Review Article

APPLICATION OF THE ERBIUM LASER IN PERIODONTAL PLASTIC SURGERY: A LITERATURE REVIEW

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Abstract

Lasers have been applied for periodontal tissue treatment such as soft tissue surgery, periodontal pocket treatment and osseous surgery. Recently, the erbium-doped yttrium aluminium garnet (Er:YAG) laser is considered one of the most promising lasers in periodontal therapy for acceptable clinical performance with less thermal damage in periodontal soft and hard tissue treatment. Furthermore, laser delivered with a fine contact tip enables precise and delicate irradiation, which is clinically useful for rigorous soft tissue management, such as gingivectomy, frenectomy, removal of melanin pigmentation and metal tattoos and crown lengthening with minimal bleeding. So, the aim of the current research was to determine application of the Erbium laser in periodontal plastic surgery using the PubMed and Medline database English literature by the terms "Erbium laser", "Periodontal plastic surgery", Dentistry". In conclusion clinical application of lasers in periodontal surgery has continued to expand in the last decade; however, controversies remain regarding their use. This article will describe the clinical application of erbium: YAG lasers for periodontal surgery: flap operations, osseous surgery, and semi-lunar coronally repositioned flap procedures, and peri-implantitis treatment by laser will be discussed.

Key words: Dentistry, Erbium laser, Periodontal plastic surgery.

Introduction

Since lasers were introduced for the treatment of dental and oral related disease, there has been considerable advancement in technology. Lasers are generally classified into two types, depending on their wavelength:

a) A deeply penetrating type, such as neodymium-doped yttrium-aluminium garnet (Nd:YAG) and diode lasers, in which the laser light penetrates and scatters deeply into tissue and
b) A superficially absorbed type (shallowly penetrating type), such as carbon dioxide (CO_2), Er: YAG and Er,Cr:YSGG lasers, in which the laser light is absorbed in the superficial layer and does not penetrate or scatter deeply.[1]

As a result, numerous laser systems are currently available for oral use. Nd:YAG, carbon dioxide laser and the semiconductor Diode lasers have already been approved by the US Food and Drug Administration for soft tissue treatment in oral cavity. The Erbium:YAG (Er:YAG) laser was approved in 1997 for hard tissue treatment in dentistry and recent studies have reported positive results. It is reported the Er:YAG laser system is a promising apparatus, which will be able to revolutionize and improve dental practice, in particular periodontal treatment. In this review, we would like to describe the positive characteristics of the Er:YAG laser which indicate its potential as a new approach modality in periodontics. Regarding the two types of erbium lasers, the effect of soft-tissue ablation seems to be greater following treatment with an Er:YAG laser than with an Er,Cr:YSGG laser.[2]

On the other hand, for Nd:YAG and diode lasers, part of the emitting light is converted into heat by refraction or diffused reflection at the tip end, creating a condition called "hot tip". Thus, the secondary thermal effects of the heated tip can cut or incise soft tissues. The tissue is coagulated and vaporized as a result of contact with the overheated tip rather than by the laser energy itself.[3] Regarding hard tissues, hard-tissue ablation with the Er:YAG laser (2,940 nm) has been speculated to occur as a result of "thermo-mechanical" effects based on photo-thermal interactions.[4] The Er,Cr:YSGG laser, closely related in wavelength (2,780 nm) to the Er:YAG laser (2,940 nm), shows physical and biological performances clinically comparable with those of the Er:YAG laser. However, the Er,Cr:YSGG laser is more highly absorbed by hydroxide (OH) ions than by water molecules. The mechanism of tissue ablation by the Er:YAG laser begins with thermal evaporation because the laser is readily absorbed in water and organic molecules within the biological tissues.[5]

So, the aim of the current research was to determine application of the Erbium laser in periodontal plastic surgery.

Materials and Methods

The keywords used for the literature search for this review was peer-reviewed articles following key-words: Erbium laser × accuracy × Periodontal plastic surgery × Dentistry. Among them, the papers were fit the criteria selected and available full-text articles read. Related articles were also scrutinized. Hand search was also driven. The search was carried out using Biological Abstracts, Chemical Abstracts, and the data bank of the PubMed and Medline database updated to 2017. The references found in the search were then studied in detail.

Periodontitis and Laser Treatment

The oral cavity is colonized by complex, relatively specific and highly interrelated micro-organisms such as Gram-positive and Gram-negative bacteria, fungi, mycoplasma, protozoa, and viruses.[6] Two of the most common bacterial diseases that afflict humans are dental caries and periodontal diseases. Broadly, PDT represents an alternative antibacterial, antifungal, and antiviral approach for drug-resistant organisms including bacteria that grow in the biofilm.[7] Previously, in this regard, reported PDT (662 nm) had crucial effect on *P. gingivalis* and *Fusobacterium nucleatum* in all subgingival areas in clinical infection animal model. There are limit information about duration of PDT therapy. A beneficial result observed at the 3 months follow-up. In contrast, few reports exist on effectiveness of PDT until six months post-treatment.[8] The progression of experimental periodontitis was substantially reduced after 3 month using PDT.[9] The PDT treatment of rats significantly diminished acid-phosphatase-positive cells, receptor activator nuclear factor-κB ligand and osteoprotegerin.[10] However, there are reports on increase cell count of *P. intermedia*, *P. nigrescens* and *T. forsythia* after PDT. Also, regrowth detected for *gingivalis* and *T. denticola* after 4 weeks of PDT.[10] In a study Copper *et al*[11] studied long term effects of PDT on oral cavity and oropharynx carcinomas. Based on their observations, only 4 lesions developed local recurrent disease after 1-6 months. It is inferred that the different periodontal treatments tested had distinct mechanisms of action against the bacteria and, thus, might have additive or even synergistic effects.[12]

Erbium:YAG laser

In 1975, Zharikov introduced the Erbium:YAG (Er:YAG) laser.[13] The active medium of this laser is a solid crystal of yttrium–aluminum–garnet that is doped with erbium. The Er:YAG laser has characteristics completely different from Nd:YAG laser. The wavelength of the Er:YAG laser lies near the boundary of the near infrared and mid-infrared, invisible portion of the spectrum. The coherent and collimated light of this laser with a wavelength of 2940 nm is highly absorbed in water.[14] Due to its high absorption by water, less tissue degeneration with very thin surface interaction occurs after Er:YAG laser irradiation. Also, the temperature rise is minimal in the presence of water irrigation, which makes hard tissue preparations, caries removal and scaling treatment easily possible with this laser, without any carbonization.[15] Due to its sterilization and soft tissue ablation characteristics, this laser can be used as a smooth laser knife, even though it is not capable of providing adequate hemostasis. However, when these lasers are applied to dental hard tissues, thermal side-effects have been a major problem. The thermal effect of the laser beam is based on the absorption of radiation by tissue and subsequent transformation of laser energy into heat. Heat generation during laser irradiation often causes carbonization, melting and cracking of the tooth structure, and inflammation and necrosis of the pulp.[16] The application of the CO_2 or Nd:YAG laser for hard tissue treatment tends to result in deleterious effects, such as carbonization, melting and denaturation of proteins, with consequent formation of toxic substances as well as compositional changes on the irradiated tissues.[17] However the Er:YAG laser showed satisfactory results for hard tissue ablation, due to its characteristic wavelength that is well absorbed by water. Hibst and Keller[18] have explained the theory of micro explosions regarding the mechanism for hard tissue ablation. According to this theory, the energy is selectively absorbed in water and other hydrous organic contents. Some vapour such as steam builds up internal pressure until explosive destruction of inorganic substance occurs before the melting point is reached. Therefore, the effects of Er:YAG laser are probably not explained completely by thermal effects, but by the micro explosions associated with water evaporation within the hard tissue. Human gingival fibroblasts were cultured on dental root fragments after calculus removal followed by Er:YAG irradiation at two different energy densities (60 and 100 mJ/pulse). The best cell adhesion and proliferation was obtained with a pulse of 60 mJ. This energy density creates a homogenous roughness similar to micro-excavations of the same depth and is distributed uniformly along the fragments.[19] The adhesion of blood components was also seen on roots modified by Er:YAG (7.6 and 12.9 J/cm^2) and diode (90 and 108 J/cm^2) lasers, forming a dense fibrin network with blood cells attached to it.[20] Both energy densities of the Er:YAG laser were more effective compared with the diode laser, which resulted in inhibition and little adhesion of blood components to the surfaces. This can be explained by the poor absorption of the diode laser by water or hydroxyapatite and because its energy is converted to heat. When compared with the control group (scaling and root planing), none of the treatments had statistically significant differences concerning adhesion of blood components.[20]

LASER Periodontal Plastic Surgery

Most lasers can be used in soft-tissue surgery where they exert a photo-thermal effect. In this, soft tissues are evaporated or incised, leaving different degrees of thermal denaturation, such as carbonization and coagulation, of the treated surface. Few studies have precisely compared wound healing among conventional instruments and lasers because it is basically difficult to prepare wounds with the same dimensions for both scalpel and laser incisions. As comparative studies available are limited and the results differ depending upon the type of laser employed, a consensus regarding the speed of wound healing following the use of lasers has not been reached.[5] Oral soft-tissue surgery using the Nd:YAG laser has been widely accepted.[21] White *et al*[22] successfully used the Nd:YAG laser for intra-oral soft tissue application, without anaesthesia and with minimal bleeding compared with scalpel surgery. It is reported that in rat skin incisions, Nd: YAG laser wounds produced with this laser at a low energy level could not be significantly differentiated from conventional incisions. However, although less damage and a lower inflammatory reaction occurred, increased matrix production and a small amount of wound contraction could be demonstrated with laser usage at a low energy level, and tissue exposed to high energy presented extensive damage, such as necrosis and an increased inflammatory reaction, and demonstrated a slower rate of wound healing.[23] Er:YAG lasers have been successfully used for osseous surgery. Abu-Serriah *et al*[24] used an Er:YAG laser to cut bone and tooth for removal of partially erupted lower third molars. They found that although laser surgery was more difficult and more time consuming, there was less postoperative pain and swelling, the cutting was less stressful and less unpleasant, and less prolonged pain was observed after laser treatment, compared with bur drilling. Lee[25] reported that despite the increased surgical time, use of an Er,Cr:YSGG laser for harvesting ramus/buccal cortical plate grafts holds promise asan alternative method to the high-speed surgical hand-piece in osseous surgery. According to Stubinger *et al*[26] successful Er:YAG laser osteotomy can be performed for intra-oral bone-grafting procedures without any complications and with an uneventful wound-healing process. In addition, erbium lasers have been applied for flapless crown-lengthening procedures.[27] Recent reports also suggest that Er:YAG laser bone surgery may be a new therapeutic approach for the treatment of bisphosphonate related osteonecrosis of the jaws.[28] Various clinical applications of erbium lasers have been reported, but their low efficiency in cutting cortical bone remains a problem. If the ablation process could be accelerated, the Er:YAG laser would be a promising alternative to conventional instruments for osteotomy, even with cortical bone. The Er:YAG laser is capable of effectively removing calculus and plaque from contaminated abutments and microstructured surfaces and removing biofilms grown on sandblasted and acid etched titanium surfaces without producing injuries in vitro.[29] The Er:YAG laser possesses a high bactericidal potential on implants with different surface characteristics, even when it is used at low energy densities. In particular, Schwarz *et al*[30] reported that irradiation with an Er:YAG laser was most suitable for the removal of plaque biofilm on a sandblasted and acid-etched surface prepared in the oral cavity compared with an ultrasonic system or plastic curette plus chlorhexidine rinsing. However, all treatment methods failed to restore the biocompatibility of previously contaminated sandblasted and acid etched titanium surfaces to the level of the non-contaminated control. Schwarz *et al*[30] also reported that the Er,Cr:YSGG laser exhibited high efficiency in removing plaque biofilm from the contaminated sandblasted and acid-etched surface in an energy dependent manner. Taniguchi *et al*[29] also reported that the anodized microstructure was always removed with the Er:YAG laser, resulting in exposure of a fresh rough titanium surface, which was beneath the original microstructure, without thermal damage. Er:YAG laser irradiation to machined, sandblasted and acid-etched and titanium plasma sprayed surface surfaces produced no or minimal alterations at the scanning electron microscopy level, but the irradiated surfaces negatively affected the viability and activity of osteoblastic cells attached on the surfaces. The removal of gingival tissue for restorative purposes is usually performed in order for a clinician to gain access and deliver treatment to areas located below the gingival margin and for the treatment of gingival hyperplasia. Alternatives for gingival tissue removal include the use of a scalpel, electro-surgery, and/or lasers. Lasers offer the potential of in-creased operator control and minimal collateral tissue damage. Diode lasers specifically, operate at a wavelength that is easily absorbed by the gingival tissues, while posing little risk of damaging the tooth structure. Naik *et al*[31] presented a 12 cases of phenytoin hyperplasia removed surgically by the CO_2 lasers and hence laser gingivectomy and suggested that in the future the laser may offer an alternative or an advancement to current procedures now used in dentistry. Lasers have been promoted for clinical crown lengthening without gingival flap reflection for both esthetic and prosthetic reasons. However, currently there are no con-trolled longitudinal or cohort studies supporting the use of lasers for clinical crown lengthening using the closed- flap technique. The only existing supports for such applications are non- con-trolled case reports. Laser can lead to warming, welding, coagulation, protein denaturation, drying, vaporization and carbonization causing the histological changes such as intracellular vacuolization, cellular hyper-chromatism and loss of intracellular structure, with the degree of charring of the tissues. Epithelial changes like blisters, clefts, erosions, and any intraepithelial or sub epithelial loss of attachment and vascular changes like intraluminal clotted erythrocytes, vascular stasis with presence of gathered erythrocytes and thrombosis or collapsed blood or lymphatic vessels can also occur. If disease-free margins are needed, the pathologist could encounter serious difficulties to evaluate them due to the presence of charred tissue, artifacts and denaturalized, coagulated and disorganized tissue of variable extension around the margins.[32] In a comparative evaluation of photoablative efficacy of Er:YAG and diode laser for the treatment of gingival hyperpigmentation. a randomized split-mouth clinical trial Giannelli *et al*[33] reported both diode and Er:YAG lasers gave excellent results in gingival hyperpigmentation. However, Er:YAG laser induced deeper gingival tissue injury than diode laser, as judged by bleeding at surgery, delayed healing, and histopathologic analysis. The use of diode laser showed additional advantages compared to Er:YAG in terms of less postoperative discomfort and pain. On dimensional changes in free gingival grafts: scalpel versus Er:YAG laser, both groups, there was a statistically significant reduction in vertical and horizontal dimensions and graft area at time points compared to the baseline measurements. There were no significant differences between the two groups with respect to vertical and horizontal dimensions and graft area at day 90. The Er:YAG laser may be used with similar effectiveness as the scalpel in the preparation of the recipient site for free gingival grafts. Thickness of the graft may be related to vascularization, healing period, and graft dimensions. Microscopically, healing of a graft of intermediate thickness is normally complete at 10.5 weeks, although thicker grafts may require 16 weeks or longer. Sullivan and Atkins reported that if the procedure is to be performed correctly, a graft thickness of 1–2 mm is crucial for the successful coverage of denuded roots. In another study, Maynard reported that a graft thickness of about 0.9 mm on the periosteal bed was sufficient for the proper functioning of the new tissue; but optimal thickness of the transplanted tissue was reported as 1–1.5 mm. While there have been different minimal thicknesses reported for successful grafting, in the present study, all grafts were standardized to 1–1.5 mm. Kara *et al*[34] evaluated of patient perceptions of frenectomy in a comparison of Nd:YAG laser and conventional techniques and revealed patients treated with the Nd:YAG laser had less postoperative pain and fewer functional complications. The results suggest that in the population studied, Nd:YAG laser treatment of soft tissue disorders provides better patient perceptions of success than those seen with conventional surgery. The Nd:YAG laser has been used for maxillary midline frenectomies, lingual frenectomies, gingivectomies, gingivoplasties, and operculum management. For routine clinical dental treatments, pain control is quite important for patient physical and dental well-being, as well as for the effectiveness of therapy. However, there are few studies comparing the postoperative effects of laser and conventional techniques.[28] However, reduced postoperative pain after oral surgery has been claimed by some after laser tissue ablation.[28]

Concern of laser therapy

Perhaps, further studies needed to determine adverse effects of PDT, if exist. Energy produced by an Er:YAG laser is absorbed by water and organic components. This will raise the temperature and convert water into vapor, thereby increasing the internal pressure within the deposits. Because of this expansion, the deposit can detach from the root surface. The Er:YAG laser also has a high bactericidal effect against periodontal bacteria at a low energy level.[20] It has the potential to ablate the root surface and remove toxins diffused into the root cementum with minimal loss of tooth substance.[12] However, there is still limited evidence to support laser therapy for subgingival debridement alone or in association with classical debridement.[15] Photodynamic therapy has also been tested in clinical studies as an adjunctive debridement method, especially during maintenance therapy. Photodynamic therapy is based on the principle that a photosensitizer binds to the target cells and is activated through light of a certain wavelength. In turn, singlet oxygen and other reactive agents are produced, which are extremely toxic to certain cells and bacteria.[15]

Case reports

In vitro studies showed that the Er:YAG laser effectively removed root-bound calculus without damage to the subjacent cementum and dentin.[5] Following Er:YAG laser–mediated scaling, root surfaces appear macroscopically smooth, although scanning electron microscopic examination reveals a relatively rough surface compared to that achieved by ultrasonic scaler instrumentation.[2] Apparently the chemical structure of Er:YAG- irradiated root surfaces is not altered and the biocompatibility of diseased surfaces is re-established, allowing fibroblast attachment.[6] Additionally, clinical studies demonstrated the effectiveness of the Er:YAG laser in SRP and in reducing subgingival bacterial loads.[6] In vivo human studies showed laser treatment alone or in combination with mechanical SRP produced positive trends with respect to gains in clinical attachment level and decreases in probing depth and bleeding on probing.[4] In a study on effect of Er:YAG laser–assisted periodontal flap surgery versus conventional treatment with the modified Widman flap procedure. A total of 146 single-rooted periodontally involved teeth from 25 patients were included in this study. In each patient, left or right maxillary single-rooted teeth were assigned randomly to one of two groups: group A (Er:YAG laser) and group B (modified Widman flap surgery). Er:YAG laser was used to debride the bone pockets, scale the root surface, and trim the periodontal flap. These authors reported Surgical treatment of single-rooted teeth with chronic periodontitis using the Er:YAG laser yields greater probing depth reduction and gains in clinical attachment level for up to 3 years compared to conventional Widman flap surgery. The short-term results obtained with both treatments can be maintained over 5 years. The nonsurgical application of an Er:YAG laser has been evaluated (Kreisler *et al*. 2002). Treatment with an Er:YAG laser led to significant clinical improvements 6 months after therapy, which were similar to conventional mechanical debridement using plastic curettes. The reduction of bleeding on probing was significantly higher in the Er:YAG laser treatment group. However, between 6 and 12 months after treatment, increased mean bleeding on probing scores and loss of mean clinical attachment level were observed at both laser and mechanically treated sites.[11] In another clinical long-term study, Schwarz *et al*[30] reported that although clinical improvements were achieved following 24 months of healing, the histopathological examination revealed the presence of a mixed chronic inflammatory cell infiltrate in the connective tissue stroma. Researchers[12] compared the nonsurgical treatment effects of an air-abrasive device and Er:YAG laser monotherapy in patients with severe peri-implantitis. Six months after therapy, bleeding on probing and suppuration significantly decreased in both groups, but the clinical treatment results were limited and similar between the two methods. Persson *et al*[21] reported the microbiologic effects of the nonsurgical treatment of peri-implantitis lesions using either an Er:YAG laser or an air-abrasive subgingival polishing method. At 1 month, the counts of *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Streptococcus anaerobius* were reduced in the air-abrasive group and those of *Fusobacterium spp.* were reduced in the laser group. Six-month data demonstrated that both methods failed to reduce bacterial counts and that the clinical improvements were limited.

Studies indicated that the renewal of biocompatibility of periodontal diseased root surfaces with Er:YAG laser radiation might enhance new attachment due to decreased bacterial loads within the pocket. In laser-tissue interaction, absorption occurs because of the presence of free water molecules, proteins, pigments and other organic matter. Laser light that is well absorbed by water (Er,Cr:YSGG, Er:YAG) is able to mechanically ablate enamel, dentin, and alveolar bone, while laser light not well absorbed by water and only absorbed by blood and tissue pigments (Diode, Nd:YAG), results in strong thermal reactions, such as carbonization, charring and melting of organic tissue.[3] Therefore, the Erbium laser ablates hard tissue through "microexplosion" rather than heating the tissue, resulting in minimal thermal effects. The Er:YAG laser can remove considerable calculus, cementum or both and penetration into cementum increased significantly at 150 MJ/pulse. Hand instrumentation may remove up to 264.4-343.3µm. The laser at 100 MJ can remove cementum up to 386.12µm. Aoki *et al*[14] conflicted with these findings and indicated the maximum removal of cementum by a laser of 140µm.[2] The favourable performance of Er: YAG laser makes them ideal for use in the treatment of both hard and soft periodontal tissues. We therefore examined the effectiveness of lasers in SLCRF procedures. An Er: YAG laser (Erwin Adv Er:LTM, J. Morita Mfg. Corp., Japan) was used to treat 46 cases of shallow gingival recession in 31 patients (8 men and 23 women, average age 47.2 years). The laser was operated at an energy output of 50-100 mJ/pulse and 10-20 Hz with water coolant. Special laser tips (S600T, C600F, and Brush) were used for incision and root preparation. SLCRF procedures were performed for 9 incisors and 14 molars in the maxilla and 6 incisors and 17 molars in the mandible. The patients were followed postoperatively for an average of 1.1 years. The amount of gingival recession was 2-4 mm (average of 2.5 mm). The Er: YAG lasers can be used surgically to vaporize and remove biofilm and calculus associated with a dental implant. Laser removal of polyps attached to bone is advantageous with respect to the production of new bone because of no smear layer remains on the osseous surface. After suturing, occasional vaporization of neighbouring epithelial tissue can be performed for the purpose of delaying invasion of the sub-implant by the epithelium.[17]

Conclusion

In conclusion clinical application of lasers in periodontal surgery has continued to expand in the last decade; however, controversies remain regarding their use. This article will describe the clinical application of erbium: YAG lasers for periodontal surgery: flap operations, osseous surgery, and semi-lunar coronally repositioned flap procedures, and peri-implantitis treatment by laser will be discussed.

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