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The Use of Lasers in the Treatment of Inflammatory Tissue Periodontal Disease

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Abstract: Peri-implantitis is a state defined as an inflammatory reaction around osseointegrated implants. Various treatment methods are suggested in the treatment of peri-implantitis and clinicians have to choose a method over a large number of treatment protocols. Lasers have shown promising therapeutic effect in treatment of peri-implantitis. The use of different lasers has also been proposed for the treatment of periodontal and peri-implant infections. Preliminary results from both basic studies and controlled clinical trials have pointed to a high potential of the Er:YAG laser. Irradiation with this specific wavelength seems to provide a bactericidal effect against periodontopathic bacteria, a reduction of lipopolysaccharides and a high ability of bacterial biofilm and calculus removal. Therefore, we aimed to review the current literature over the past 10 year for the use of lasers in treatment of peri-implantitis and evaluate, based on the currently available evidence, the use of an Er:YAG laser for treatment of periodontitis and peri-implantitis and to indicate its potential as a new treatment modality.

Key words: Peri-implantitis, Er:YAG laser, therapy, dental implants, Iran

INTRODUCTION

The term ‘‘periodontal disease’’ in its strictest sense refers to both gingivitis and periodontitis (Kinane, 2001). Gingivitis has been defined as an inflammatory condition of the soft tissues surrounding the teeth and seems to be a direct immune response to microbial plaque biofilms building up on teeth. It may be modified by several factors such as smoking, certain drugs and hormonal changes that occur in puberty and pregnancy (Nunn, 2003). Special drug therapies such as nifedipine and cyclosporine can result in gingival overgrowth in approximately 30% of individuals taking these medications. Chronic gingivitis is seen commonly in individuals with poor oral hygiene procedures for between 10 and 20 days (Loe *et al.*., 1965). Periodontitis follows gingivitis and is also influenced by the individual’s immune and inflammatory response. It is characterized as a destruction of the supporting structures of the teeth including the Periodontal Ligament (PDL), bone and soft tissues which in turn may cause tooth loss (Kinane, 2001).

The prevalence of peri-implantitis in man is difficult to estimate but may vary for most implant systems between 2 and 10% (Esposito *et al.*, 1998; Mombelli and Lang, 1998). The response of the soft tissues surrounding both teeth and implants to early and more long-standing periods of plaque formation was analysed in experimental animal (Berglundh *et al.*, 1992; Ericsson *et al.*, 1992) as well as in human studies (Pontoriero, *et al.*, 1994). During the course of the study, it was observed that similar amounts of plaque formed on the tooth and implant segments of the dog dentition. The composition of the two developing bacterial biofilms was also similar. Therefore, it may be concluded that early microbial colonization on titanium implants followed the same patterns as that on teeth (Leonhardt *et al.*, 1992). Biofilm host response to formation on implant surfaces includes a series of inflammatory reactions which initially occur in the soft tissue but which may subsequently progress and lead to loss of supporting bone. The presence of bacteria on implant surfaces may result in an inflammation of the peri-implant mucosa and, if left untreated, it may lead to a progressive destruction of the alveolar bone supporting the implant which has been named periimplantitis (Mombelli and Lang, 1994; Mombelli *et al.*, 1987).

Ideally, periodontal therapy does not only include arresting the disease but also regeneration of the tissues which have been lost due to disease. This includes de novo formation of connective tissue attachment and the regrowth of alveolar bone (Caton and Greenstein, 1993). A major goal of periodontal treatment is to resolve inflammation and thereby arrest disease progression (Caffesse *et al.*, 1995). The results from controlled clinical

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studies have shown that nonsurgical (i.e., scaling and root planing using hand instruments) and various types of conventional surgical treatment may lead to a clinically important and statistically significant probing pocket depth reduction and Clinical Attachment (CAL) level gain (Isidor and Karring, 1986; Kaldahl *et al*., 1996; Ramfjord *et al*., 1987). However, histologic studies demonstrated that healing following nonsurgical and any type of conventional surgical periodontal therapy is mainly characterized by formation of a long junctional epithelium along the instrumented root surfaces and no predictable regeneration of attachment apparatus (Caton and Greenstein, 1993; Aukhil *et al*., 1988; Bowers *et al*., 1989; Caton *et al*., 1980; Sculean *et al*., 2000; Sculean *et al*., 2003). In this context, the formation of a smear layer after both mechanical scaling and root planing and ultrasonic instrumentation has been reported to be detrimental to periodontal tissue healing as it may inhibit reattachment of cells to the root surface (Blomlo and Lindskog, 1995; Blomlof *et al*., 1997). However, additional root surface conditioning with various substances such as Ethylenediaminetetraacetic acid gel (EDTA) at neutral pH, citricand ortho-phosphoric acids has been shown to be effective in removing the smear layer and exposing the collagenous matrix of dentin (Blomlof *et al*., 1996, 1997; Blomlof and Lindskog, 1995).

The use of laser radiation has been expected to serve as an alternative or adjunctive treatment to conventional, mechanical periodontal therapy. Various advantageous characteristics, such as hemostatic effects, selective calculus ablation or bactericidal effects against periodontopathic pathogens might lead to improved treatment outcomes (Ando *et al*., 1996; Aoki *et al*., 1994; Folwaczny *et al*., 2002). The wavelengths of the lasers most commonly used in periodontics which include diode lasers, the Nd:YAG laser (neodymium-doped: yttrium, aluminium and garnet), the Er:YAG laser (erbiumdoped: yttrium, aluminium and garnet) and the CO_2 (carbon-dioxide) laser, range from 819-10,600 nm.

INSTRUMENTS

This fiberoptic technology allows for contact with the target tissue. The fiberoptic cables are attached to a small handpiece similar in size to a dental turbine and are available in sizes ranging from 200 Lm in diameter to 1000 Lm in diameter. Fiberoptic cables also are relatively flexible. This flexibility allows for easy transmission of the laser energy throughout the oral cavity, including into periodontal pockets. Fiberoptic delivery and articulated arm systems are not the only two delivery systems currently on the market. One manufacturer has developed a hollow waveguide delivery system. In contrast to an articulated arm system, this waveguide is a single

Fig. 1: Waveguide delivery system (Courtesy of Opus Dent, Santa Clara, CA)

long, semiflexible tube, without knuckles or mirrors. The laser energy is transmitted along the reflective inner lumen of this tube and exits through a handpiece at the end of the tube (Fig. 1). This handpiece comes with various attachments that the dentist may select, depending on the procedure to be performed and may be used either in contact or out of contact with the target tissue. Figure 2 illustrates fiberoptic cables of various diameters and handpieces from a Carbon dioxide (CO_2) waveguide delivery system.

The final delivery system is the air-cooled fiberoptic delivery system. This type of delivery system is unique to the erbium family of lasers. A conventional fiberoptic delivery system cannot transmit the wavelength of the erbium family of lasers, owing to the specific characteristics of the erbium wavelength. These special air-cooled fibers terminate in a handpiece with quartz or sapphire tips. These tips are used slightly (1-2 mm) out of contact with the target tissue.

Laser procedures categorize: Most soft tissue laser procedures can be categorized into one of three simple

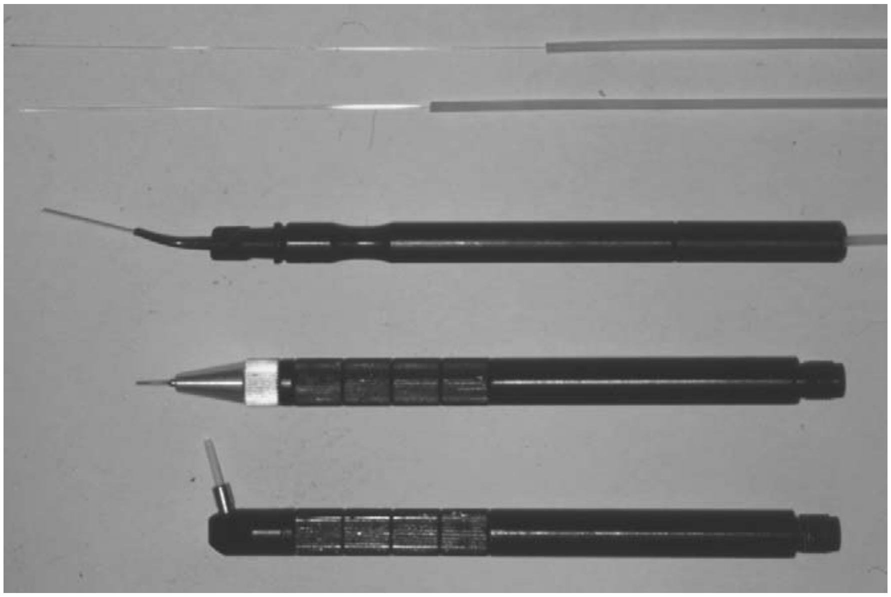

Fig. 2: Fiberoptic cables of various diameters and handpieces from a CO_2 waveguide delivery system. (Courtesy of Robert Convissar, DDS, New York, NY)

processes: incision, excision or ablation. Whether the dentist is performing a soft tissue tuberosity reduction (excision) to enhance the results of a removable prosthetic treatment plan, performing a small biopsy of a large lesion on the palate (incision) or removing an area of lichen planus from the buccal mucosa (ablation), the basic processes are the same, no matter which wavelength is used. There is a difference in how the various lasers interact with oral tissue, depending on the ability of the target tissues to absorb the laser energy. The most significant differences among the different types of oral soft tissues are the pigmentation, vascularity and water content. As an example of how these differences affect the selection of a wavelength, imagine two patients who need a gingivectomy. The first patient has light, coral pink gingiva; the second patient has dark, melanotic gingiva. The chromophore for the CO_2 laser is water. There would be no difference in the cutting efficiency when using a CO_2 laser on these patients.

Using the same patient models, gingivectomies performed with the Nd:YAG and diode lasers would result in a significant difference in the cutting efficiency. Diode and Nd:YAG lasers are absorbed preferentially by tissue pigments, such as hemoglobin and melanin. The darker melanotic gingiva would absorb the laser energy much more easily; it would cut more quickly and easily than the coral pink gingiva. The melanotic tissue might cut more rapidly than the clinician would like, possibly damaging the tissue or creating a larger zone of thermal necrosis around the target tissue. In this case, laser parameters (pulse duration, hertz, joules) would need to be modified from one patient to another. Laser parameters suggested by the manufacturers are for the ''average'' patient. These parameters must be modified based on many factors with tissue pigmentation being one crucial factor. This is an important fact that might be lost on new laser users.

Imagine two orthodontic patients wearing full bands and arch wires. The first orthodontic patient has immaculate home care. The gingiva is firm, pink and stippled. The second patient's home care is practically nonexistent. The combination of poor home care and a foreign body (orthodontic appliance) acting as a plaque trap has led to gingival hyperplasia. The gingiva is hyperemic, red and inflamed. Both patients need gingivectomies to increase the gingivoincisal length of the teeth. Comparing the results of treatment with a diode and an Nd:YAG laser would show large differences in treatment outcomes. The chromophore that is absorbing the laser energy in this case is the hemoglobin. The hyperemic, swollen tissue with more vascularity cuts more quickly with the diode and Nd:YAG lasers than the healthy pink tissue. In the case of the CO_2 laser gingivectomies, the chromophore is water. The swollen, hyperemic tissue would have more water content and would absorb the CO_2 laser energy more readily.

Due to an excellent soft tissue ablation capacity, CO_2 lasers have been successfully used as an adjunctive tool

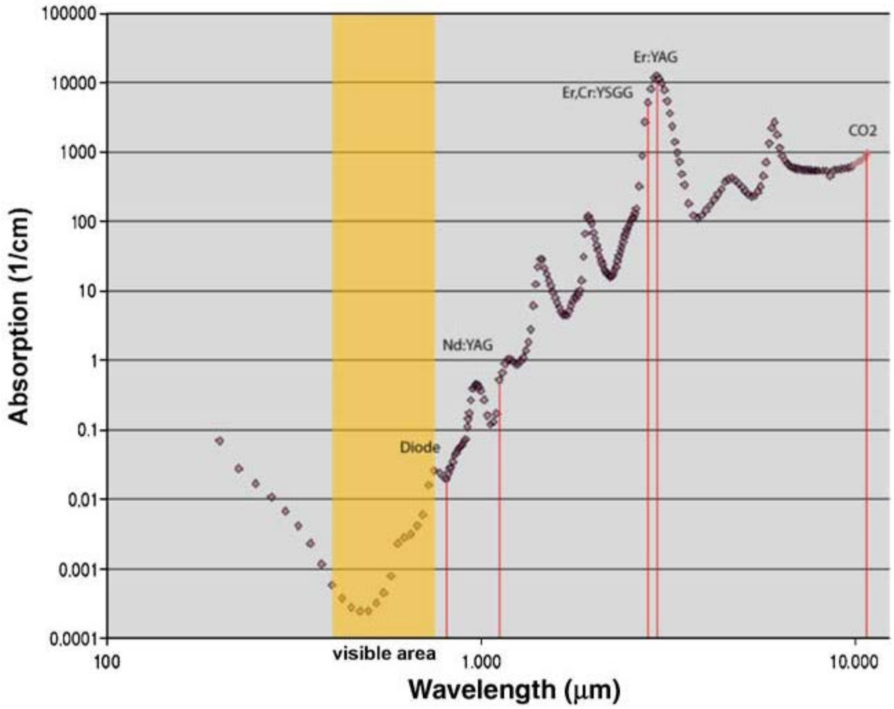

Fig. 3: Water absorption characteristics of different laser wavelengths

to deepithelialize the mucoperiosteal flap during traditional flap surgery (Centty *et al*., 1997). Diode and Nd:YAG lasers were mainly used for laser-assisted subgingival curettage and disinfection of the periodontal pocket with various degrees of success (Cobb *et al*., 1992; Liu *et al*., 1999; Moritz *et al*., 1998). However, several studies reported on thermal side effects, such as melting, cracking or carbonization when CO_2 and Nd:YAG lasers were used directly on root surfaces (Israel *et al*., 1997; Tewfik *et al*., 1994; Tucker *et al*., 1996; Wilder *et al*., 1995). In case of the CO_2 laser these negative effects could be avoided when irradiation was performed in a pulsed mode with a defocused beam (Barone *et al*., 2002). So far, there is limited information about the effects of diode laser radiation on the surface properties of root surfaces.

This laser may also cause damage to periodontal hard tissues if irradiation parameters are not adequate (Kreisler *et al*., 2002). Furthermore, neither CO_2 nor Nd:YAG nor diode lasers were effective in removing calculus from the root surface (Liu *et al*., 1999). Since, according to the cause-related concept of periodontal therapy, the main objective of treatment is to remove all calcified deposits from the root surface (Oleary, 1986), these types of lasers should only be used as an adjunct to mechanical periodontal treatment. Close attention has been paid to the clinical applicability of the Er:YAG laser with a wavelength of 2.94 mm in the near infrared spectrum. Because of the high absorption of its emission wavelength by water, this laser system provides a capability to effectively remove calculus from periodontally diseased root surfaces without causing thermal side effects to the adjacent tissue (Aoki *et al*., 1994). The absence of thermal damages was most likely due to the optical characteristics of its wavelength of 2940 nm, since the Er:YAG laser theoretically has a 10 and 15.000-20.000 times higher absorption coefficient of water than the CO_2 and the Nd:YAG lasers, respectively (Fig. 3).

LITERATURE REVIEW

Aoki *et al*. (1994) reported on the effectiveness of Er:YAG laser scaling in comparison with ultrasonic scaling in vitro. This laser provided calculus removal on a level equivalent to that provided by an ultrasonic scaler. The efficiency of laser scaling was lower than that of the ultrasonic device. Although periodontal treatment with an Er:YAG laser may offer some interesting perspectives to the clinician, some questions are still present and need to be solved. One of them is the extent of the root surface damage after laser application. Histological and Scanning Electron Microscopic (SEM) examinations have shown that under in vitro conditions the Er:YAG laser ablated not only the calculus but also the superficial portion of the underlying cementum.

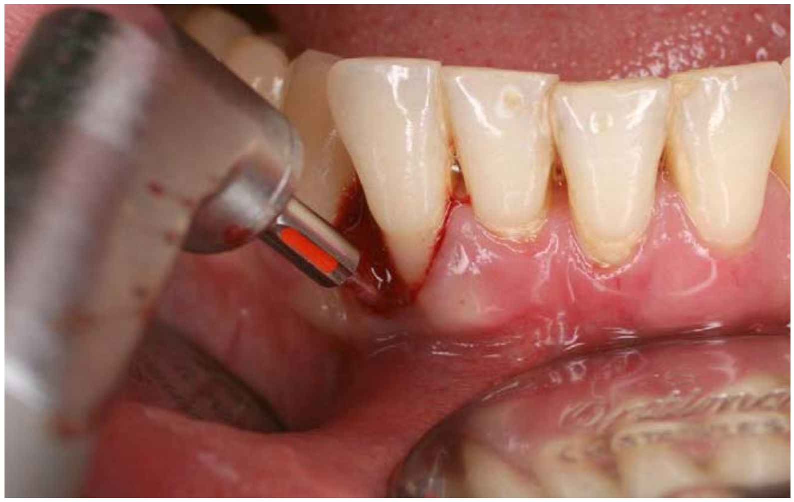

Fig. 4: The chisel-shaped glass fibre tip of the Er:YAG laser should be moved from coronal to apical in parallel paths with an 151 inclination of the fibre to the root surface

The surface was left with an acid-etched appearance microscopically (Aoki *et al*., 1994). However, this microstructured root surface showed no cracks or thermal effects like carbonization or melting after CO_2 and Nd:YAG laser irradiation (Israel *et al*., 1997). The absence of thermal side effects following Er:YAG laser irradiation of root surfaces has been confirmed by several researchers. Aoki *et al*. (1994) also have demonstrated that a pulsed Er:YAG laser may be suitable for an effective removal of subgingival calculus from periodontally diseased root surfaces using a glass-fibre tip in contact mode under water irrigation (energy density: 10.6 J cm^{-2}).

The lack of a smear layer formation on the root surface after Er:YAG laser instrumentation was Another important observation (Centty *et al*., 1997). The formation of a smear layer after mechanical root surface debridement with hand or ultrasonic instruments has been reported to be detrimental to periodontal tissue healing as it may inhibit cell migration and attachment (Wilder *et al*., 1995). It is important to point to the results from previous studies which have shown that the surface structure of previously diseased roots after Er:YAG laser instrumentation seemed to offer better conditions for the adherence of PDL fibroblasts than scaling and root planing with hand instruments (Israel *et al*., 1997).

A recent histological study, evaluating human intrabony defects following access flap surgery with root surface and defect debridement using an Er:YAG laser, revealed that healing was predominantly characterized by formation of a long junctional epithelium along the instrumented root surface. Formation of a new connective tissue attachment (i.e., new cementum with inserting collagen fibres) was only observed occasionally. Finally, several studies have reported antimicrobial effects against periodontopathic bacteria and the removal of lipopolysaccharides by Er:YAG laser radiation from root surfaces *in vitro* (Ando *et al*., 1996). However, preliminary clinical data failed to demonstrate any additional bactericidal effects following Er:YAG laser irradiation of periodontal pockets when compared to scaling and root planing using hand instruments (Ando *et al*., 1996). In this context, it must be emphasized that a bacterial recolonization of the periodontal pocket occurs after 3 months (Schwarz *et al*., 2003).

Controlled clinical trials have indicated that nonsurgical periodontal treatment with an Er:YAG laser may lead to significant clinical improvements as evidenced by Probing Depth (PD) reduction and gain of CAL. In particular, in a clinical case report study evaluating the clinical assessments of an Er:YAG laser for soft tissue surgery and scaling, a total of 38 patients with moderate to advanced periodontitis were treated (Moritz *et al*., 1998). Each subject was evaluated on the day of laser application and after 1-4 weeks. Mean PD was reduced from 5.672.0-2.670.9 mm. These results were statistically and clinically significant compared to baseline.

In a first controlled clinical study, Er:YAG laser irradiation was compared to conventional scaling and root planing using a split-mouth design in 20 patients (Folwaczny *et al*., 2002). Periodontal pockets of 110 teeth exhibiting subgingival calculus with moderate to advanced periodontal destruction were treated under local anesthesia with either the Er:YAG laser or hand instruments. Laser treatment was performed using chisel typed contact tips (1.10×0.5 or 1.65×0.5 mm) under water irrigation (Fig. 4). No further details concerning the development of Gingival Recessions (GR) and CAL were given. Schwarz have treated 15 patients, suffering from chronic periodontitis with an Er:YAG laser. The postoperative healing was uneventful in all cases. No complications such as abscesses or infections were observed throughout the study period of 6 months. Subsequent to instrumentation, mean CAL was statistically significant improved when compared to the baseline scores.

Schwarz *et al.* (2003) investigated the necessity of adjunctive scaling and root planing after Er:YAG laser treatment. However, it was observed that the combined treatment Er:YAG laser and scaling and root planning did not seem to additionally improve the outcome of the therapy compared to laser treatment alone. Most recently, Sculean *et al.* (2000) compared the effectiveness of an Er:YAG laser to that of ultrasonic instrumentation for nonsurgical periodontal treatment. Twenty patients with moderate to advanced periodontal destruction were randomly treated in a split-mouth design with a single episode of subgingival debridement using either an Er:YAG laser device combined with a calculus detection system with fluorescence induced by 655 nm InGaAsP diode laser radiation, or an ultrasonic instrument. Use of lasers for the treatment of peri-implant infections.

There is considerable evidence to support a cause-effect relationship between microbial colonization and the pathogenesis of implant failures. The presence of bacteria on implant surfaces may result in an inflammation of the peri-implant mucosa and, if left untreated, it may lead to a progressive destruction of the alveolar bone supporting the implant which has been named peri-implantitis (Mombelli and Lang, 1994; Mombelli *et al.*, 1987). Therefore, the removal of bacterial plaque biofilms is a prerequisite for the therapy of peri-implant infections (Mombelli and Lang, 1994). In recent years, several maintenance regimens and treatment strategies, (i.e., mechanical, chemical) for failing implants have been suggested (Folwaczny *et al.*, 2002). Mechanical debridement is usually performed using specific instruments made out of materials less hard than titanium, (i.e., plastic curettes, polishing with rubber cups) in order to avoid a roughening of the metallic surface which in turn may favour bacterial colonization (Eberhard *et al.*, 2003; Aoki *et al.*, 2000; Folwaczny *et al.*, 2000). Since, mechanical methods alone are insufficient in the elimination of bacteria on roughened implant surfaces, adjunctive chemical agents (i.e. irrigation with local disinfectants, local or systemic antibiotic therapy) were examined clinically and proven to enhance healing following treatment (Moritz *et al.*, 1998; Israel *et al.*, 1997; Tewfik *et al.*, 1994; Tucker *et al.*, 1996). Although, air-powderflow was also successfully used for implant surface decontamination *in vitro*, there are limitations in the application because it can lead to microscopically visible alterations of the implant surface and be associated with an increased risk of emphysema (Kreisler *et al.*, 2002). Recently, in addition to these conventional tools, the use of different laser systems has also been proposed for treatment of peri-implant infections. As lasers can perform excellent tissue ablation with high bactericidal and detoxification effects, they are expected to be one of the most promising new technical modalities for treatment of failing implants (Liu *et al.*, 1999).

The interaction between laser light and metal surfaces is mainly determined by the degree of absorption and reflection. Each metal features a certain spectral reflection capacity which is dependant on the specific wavelenght of the laser. The reflection capacity of titanium for the Er:YAG laser with its wavelenght of 2940 nm in the near infrared spectrum is 71% and rises up to 96% for the CO_2 laser at 10,000nm (Aoki *et al.*, 1994). In this situation, the implant surface does not absorb the irradiation and subsequently there is no temperature increase which would damage the implant surface.

Indeed, recent in vitro studies have demonstrated that, in an energy dependent manner, only the CO_2 laser, the diode laser and the Er:YAG laser may be suitable for the irradiation of implant surfaces, since the implant body temperature did not increase significantly during irradiation (Blomlo *et al.*, 1996, 1997; Polson *et al.*, 1984; Ando *et al.*, 1994, 1996). Regarding the effect of lasers on titanium, the Nd:YAG laser is not suitable for implant therapy, since it easily ablates the titanium irrespective of output energy. So far, bactericidal effects on textured implant surfaces in vitro were only reported for the CO_2 and Er:YAG laser. Since, neither CO_2 nor diode lasers were effective in removing plaque biofilms from root surfaces or titanium implants, both types of lasers were only used adjunctive to mechanical treatment procedures (Moritz *et al.*, 1998; Tucker *et al.*, 1996). In contrast, as described above, several investigations have reported on the promising ability of the Er:YAG laser for subgingival calculus removal from periodontally diseased root surfaces without producing major thermal side-effects to adjacent tissue (Aoki *et al.*, 1994).

CONCLUSION

When selecting a laser for a specific procedure, the dentist must consider the interaction between the wavelength, target tissue and surrounding tissue. For many dental procedures, most soft tissue lasers produce excellent results. For these procedures in which the selection of wavelength is a matter of personal preference, the selection of the correct operating parameters (joules, hertz, pulse duration) is crucial to the success of the procedure. For certain specific procedures, the choice of wavelength is crucial for the success of the procedure.

The use of laser radiation has been expected to serve as an alternative or adjunctive treatment to conventional, mechanical periodontal therapy. Among all lasers used in the field of dentistry, the Er:YAG laser seems to possess characteristics most suitable for oral treatment, due to its ability to ablate both soft and hard tissues as well as bacterial biofilms and calculus without causing major thermal damage to the adjacent tissue.

Indeed, a huge number of experimental and clinical studies have pointed to a high potential of this kind of laser for periodontal treatment, suggesting from a clinical point of view, that the Er:YAG laser may serve as an alternative treatment modality to conventional, mechanical periodontal therapy. These observations, taken together with the finding that periimplantitis has been classified as a disease process associated with microorganisms known from chronic periodontitis, suggest that the Er:YAG laser may also be used for treatment of peri-implant infections.

Indeed, when interpreting the results of the presented studies, it may be concluded that the Er:YAG laser seems to be more suitable for the removal of early plaque biofilms grown on SLA titanium implants than conventional, mechanical treatment approaches. Furthermore, preliminary clinical results suggest, that nonsurgical treatment of peri-implantitis with an Er:YAG laser may lead to significant improvements of all of the investigated clinical parameters. Previous case report studies have shown that the use of adjunctive local or systemic antibiotic therapy also had a positive effect on clinical and microbiological parameters. In this context, it must be pointed out, that currently there is still a lack of clinical data evaluating the subgingival microflora associated with peri-implant infections following Er:YAG laser irradiation in vivo. Therefore, further studies are needed in order to compare the effectiveness of this treatment modality on microbiological changes to that of adjunctive local or systemic antibiotic therapy.

Another point of interest may be the evaluation of the relative cost-effectiveness of different treatment approaches. From a clinical point of view, it should also be taken into account that a huge number of different implant types and surface characteristics complicate a generalization of the present results.

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