

The Use of Laser Energy in Implantology

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SYNOPSIS

This article discusses how lasers can be used during various dental implant procedures, including assisting in the osseous site preparation, second stage exposure, and the treatment of peri-

Introduction

The use of laser photonic energy has been shown to be effective in many aspects of clinical dentistry. The benefits of laser use include precision, hemostasis, pathogen reduction, and interaction with both hard and soft oral and dental tissue, depending on the laser wavelength employed.¹ In consideration of the breadth of application of laser therapy with oral tissue and bacteria, the areas of implantology in clinical dental practice that might be applicable to the use of laser photonic energy are the possible preparation of osteotomy sites for placement, together with bone modification procedures, soft

tissue manipulation in assisting the second-stage recovery of healed implants, and in the treatment of peri-implantitis.

Laser-Assisted Osteotomy Site Preparation

Bone is a connective tissue derived from hyaline cartilage whose matrix, under the influence of calciferol, has been hardened by the deposition of calcium and phosphate to form a carbonated hydroxyapatite-like mineral.² Erbium:YAG (2940 nm) and erbium,chromium:YSGG (2780 nm) are the two lasers in current clinical practice that are used for osseous procedures. Erbium laser energy is

absorbed by chromophores (naturally occurring substances) found in bone tissue — water and the hydroxyl groups of the hydroxyapatite mineral. Ablation occurs through vaporization of water and explosive dislocation of mineralized tissue.^{3,4} The nature of the ablative process achieved with commercially available microsecond pulse emission, together with the

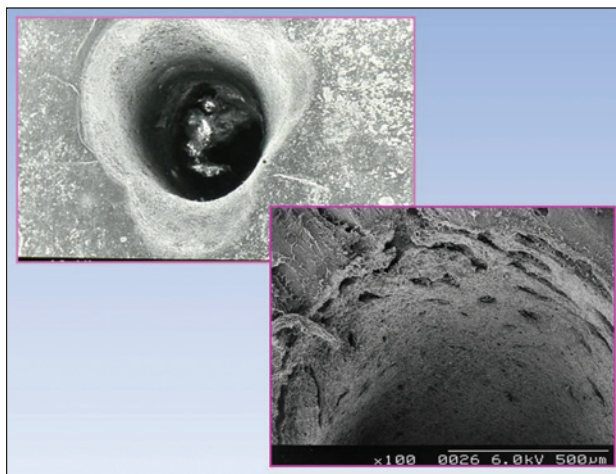


Figure 1: Scanning electron micrographs of animal specimen bone showing ablation crater prepared with an Er:YAG laser. **Key:** Upper left specimen x20 magnification, lower right specimen further magnified to x100 power. Laser parameters used: 400 mJ per pulse / 10 Hz / Average Power 4.0 Watts / Beam size 600 μ m / Water spray

ABSTRACT

Laser use in dentistry is well-founded. The emergence of many laser wavelengths in commercially available machines has allowed evidence-based application of photonic energy in aspects of oral and dental surgery. In addition, the prime benefits of incisional hemostasis, precision, and pathogen reduction have enabled the surgical manipulation of both hard and soft tissue within clinical dentistry.

Dental implantology demands well-defined protocols to ensure the osseointegration of root-form titanium abutments is predictable and maintainable. Early stability of the fixture within the osteotomy site appears necessary to ensure approximation of osseous tissue, and the proportionate loading of the integrated implant, together with appropriate maintenance, are protocols to ensure long-term survivability.

With the introduction of dental laser therapy, a growing interest in the application of this therapy in implantology has allowed laser-assisted treatment to be investigated in the areas of implant placement, second-stage recovery, and treatment of peri-implantitis.

The purpose of this paper is to examine how photonic energy

inherently low absorption of these wavelengths in pigmented blood proteins, offers limited opportunity for conductive thermal rise; consequently, there is minimal hemostasis with the use of these wavelengths and their emission parameters, which is a desired effect in bone surgery procedures (Figure 1).

With laser energy, it is possible to cut bone which allows graft harvesting and sinus-lift procedures to be carried out. The fundamental concern in any bone surgical procedure is to limit thermal rise to within 47 °C and for less than one minute,⁵ in order to avoid damage to cellular components of bone metabolism and delayed healing.⁶ With regard to this limit, studies have been carried out to investigate the physical and thermal effects of rotary instrumentation and Er:YAG and CO₂ laser wavelengths on bone tissue.⁷⁻⁸ Conclusions have been drawn as to the benefits of the erbium laser wavelengths with water spray in limiting the thermal rise,⁹⁻¹¹ and one study alluded to the possible promotion of osteogenic biochemical agents that might induce accelerated healing of the bone tissue.¹²

The conventional protocol of osteotomy site preparation involves the use of burs, which may be internally irrigated and which are operated at an appropriate speed in order to minimize thermal rise in the hard tissue.¹³ Such preparation

allows the implant to be either tapped into position or thread-driven using a torque wrench or low-ratio handpiece.

Although laser use is considered precise for many procedures, the mode of action of the emerging photonic beam is end-cutting and does not allow for a measured development of a fixed diameter three-dimensional preparation of the bone.¹⁴ In addition, the delivery of adequate water spray that is necessary when using erbium lasers may be difficult in deep preparations (Figure 2).

In a study of tissue healing by Kesler and colleagues, a 2-mm diameter osteotomy was performed and titanium implants were placed. The measured parameter of bone-implant contact demonstrated greater value in the sites prepared with an Er:YAG laser compared to the control.¹⁵ In practice, there are anecdotal reports of site preparation in bone prior to implant placement, where an Er,Cr:YSGG laser is used with specially designed, lengthened delivery tips to allow adequate water irrigation of the target site.¹⁶ Although

success has been demonstrated, there remains concern as to the accuracy of the preparation when compared to conventional bone drilling.

Laser-Assisted Second-Stage Recovery of Implants

In some cases, the implant site may be subject to immediate loading, although the majority of sites are allowed to heal for at least a 3-month period, prefer-

ably with a closed soft tissue layer.¹⁷⁻¹⁹ The restorative phase requires the exposure of the implant cover screw and at this time a decision is made as to how much modification of the soft tissue is needed. In an ideal case, or where aesthetics is not a prime consideration, the simple exposure of the cover screw involves a mucoperiosteal flap, a soft tissue punch, or the use of a suitable laser to ablate the overlying epithelium. All laser wavelengths commercially available in dentistry are capable of positive interaction with target soft tissue, although the longer wavelengths (erbium family at 2780 and 2940 nm or CO₂ at 10,600 nm) preferentially react with the water content of that tissue.²⁰ Where the tissue is pigmented or liable to bleeding, a shorter laser wavelength, such as the frequency-doubled Nd:YAG or KTP (potassium titanyl phosphate) (532 nm), diode (810 to 980 nm), or Nd:YAG (1064 nm), may be preferable.²¹ Each tissue element is capable of absorbing incident photonic energy, dependent on the laser wavelength. The consequent conversion of this laser energy into thermal energy will result in tissue change.²² The benefits of laser use include precision, hemostasis (which can be varyingly effective depending on the wavelength), and immediate postoperative protection through a coagulum surface.²³⁻²⁴

It is essential to accurately assess the position of the implant site relative to the edentulous ridge. This may be done through X-ray, model mapping, and using natural landmarks; exposure of the cover screw allows an impression to be taken from which the prosthetic superstructure can be made. Further assessment must be made of the soft tissue emergence profile, to establish whether augmentation is required to support the aesthetic appearance or whether modification is required to reduce the soft tissue peri-implant collar to allow

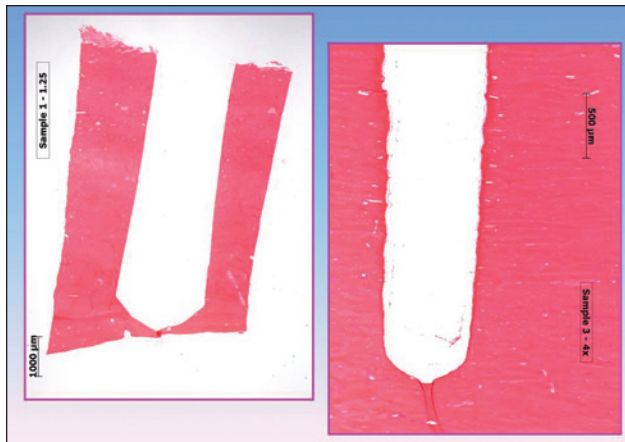


Figure 2: Light micrograph of demineralized, sectioned, and stained osteotomy preparations in animal specimen bone. Key: Left specimen shows preparation with conventional internally irrigated implant osteotomy bur. Right specimen shows similar preparation with an Er:YAG laser, with evidence of marginal irregularities and charred residues, indicative of poor water cooling. Laser parameters used: 400 mJ per pulse / 10 Hz / Average Power 4.0 Watts / Beam size 600 µm /

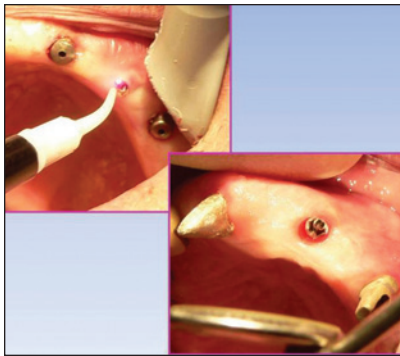


Figure 3: Second-stage recovery of implant using a diode (810 nm) laser. Key: Upper left showing laser ablation of soft tissue, lower right showing healed collar at 10 days. Laser parameters used: 1.4 Watts CW / Beam size 320 μ m / Contact mode



Figure 6: Case as in Figure 5, showing abutment placement and final prosthesis

correct maintenance.

The use of lasers in the harvesting of distant connective tissue grafts has been reported through case reports and anecdotal accounts.²⁵⁻²⁶ Specifically, however, it is the subject of this review to examine the use of varying laser wavelengths to remove the tissue immediately overlying the implant site.

Local anesthetic may or may not be used, depending on patient and operator preference. Some analysis of the form, thickness, and vascularity of the tissue should be made, which will define a choice of laser wavelength or, if not possible, the operating parameters. By use of a minimal power value commensurate with tissue ablation, a small cone of tissue is removed until



Figure 4: Case as in Figure 3, showing abutment placement and final prosthesis

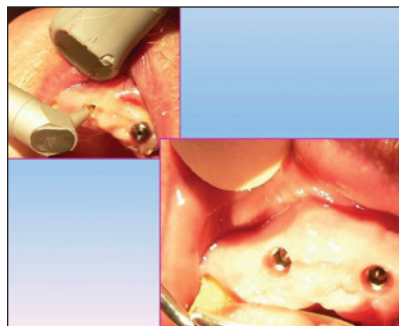


Figure 7: Second-stage recovery of implant using a CO₂ (10,600 nm) laser. Key: Upper left showing laser ablation of soft tissue, lower right showing healed collar at 10 days. Laser parameters used: 1.5 Watts pulsed / Beam size 600 μ m / Noncontact mode

near-contact with the screw is made. From this, the tissue opening is extended to a point within the diameter of the cover screw. Typical laser average power values should be in the range of 1 to 1.5 Watts to assess the ablation efficiency and increased slightly as required. However, care should be exercised to avoid the buildup of any carbonized material.²⁷

In the author's experience, at the stage of near-contact with the cover screw any remaining tissue tags should be removed with a sharp curette; the screw is removed and a suitable healing cap placed. The immediate post-surgery phase can be suitably managed through the topical application of a chlorhexidine mouthwash. With correct laser power settings, the choice of laser wavelength may be viewed as often irrelevant to the

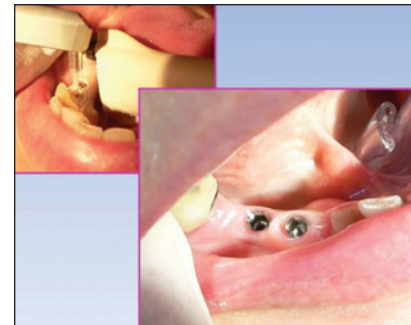


Figure 5: Second-stage recovery of implant using an Er:YAG laser. Key: Upper left showing laser ablation of soft tissue, lower right showing healed collar at 10 days. Laser parameters used: 250 mJ per pulse / 10 Hz / Average Power 2.5 Watts / Beam size



Figure 8: Case as in Figure 7, showing abutment placement and final prosthesis

predictability of healing of the soft tissue collar (Figures 3-8).

The management of excessive soft tissue may be addressed in the same way as any laser-assisted debulking procedure – pedunculated overgrowths can be excised immediately above the base, and less-defined excess tissue can be incised under tension or, in the case of longer laser wavelengths, reduced by surface ablation. Where the objective is to reduce the thickness of the gingival collar around the transmucosal element, a technique similar to gingivoplasty / gingivectomy can be employed, using either a provisional crown or custom-made acrylic abutments to protect the metal surface of the transmucosal element (TME). In those cases where a more radical adjustment of overlying soft tissue



Figure 9: Use of a diode (810 nm) laser in gingival margin modification associated with three upper right quadrant implants. Key: Upper left – Preoperative view with acrylic temporary crowns in place to provide protection to the TME and allow accuracy of the gingivectomy. Lower left – Immediately post-laser use with crowns removed. Right – Healing at 3 months with final restorations in place. Laser parameters used: 1.4 Watts CW / Beam size 320 μ m / Contact

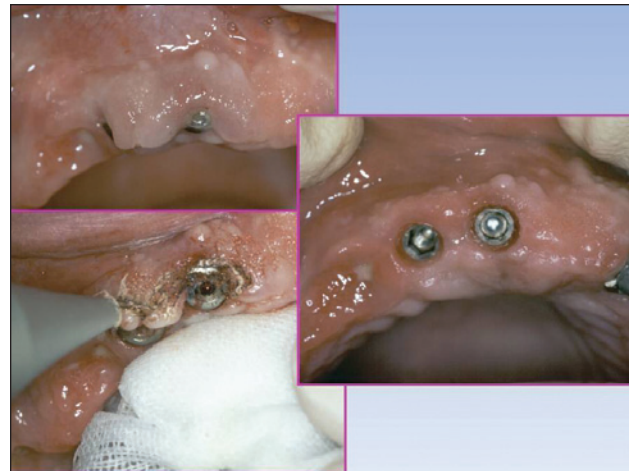


Figure 10: Use of a CO₂ (10,600 nm) laser to correct gingival contour. Original second-stage exposure of two implants, using scalpel and flap procedure has led to inappropriate gingival contour. Key: Upper left – Post-scalpel excision at three weeks. Lower left – Laser used to ablate excess soft tissue. Right – Healing cap exposure and healing at 10 days. Laser parameters used: 2.0 Watts pulsed / Beam size 600 μ m / Noncontact mode

is required, careful dissection of the tissue should be carried out using the laser with minimal power levels to avoid any heat buildup or pitting in the abutment (Figures 9-10).

Laser-Assisted Therapy in Peri-Implantitis

According to the 1st European Workshop on Periodontology, peri-implantitis is defined as the “term for inflammatory reactions with loss of supporting bone in the tissues surrounding a functioning implant.”²⁸ Associated definitions exist to identify the nontissue nature of the metal fixture — the American Academy of Implant Dentistry has noted “implant histioclasia” or “peri-implantoclasia” as appropriate terms to denote conditions around the implant and these terms are published in the 1974 *Current Clinical Dental Terminology’s* glossary of terms.²⁹ Nonetheless, the term *peri-implantitis* has persisted, and as a rapidly progressive failure of osseointegration, the condition is due to bacterial toxins and yeasts disrupting the bone homeostasis.³⁰

The condition occurs irrespective of implant type,³¹⁻³² and is part of the etiology of implant loss, along with associated phenomena such as occlusal overloading and poor emergence profiles of the restoration.³³⁻³⁴ A review of 26 articles mapping the survivability of implant-supported single crowns showed that 9.7% of treatment sites had evidence of peri-implantitis and 6.3% showed greater than 2 mm of crestal bone loss over a 5-year observation period.³⁵

The distinction must be made as to whether the implant site exhibits essentially treatable peri-implantitis (the “ailing” implant), or whether the loss of the fixture is inevitable (the “failing” implant). Wherever possible, the implant should be isolated; and, if it is not mobile, reparative treatment could be undertaken.³⁶ The underlying bacterial involvement in cases of peri-implantitis — overt signs of infection and inflammation, marked infiltration of the peri-implant connective tissue by inflammatory cells, ulceration and proliferation of the junctional

epithelium — has been demonstrated. However, microflora associated with infective failure are those that also cause periodontitis.³⁷

Attempts to establish treatment protocols for the treatment of peri-implantitis include the application of an antimicrobial agent,³⁸⁻⁴⁰ local and systemic antibiotics,⁴¹ air- or abrasive-polishing,⁴² guided tissue regeneration,⁴³⁻⁴⁴ combination techniques using detoxification, tetracycline, citric acid, and guided bone regeneration.⁴⁵ A review of published literature concluded that “most of the information accessible at this time derives from case reports ... Several uncertainties remain regarding the treatment of peri-implantitis.”⁴⁶

Early investigations into the effects of Nd:YAG laser photonic energy on a range of pathogens showed significant results, but in the early 1990s two studies concluded that the thermal effects of an Nd:YAG laser resulted in damage to the titanium surface.⁴⁷⁻⁴⁸ The effects of such thermal rise may be seen in site defects (pitting,



Figure 11: Use of a diode (810 nm) laser in the treatment of peri-implantitis. Key: Upper left – pretreatment; Upper right – Surgical exposure through scalpel-assisted flap procedure, showing granulation tissue; Lower – Preoperative radiograph showing marginal bone loss and extent of bone defect, and photography showing granulation tissue removed

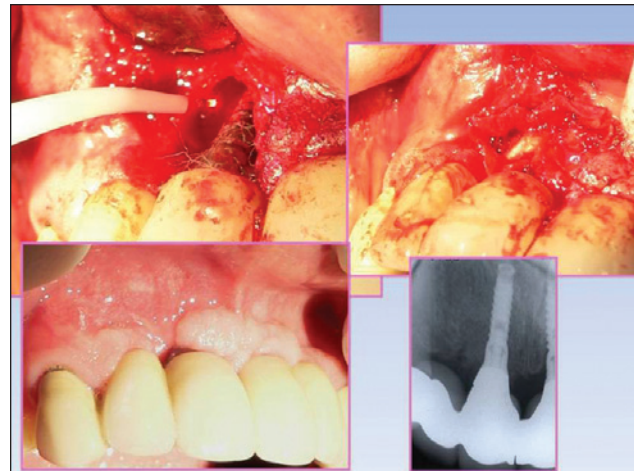


Figure 12: Treatment case as in Figure 11. Key: Upper left and right – Use of laser fiber tip to decontaminate implant surface prior to application of bone matrix and barrier membrane; Lower – Healing at six months and radiograph of postoperative bone regrowth at six months. Laser parameters used: 810 nm / 0.7 Watt CW / Beam size 320 μ m / Contact mode

melting craters), and local conductive effects into the bone. Furthermore a study using a CO₂ laser showed possible distant transportation of metal substrates to organs such as the liver, spleen, and kidney.⁴⁹ A comparative *in vitro* study undertaken by Kreisler of most commercially available laser wavelengths used without water cooling concluded that Nd:YAG and Ho:YAG lasers should not be used irrespective of the power output; CO₂ and Er:YAG laser should be used at low powers; and only the 809-nm diode group appeared to not cause any surface alterations.⁵⁰ Kreisler also showed the high bactericidal potential of the Er:YAG laser on the implant surface.⁵¹ Another study demonstrated that the Er:YAG laser at approximately 1 W (which is “low” power) with a water spray could effectively remove plaque and calculus from the implant surface without damage.⁵²

In consideration of the above studies, other factors will be discussed, such as reflectance from the implant fixture, power density, and thermal relaxation.

In analyses of the reflectance

and absorption of titanium, two studies yielded different results. Rechmann showed the metal to be more reflective of long (CO₂) wavelengths compared to visible (532-nm) light, but indicated no damage with the CO₂ wavelengths.⁵³ As previously stated, Kreisler’s investigation showed damage with Nd:YAG, Ho:YAG, Er:YAG, and CO₂ lasers.⁵⁰

Power density effects relate to emission of photonic energy and the radiated beam (spot) size. The power density values of microsecond pulses may be several thousand Watts/cm², compared to few hundred found with continuous-wave emission. Power density may be viewed as the concentration of laser energy over an area, and (assuming some absorption occurs) this will lead to greater temperature rise with decreasing spot size. Boulnois⁵⁴ and Niemi⁵⁵ provide models that associate power density and exposure time in terms of tissue effects and allow deduction to be made that with lower power density values there is a longer exposure time before damaging effects may occur. Within such theoretical consideration, this

supports the relatively safe use of a continuous-wave diode laser on titanium.

In their work with carbon dioxide lasers, Fried and colleagues explain that thermal relaxation is inversely related to the thermal diffusivity of the tissue (material) exposed to photonic energy, assuming that absorption of the energy occurs.⁵⁶ One *in vitro* study with a continuous-wave 809-nm diode laser considered that the conditioning effect of local cooling measures (exposure of implants to laser energy within a body-temperature water bath) might approximate those found *in vivo* and concluded that this laser could be used on titanium implant surfaces, provided that exposure be limited in time and power to allow the implant and bone to cool to avoid tissue damage.⁵⁷ On zirconia implants, one study using 810-nm diode, Er:YAG, and CO₂ lasers, the Er:YAG wavelength was transmitted through the material and may cause damage to adjacent tissues, and CO₂ altered the surface.⁵⁸

The author’s own clinical experience has shown a number of important factors to consider when

selecting parameters for laser use in implant surgery:

- Power density
- Exposure duration
- Thermal relaxation potential, including the local cooling effect of circulating blood
- Use of coaxial water spray, if available
- Reflectance from the implant fixture
- Presence of energy-absorbing organic debris on the ailing implant surface
- Type of implant material.

The potential for all laser wavelengths to exert a bactericidal effect and the wish to define a more predictable protocol for treating peri-implantitis have prompted a number of studies into some of those wavelengths,⁵⁹⁻⁶² but not all have been shown to be positively conclusive. This has prompted concerns as to the effects of biofilm.

A biofilm is “a structured community of microorganisms encapsulated within a self-developed polymeric matrix and adherent to a living or inert surface. Biofilms are also often characterized by surface attachment, structural heterogeneity, genetic diversity, complex community interactions, and an extracellular matrix of polymeric substances.”⁶³ Some studies have examined the effect of applying photonic energy to biofilm on implant surfaces.⁶⁴⁻⁶⁶ As such, low-level laser photoactivated disinfection (PAD) technique, used for endodontic canal disinfection as well as treatment of carious lesions,⁶⁷⁻⁶⁸ might allow inaccessible areas of infected implant surfaces to be adequately decontaminated. The author suggests the treatment protocol shown in the accompanying table.

Conclusion

Modern implantology is based on strict protocols of pretreatment assessment, placement, and considerate functional force dissipation. The success of integration of laser-assisted surgical therapy with hard and soft oral tissue manipulation has led to an understandable wish to bring such advantages within the placement and recovery stages of implant therapy. Apart from the evidence-based ability of erbium laser wavelengths to cut bone tissue, they are only in the developmental stage for use as the sole instrument to produce the osteotomy site. The second-stage recovery and any associated soft tissue manipulation can be usefully and predictably accomplished with any of the currently commercially available laser wavelengths used in dentistry. The extensive investigations into the possible use of laser photonic energy in the treatment of peri-implantitis have acknowledged the inherent dangers of such energy on metal and have been modified with greater understanding of the multifactorial aspects of laser use and the *in vivo* conditions that accompany the majority of peri-implantitis cases. A protocol that may address these factors and prompt greater research has been suggested. It remains the responsibility of the clinician to employ lasers within one's level of competence and understanding of laser-tissue interaction and the added respect for the demands of implant placement, function, and maintenance.

AUTHOR BIOGRAPHY

Dr. Steven Parker is in private practice in Harrogate, UK. He has been involved in the use, investigation, education, and examination of all aspects of laser dentistry since 1990. He holds Advanced Proficiency in four laser wavelengths, is an Educator and Recognized Course Provider with the Academy, and a past editor of

Suggested Protocol for Laser-Assisted Treatment of Peri-Implantitis	
Step	Considerations
Pretreatment assessment	Etiological factors – oral hygiene, occlusion, host local and general response factors, smoking. Establishment of cause of infection or trauma. Determination of whether the
Access / surgical technique	Debridement of granulation tissue – curette / laser-assisted
Disruption of biofilm	Examples: sodium lauryl sulfate, chlorhexidene, polyhexamethylene biguanide (PHMB), triclosan
Pathogen reduction (part 1)	Laser wavelength of choice. Minimal power levels – Average power 0.7 to 1.0 Watt. Use of water spray. Exposure of treatment site (10 to 15 seconds, repeated with intervals as required (maximum 3 passes)
Pathogen reduction (part 2), if available*	PAD (proprietary tlonium chloride solution used with the 670-nm Periowave™ (Oraldent Ltd., Kimbolton, Cambs, UK), diffuser tip, 60 sec. expo-
Reestablishment of biocompatibility / new bone growth	Guided bone regeneration procedure / membrane
Continuing care / maintenance	Professional review / radiographs / hygienist / home care

*Editor's Note: The Periowave™ device has not received U.S. Food and Drug Administration marketing clearance in the United States.

Wavelengths. He is the 1998 recipient of the Leon Goldman Award for Clinical Excellence in Laser Dentistry and the 2005 President of the Academy of Laser Dentistry. His publications include a chapter on laser use in fixed prosthodontics in *Dental Clinics of North America*, peer-reviewed papers on laser use with hard tissue in the *Journal of Laser Dentistry* and a nine-part (peer-reviewed) series "Lasers in Dentistry," published in the *British Dental Journal* in 2007. Dr. Parker may be contacted by e-mail at thewholetooth@easynet.co.uk.

Disclosure: Dr. Parker has no company affiliation.

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