et al., 2007). Also, CO2 irradiation of the periodontal pocket using a special tip failed to result in a reduction of bacterial counts, and potentially damaged the soft tissue surrounding the periodontal pocket itself with cases of residual melted calculus being reported.

2.2 Nd:YAG laser

The Nd:YAG laser has a wavelength of 1.064 nm and operates in a free running pulsed mode. It is commonly used in periodontal therapy to incise and excise soft tissues as well for the curettage and disinfection of periodontal pockets. The Nd:YAG laser has low absorption in water, and the energy scatters or penetrates into the biological tissues. In water, the Nd:YAG laser will theoretically penetrate to a depth of 60mm before it is attenuated to 10% of its original strength (AAP, 2002). In soft tissue treatments, this laser is very effective at producing coagulation and haemostasis, in a relatively thick layer of soft tissues. Hence, the Nd:YAG laser is basically effective for ablation of potentially hemorrhagic soft tissue, being the width of coagulation from 0.3 to 0.8 mm at 3-10 W of laser power. However these effects are primarily caused by tissue heating and therefore irradiated surfaces usually exhibit a thick layer of coagulated tissue. Because of its high penetrability, the possible thermal effects on tissues laying below the irradiated are, such as dental pulp or bone tissue, is occasionally a matter of concern during periodontal treatment (Schwarz et al., 2009).

In dentistry, soft tissue surgery using the Nd:YAG laser has been widely accepted. In 1990, the FDA approved soft tissue removal by means of a pulsed Nd:YAG laser for intraoral soft tissue application without anaesthesia, with a minimal bleeding compared to scalpel surgery. The delivery system of the laser is flexible and suitable for periodontal employment, being a flexible optical fiber with a contact tip of 400 µm. In 1997 the FDA approved the use of Nd:YAG laser in sulcular debridement (Aoki et al., 2004).

2.2.1 Periodontal applications of Nd:YAG laser

The first in vitro studies on the use of Nd:YAG laser for calculus removal showed that its ability to remove calculus at a level equivalent to mechanical treatment is not easily clinically expectable. Different studies with different irradiation power and mode gave different degrees of calculus removal from the root and different effects on the root itself. Tseng & Liew (1990) demonstrated that partial removal and detachment of the calculus from the root surface was achieved by 2.0 to 2.75 W of power at 20 Hz pulse. However, melting of calculus and thermal damage was noted in localized areas of cementum and even dentin.

Morlock et al. (1992) showed that the Nd:YAG laser at 1.25-1.50 W, pulse 20 Hz, produced surface pitting and crater formation with charring, carbonization, melting, even when irradiation was performed parallel to root surface. Other authors demonstrated how the root surface was modified by Nd:YAG irradiation in a way that affected fibroblast recolonization and reattachment.

Also the removal of smear layer from the root surface is obtained only at powers that are not suitable for clinical use, either for a root alteration or for significant intrapulpal temperature rise.

Other authors demonstrated the possibility of calculus removal from the root with more or less extent of root damages. As subgingival calculus is often dark coloured, the Nd:YAG laser has the advantage of being absorbed by deposits. However the energy capable of detaching the calculus may be inappropriate for clinical usage due to increased thermal side-effects. Clinically an application of a low power Nd:YAG laser can result in an ineffective and patchy removal of calculus from the root surface. However, it would result in an alteration of calculus that should followed by facilitation of mechanical debridement.

Nd:YAG laser was the first to be approved by FDA for applying in periodontal pockets . It has been widely used by general practioners because of its ease of use. However, in spite of its long time use, there is still very insufficient proof of a positive effect from scientific studies.

Nd:YAG laser cannot achieve root surface debridement to a satisfactory degree, due to insufficient ability to remove calculus and to distinguish calculus from the root. If utilized, Nd:YAG laser should employed as an adjunct to conventional mechanical treatment to exploit the ability of curettage of the soft wall of pocket, to remove infected granulation tissue and epithelium, as for its ability of detoxification at a relatively low energy level.

Nonetheless, it has to be kept in mind that Nd:YAG laser has the capability of a deep penetration in oral tissue and the risk of a pulpal or alveolar bone temperature rise is high.

2.3 Nd:YAP laser

The Nd:YAP laser has a wavelength of 1.340 nm and it is mainly absorbed by black-pigmented tissues. Its employment in periodontal pocket treatment is still under investigation at first stages, however the concern related to a potential increase in temperature of the target is similar to that of Nd:YAG laser (Lee et al., 2005).

2.4 Er:YAG laser

The Er:YAG laser has a wavelength of 2.940 nm. It has a great absorption in water, theoretically 10.000 -20.000 times higher than that of CO2 and Nd:YAG lasers. Its light is well absorbed by all biological tissue that contain water molecules, so that Er:YAG laser is indicated not only for soft tissues but also for ablation of hard tissues (Aoki et al., 2004). In dental hard tissues the Er:YAG laser is absorbed by intrinsic water in apatite crystals and by OH group of the mineral apatite. So, Er:YAG laser has been used in a free-running pulse mode for caries removal and cavity preparation (Cozean et al., 1997).

Er:YAG laser was first approved for cavity preparation, and in 1999 it was accepted for soft tissue surgery, sulcular debridement and finally for osseous surgery. The huge absorption by water minimize, in fact, the thermal effect on surrounding tissues during irradiation, with a very thin penetration in soft tissues (10-50 μm) and only some degrees of heating in hard tissue. Because of the very low water content of hard tissues, since the Er:YAG laser emits in the infrared spectrum, some water coolant is advisable to reduce heat generation and absorb excessive laser energy (Burkes et al., 1992).

During Er:YAG laser irradiation, the laser energy is absorbed selectively by water molecules and hydrous organic components of biological tissues, causing evaporation of water by a "photothermal evaporation". Moreover, in hard tissue procedures, the water vapour production induces an increase of internal pressure within the tissue, resulting in an explosive expansion called "microexplosion" (Aiko et al., 2004) principle because of hard tissue ablation. The absorption of the Er:YAG laser by inorganic components (Hydroxyapatite) is however much lower than that of the CO2 laser, so that the absorption in water and in organic compounds with a water content is fast and occurs before heat accumulation into inorganic compounds. For these characteristics, Er:YAG laser received much attention by researcher both for soft tissue and for hard tissue applications.

2.4.1 Periodontal applications of Er:YAG laser

The ability of Er:YAG laser to remove subgingival dental calculus has already been shown in in vitro studies (Aoki et al., 1994; Aoki et al. ,2000; Folcwaczny et al.,2000; Frentzen et al., 2002). In 1994 Aoki et al. first documented the capacity of Er:YAG laser to remove dental calculus in an in vitro study, using a pulsed mode under irrigation. The laser was set at 30 mJ/pulse (energy density of single pulse at the tip:10.6 J/cm^2 per pulse) and 10 Hz, in the contact mode, directed perpendicular to the root surface using a conventional 600μm tip. The ablation of cementum was of little substance and the rise in pulpal temperature moderate. Stock et al. (1996) introduced a new tip, a chisel tip, suitable for root surface treatment within periodontal pockets. The authors utilized the tip with a power of 120 mJ/pulse (8 J/cm^2 per pulse) and 15 Hz with water spray and an angulation of the tip of 20° to the root surface, reporting that only smooth ablation traces were visible in the cementum. The calculus was completely removed without thermal change of the root surface. Aoki et al. (1994) evaluated the effectiveness of Er:YAG laser compared to conventional ultrasonic scaling. The panel set was 40 mJ/pulse (14.2 J/cm^2 per pulse) and 10 Hz with water spray using a conventional tip at 30° to the root surface. The level of calculus removal by laser was similar to that with ultrasonic scaling, although the laser was slightly less efficient. The depth of cementum removal varies between 15 and 150 µm depending on the output power. At a power up to 100 mJ/pulse (12.2 J/cm^2 per pulse) the root substance removal is similar to that with curettes and a selective calculus removal can be feasible using lower radiation energies (Aoki et al. 2000).

Thus, the Er:YAG laser does not accomplish selective ablation of dental calculus in vitro, as the tissue underlying dental calculus is also removed. However, for a safe but effective clinical use, a combination of a higher pulse repetition rate and a lower energy output is recommended to obtain a smooth root surface with less tissue removal.

On the contrary, supragingival scaling on enamel is contraindicated, since complete calculus removal occurs with a certain removal of enamel too, and this fact has no positive relevance compared to the removal of a thin layer of contaminated cementum.

Er:YAG laser does not cause carbonization of the irradiated root surface, that becomes chalky due to the mechanical ablation. In particular the layer just beneath the ablated cementum reveals more structural changes and damages, with microstructural degradation and thermal denaturation. The use of a water coolant results in less damage and a cleaner surface (Aoki et al. 2004). On periodontal diseased root, the Er:YAG laser treatment shows a better attachment and a better condition for fibroblast adherence compared to a diseased root treated only by mechanical means. These better results may be due to detoxification and disinfection obtained by laser and to the absence of a smear layer on the surface.

In animal studies Er:YAG laser showed no major thermal side-effects on pulp, when used under irrigation. It may be presumed that Er:YAG laser subgingival scaling at low level energy, especially with the contact tip directed obliquely or parallel to the root surface, does not produce any major deleterious outcomes in the pulp tissue.

The Er:YAG laser offers several antimicrobial advantages over conventional mechanical scaling, due to its bactericidal effect, degradation and removal of bacterial endotoxins, ablation effects without producing a smear layer (Aiko et al. 2004). Ando et al. (1996) observed a bactericidal effect against *P. gingivalis* and *A. actinomycetemcomitans* even at low energy level (Ando et al. 1996). Moreover, the wavelength of Er:YAG laser correspond to the peak of absorbance of bacterial lipopolysaccharide, so that the Er:YAG laser can effectively and rapidly remove most of the lipopolysaccharide that coat the teeth (Yamaguchi et al.,1997).

Based on the results of several in vitro studies, a clinical phase of controlling the effects of Er:YAG laser started in 1996 by Watanabe et al. (1996). The laser scaling was performed with a panel set of 40 mJ/pulse (11.3 J/cm^2 per pulse) at 10 Hz using a straight contact tip of 600 µm. According to authors 95% of calculus was removed, with only some irregularity left on tooth surface. More recently, Schwarz et al. (2001) reported a split mouth study comparing the effects of conventional scaling and root planing with two different laser tips. Periodontal pockets were treated under anaesthesia with hand instruments or one of the two tips, in an angulation of 15-20° to the root surface. Laser setting was 160 mJ/pulse with an energy density of 18.8 J/cm^2 or 14.5 J/cm^2 according to the tip. Laser treatment required less time than scaling and root planing, with similar or better results in terms of periodontal parameters (reduction of pockets, reduction of bleeding on probing, gain of attachment level). Laser advantage was higher in deep pockets and the clinical attachment gain obtained by laser was stable for 2 years.

Schwarz et al. (2001) showed that the clinical use of Er:YAG laser resulted in a smooth root surface, favourable for new attachment. However, histological studies have not been performed yet.

For clinical application the Er:YAG laser has some limitations that have to be taken into account. When used subgingivally, with a water coolant, it causes a splash of water and blood from pockets as the result of explosive ablation and so it requires an extraoral apparatus for high speed evacuation. Moreover, in periodontal pockets, the operator cannot see the calculus and the irradiated surface. Recently as a novel application of laser, the use of diode fluorescence spectroscopy for detection of dental calculus has been suggested by Hibst et al. (2001) and Keller et al. (2001).

In summary, in vitro and in vivo researches indicated the safety and effectiveness of clinical application of the Er:YAG laser for periodontal pocket treatment. However, the energy set, the energy output, the energy at the tip, the shape of the tip, the contact mode are key factors to obtain a satisfying clinical result. More studies are needed to design protocols of employment, however Er:YAG laser can be considered a promising adjunctive or alternative method for non surgical periodontal therapy.

2.5 Diode lasers

These lasers are a group of laser operating by a solid-state semiconductor, among which the most commonly used are the Gallium-aluminium-arsenide (GaAlAs) laser with a wavelength of 810 nm, and the indium-gallium-arsenide-phosphide (InGaAsP) laser at 980 nm of wavelength. The laser is emitted in continuous-wave mode and gated-pulsed mode using a flexible fiber optic delivery system (Figure 5).

Fig. 5. The diode laser fiber in clinical use in a pocket of a patient with chronic periodontitis.

Laser light at 800-980 nm is very poorly absorbed by water and by hard tissues, being highly absorbed by haemoglobin and pigments. The diode laser is indicated for soft tissue surgery and for curettage. The diode laser exhibits a great thermal effect at the tip, caused by heat accumulation and produces a very good haemostasis, with an effect similar to electrocauterization (ALD, 2000).

The very user-friendly hand-piece and the low cost of the unit, would make it suitable for periodontal pocket therapy, however the features of the laser light are more indicated for sulcular debridement.

2.5.1 Periodontal applications of diode lasers

The diode laser used on the root surface after scaling and root planing with curettes, showed no alteration on the root microstructure and the periodontal ligament cells attached on the treated roots as on the control roots which were unirradiated (Kreisler et al., 2001). However if the root was covered by blood, the roots were altered by laser irradiation with severe damages till carbonization. Temperature elevation was time and energy-dependant. The diode laser irradiation may jeopardize pulp vitality during root surface instrumentation.

Schwarz et al. (2003) performed in vivo on hopeless roots, a GaAlAs diode laser treatment (810 nm wavelength). They reported that diode laser was ineffective in removing calculus and altered the root in an unfavourable way. However, given the recommended parameters, the possibility of inducing root surface damages is virtually absent (Cobb et al. 2010).

Some studies demonstrated that diode laser is effective in bacterial elimination, resulting in a better healing. Moritz et al. (1997) showed a significant reduction of bacteria, as *A. actynomicetemcomitans*, with a parallel improvement of periodontal parameters. Caruso et al. (2008) compared the effectiveness of a diode laser (980 nm wavelength) used as an adjunct to SRP to SRP alone, with a power output of 2.5 W in a pulse mode (30 Hz) and a tip (400 µm) angulated at 20°. Findings indicated a slightly better periodontal healing, in terms of clinical parameters at 4, 8 and 12 weeks. However, the microbiological parameters revealed no differences between groups, showing no additional benefit of diode laser on the treated pockets.

Most recently, 655 nm InGaAsP (indium gallium arsenide phosphate) diode laser radiation has been included in an Er:YAG laser device to induce fluorescence in subgingival calculus (Folwaczny et al. 2002, Krause et al. 2003). Preliminary clinical and histological results have shown that fluorescence- controlled (feedback system) Er:YAG laser radiation enabled an effective removal of subgingival calculus and a predictable root surface preservation in comparison with hand instruments (Schwarz et al. 2006, Krause et al. 2007).

In recent years, it has also been suggested that GaAlAs radiation within the milliwatt range, referred to as "low-level laser therapy", may have a positive influence on the proliferation of gingival fibroblasts or periodontal ligament fibroblasts, thus supporting periodontal wound healing (Khadra et al. 2005)

2.6 Argon laser

The argon laser operates at a wavelength of 488 nm (blue) and 514 nm (blue-green). It is poorly absorbed by water so that it is not indicated for hard tissue treatments. It is well absorbed in pigmented tissues, including haemoglobin and melanin, and in pigmented bacteria. Thanks to this characteristic the argon laser was clinically studied to test its effect on pigmented bacteria in periodontal pockets in combination with mechanical root planing (Finkbeiner 1995). The author reported a significant pocket reduction. Considering the advantages of eradication of pigmented bacteria, this laser may be useful for the treatment of periodontal pockets, requiring, however, further studies.

2.7 Alexandrite laser

In 1995 Rechmann & Henning assumed that the wavelength of alexandrite laser (337nm) may be favourable for selective calculus ablation, basing the theory on the difference in spectral region of fluorescence emission from dentin and that from subgingival calculus. Their study revealed that the alexandrite laser at the power of 1 J/cm^2 of pulse and pulse repetition of 55Hz under water cooling, could selectively ablate dental calculus, supra and sub-gingivally, as well as dental plaque. The laser has a wavelength in the spectrum of ultraviolet and does not produce any damage or effect on enamel or cementum. The development of this laser is widely expected in relation to its capability of being selective, however, there is a main concern regarding the use of ultraviolet light and further studies are needed to demonstrate the safety and effectiveness of this laser.

3. Photodynamic laser therapy

Photodynamic therapy (PDT) is a minimally invasive process that utilizes photosensitizing drugs (photosensitizers), which, when administered systemically or locally to a patient, may be selectively retained by diseased tissues preferentially over normal healthy tissues. These drugs can be activated by intense and wavelength-specific light to achieve selective photochemical destruction of diseased cells, by the generation of a reaction that produces singlet oxygen and free radicals with a subsequent cytotoxic and vasculotoxic effect. Due to the highly reactive nature of radicals formed trough the process, activity is confined to their immediate environment. Thus activity is selective and dependent on the delivery of the photosensitizer to the target (Nastri et al., 2010). Theoretically, neither the photosensitizer nor light alone can induce an efficient cytotoxic effect on the cells. The light that activates the photosensitizer must be of a specific wavelength with a relatively high intensity. With the discovery of lasers that are collimated, coherent and monochromatic, the process became more specific and it was possible to use intensive light with low-level energy.

Depending on the type of drug, photosensitizer may be injected intravenously, ingested orally, or applied topically. Currently, PDT has been approved in many countries for clinical uses, mostly for the treatment of cancer (Meisel & Kocher, 2005).

Several studies have shown that PDT has also antimicrobial properties (Photodynamic Antimicrobial Therapy).

The human tissue efficiently transmits the red light and a wider wavelength activation photosensitising results in a deeper penetration of light. Most of the photosensitizers are activated by red light between 630 nm and 700 nm, corresponding to a depth of penetration of light by 0.5 cm (630 nm) to 1.5 cm (about 700 nm). This limits the degree of necrosis or apoptosis, and defines the therapeutic effect. While not every district in the human body is accessible to light, the periodontal pockets are easily exposed by using particular hand piece and the PDT could be effective.

Various photoactive compounds, natural and synthetic, have a photosensitising potential; they include degradation products of chlorophyll polyacetilen, thiophene (Meisel & Kocher, 2005).

In antimicrobial photodynamic therapy, the particular photosensitizers are toluidine blue O, methylene blue, erithrosine, povidone-iodine, which have been shown to be safe when employed in the medical field and are effective in both gram+ and gram- bacteria. As a light source, the diode lasers are the light source predominantly applied.

Nastri et al.(2010) presented a research with the aim of evaluating the bactericidal *in vitro* effect of laser diodes 830 nm (as the light source) after photosensitization with Toluidine Blue (TBO), on periopathogenic bacteria as *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, *Fusobacterium nucleatum* and *Prevotella intermedia*. After evaluating the effect on the single bacterial strain, authors also evaluated the ability of Diode Laser to disrupt the structure of biofilms produced by *A. actinomycetemcomitans* after photosensitization with TBO.

The study suggested that the association of TBO and diode laser light 830 nm was effective for the killing of both the main periopathogenic species alone (*Aggregatibacter actinomycetemcomitans, Prevotella intermedia, Porphyromonas gingivalis, Fusobacterium nucleatum*) and biofilms.

In a recent split-mouth study, it was demonstrated that non surgical periodontal treatment performed on patients with aggressive periodontitis, by applying photodynamic therapy alone, showed clinical improvements similar to that of conventional scaling and root planing (De oliveira et al., 2007). Also, it has been demonstrated that scaling and root planing combined with photo disinfection, or the application of photodynamic therapy alone, leads to reduction of pocket depth and clinical attachment gain (Andersen et al., 2007).

Braun et al. (2008) evaluated the effect of adjunctive antimicrobial photodynamic therapy (methylene blue + 100 mW diode laser) in chronic periodontitis using a split mouth design. After 3 months of healing, the adjunctive use of photodynamic therapy resulted in a significant higher change in mean relative attachment level, probing pocket depth, sulcus fluid flow rate and bleeding on probing at the sites receiving PDT than the control sites.

Taken together, the few data available from controlled studies suggest that in patients with chronic periodontitis, the adjunctive use of PDT to scaling and root planing may result in higher reductions in bleeding on probing, probing depth and higher CAL gain on a short term basis (3 to 6 months).

Therefore, photodynamic therapy as a low-level therapy, using a diode laser with short irradiation time, is considered not to produce side effects, like thermal changes, injuries to gingival or pulp tissues and to the intact periodontal apparatus at the basis of the pocket. Nevertheless, it is important to remind that the dye itself can be cytotoxic and that it remains in the pocket, potentially interfering with periodontal reattachment and compromise patients aesthetics by producing temporary pigmentation of the periodontal tissue (Takasaki et al., 2009). In addition it has to be clarified if selective killing of periodontopathogens by antimicrobial photodynamic therapy really occurs without affecting the normal oral microflora. However, it is still not known how many applications of PDT are necessary to completely eliminate bacteria and to prevent recolonization.

New basic and controlled clinical studies are needed to clarify the advantages or the limits of PDT, if it has to become widely applied in clinical practice. However, there can be several indications for PDT, as an adjunctive therapy to mechanical periodontal treatment, during surgical therapy or during maintenance.

4. Advantages of lasers

Irradiation shows a great power of ablation, haemostasis, detoxification and bactericidal effects. These features could potentially be a tool for periodontal therapy, especially for cutting of soft tissues as in the debridement of diseased tissue, in this sense being the laser an adjunctive therapy to mechanical approaches. However, laser showed strong thermal effects, causing melting, carbonization and cracking of hard tissues, such as root and bone (Ishikawa et al. 2009).

The recently developed Er:YAG and Er,Cr:YSGG lasers, can ablate both soft and hard tissues and are applicable with water irrigation to a safe periodontal therapy such as scaling and root planing, even in an alternative, unique treatment. These lasers may be capable of effective removing not only dental plaque but also calculus from the root surface, with extremely low mechanical stress and no formation of smear layer on the treated root surface.

Furthermore, potential biostimulation effects of scattering and penetrating lasers on the cells surrounding the irradiated tissues may be helpful for reduction of inflammation and healing of periodontal tissues.

Moreover, considering that most periodontopathogens have the capability of soft tissue invasion, not only debridement of the root surface but also removal of the epithelium lining and granulation tissue of the gingival wall within the pocket, could be important factors in the treatment of moderate to deep pockets in order to promote reattachment (Aoki et al. 2004). This may be particularly important for non healed pockets or for recurrent acute phase in residual pockets.

5. Disadvantages of lasers

Although the use of lasers for subgingival curettage and calculus removal in the treatment of periodontal pockets has been increasing among practioners, the scientific studies indicating positive results of laser are still insufficient. The use of lasers in a safe mode during routine clinic is still far to become a reality. The clinician should have a precise knowledge of characteristics and effects, of risks and disadvantages of each type of laser before using one of them for a certain clinical procedure. It has also to be reminded that different lasers have different characteristics and are not useful for everything. Due to the high cost of each apparatus, it is very difficult to have all the different lasers indicated for different procedures in a private practice

Improper irradiation of teeth and periodontal pockets by lasers can damage the tooth and root surface as well as the attachment at the base of the pockets. Possible damages to underlying bone and pulp are also to be considered. The risk of thermal injuries has always to be considered, as explained before, and the set of the laser power always accurately chosen in order to provide the less risk of damage to bone, root, pulp and surrounding tissues.

Lasers are completely different from conventional mechanical therapy because they exert their effects not only in a contact mode but also at distance. Inadvertent irradiation of patient's eyes or tissue outside the target must be strictly prevented. It is necessary that patient, operator and assistant wear special glasses to protect for the wavelength of the laser that has to be used. Use of wet gauze packs may be occasionally useful for protection of the surrounding tissues from accidental beam impact.

Furthermore, high speed evacuation systems are required to capture the water and blood vaporization produced by laser light and development of new apparatus with little hand pieces and thin tips, useful in periodontal pockets, is still at work.

6. Conclusions

Laser periodontal treatment for periodontitis is being receiving much attention both from researchers and clinicians. At the present state, there is a great need to develop an evidence-based approach to the study of lasers. The different studies and clinical application, even if performed with the same wavelength, may be different in several other set parameters, making it very difficult to compare the lasers and the gold standard of periodontal therapy: mechanical scaling and root planing. If CAL gain is the main parameter of success in periodontal non surgical therapy, there is scarce evidence that laser therapy can be superior to conventional treatment. Moreover, the evidence of some additional benefits coming from laser therapy as an adjunctive treatment to conventional mechanical treatment is minimal.

In conclusion, the use of lasers still requires many studies to become a routine therapy with the same advantages and low risks of conventional periodontal therapy. The most promising one is Er:YAG laser for its ability of calculus removing and with a relatively safe modality of use under water cooling. However, the high cost and the little demonstration of real superiority to conventional therapy is still a refrain. The perfect wavelength, power set and tip have not been studied yet. A reliable procedure for laser application in non surgical periodontal therapy should be established by further studies, and clinicians should have the precise knowledge of the potential benefits or damages before using this relatively new instruments, which are still under debate.

In summary, the use of lasers to debride root surface is in its infancy. They showed several positive effects, due to their characteristics of working in a noncontact mode, useful for very deep pockets and furcations, of bacterial detoxification and decontamination, to be more patient –tolerated etc. However, lasers show a history of significant side-effects, that should at least induce caution for their safe use.

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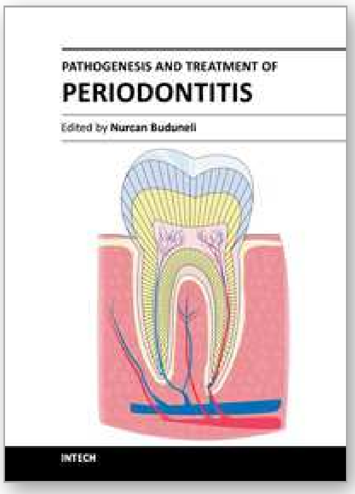

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Pathogenesis and Treatment of Periodontitis includes comprehensive reviews on etiopathogenic factors of periodontal tissue destruction related to microbial dental plaque and also host response components. Adjunctive treatment modalities are also addressed in the book. Topics covered range from microbial pathogenic factors of P. gingivalis to the relationship between metabolic syndrome and periodontal disease, and from management of open gingival embrasures to laser application in periodontal treatment.

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