

CASE REPORT: Alveolar Bone Regeneration Using Nd:YAG Laser

Zelimir Bozic

Dental Clinic Bozic, 6218 Prestranek, Slovenia

ABSTRACT

The loss of alveolar bone, which is very often a consequence of long-lasting inflammation of dental tissue, usually results in loose teeth and eventually the loss of the affected teeth. Removing the causes of periodontal disease with periodontal treatment can stop further alveolar bone decay, however, the problem remains unsolved of how to fix an affected tooth that has more than half of its root loose in alveolar tissue. In this paper, the successful use of an Nd:YAG laser is reported for stimulating the growth of osteoblasts and inducing bone regeneration. Stabilization and preservation of the tooth and its functions were achieved without any surgical or other invasive medical methods.

A review of laser periodontal studies shows that there exists a relatively broad range of Nd:YAG and Er:YAG laser devices, laser parameters and treatment protocols with which there is at least some degree of bone regeneration achieved whenever FDA-cleared periodontal indications are treated with Nd:YAG and/or Er:YAG lasers.

Key words: Nd:YAG, Er:YAG, laser, periodontics, alveolar bone, bone regeneration.

Article: J. LA&HA, Vol. 2017, pp.08-13.

Received: July 24, 2017; Accepted: Nov 6, 2017

© Laser and Health Academy. All rights reserved.

Printed in Europe. www.laserandhealth.com

I. INTRODUCTION

A wide range of inflammatory conditions is involved in periodontal diseases that affect the supporting structures of the teeth (the gingiva, bone and periodontal ligament). This may result in tooth loss and contribute to systemic inflammation [1]. The periodontal situation persists until the affected tooth is extracted or the microbial biofilm is therapeutically removed and the inflammation subsides. In the recent years, new treatment modalities have been explored, such as antimicrobial therapy, host modulation therapy, laser therapy and tissue engineering for tissue repair and regeneration [1].

Chronic periodontitis can be clinically observed through redness, changed texture and swelling of the marginal gingiva, bleeding of the gingival pocket area on probing, increased depth of the periodontal pocket, destruction of the supporting structures of the teeth (ligament and alveolar bone), recession of the marginal gingiva (which exposes the root), increased tooth mobility and drifting, and, eventually, tooth loss. The diagnosis of periodontitis is typically based on clinical measurements such as clinical attachment level (CAL), bleeding on probing (BOP), probing depth (PD or PPD) and radiographic findings [1].

Depending on the severity of disease and the architecture of the resulting bone loss, periodontitis has traditionally been treated non-surgically, by osteoplasty and/or ostectomy combined with ablation of the periodontal pocket, by regenerative surgery or using a combination of methods [2]. Nonsurgical therapy generally includes intensive instruction in oral hygiene techniques, scaling and root planing, use of antimicrobial oral rinses and occasionally the local application of an antibiotic or use of a systemic antibiotic. This form of therapy is most often selected for treatment of slight and moderate forms of periodontitis, whereas severe periodontitis is usually treated with either ablative or regenerative surgical techniques.

In non-surgical as well as the majority of surgical periodontal therapies, healing occurs through the formation of a long junctional epithelium or a new connective tissue attachment to the previously diseased root surface [1]. Regenerative surgical procedures have the potential to also induce the restoration of lost alveolar bone, periodontal ligament and cementum (the surface layer of the root), and are the ultimate form of periodontal healing [1]. It is sometimes difficult in clinical and experimental situations to determine whether regeneration or new attachment has occurred and the extent to which it has occurred [3]. Although there are various evidences of reconstruction, the proof of principle for the type of healing is determined by radiographic imaging and/or histological studies.

Lasers can provide distinct advantages over the traditional scalpel, such as easy ablation of small volumes of tissue, hemostasis (which, in turn, offers

better visualization of the surgical field), sterilization of the incision or target surface area and less post-treatment tissue edema and swelling [2]. For many procedures the use of a laser can be considered a minimally invasive technique, with less discomfort than traditional approaches [2]. Furthermore, lasers may have bio-stimulatory effects (i.e. photobiomodulation), that are reported to result in better wound healing compared to traditional approaches and in periodontal tissue regeneration [2]. Lastly, there is a developing body of evidence indicating that laser periodontal therapy may have the beneficial side-effect of reducing inflammatory mediators [2].

A true understanding of laser–tissue interactions requires a working knowledge of the composition of the various oral tissues, laser physics and how a change in laser wavelength, pulse duration and pulse energy can impact such interactions.

The Er:YAG wavelength of 2,940 nm coincides with the absorption peak of water and is also effectively absorbed by the hydroxyl radical component of calcium hydroxyapatite². It is estimated that the water absorption characteristic of the wavelength of the Er:YAG laser is 2.5x greater than that of the Er,Cr: YSGG laser, 10x greater than that of the CO₂ laser and 15,000x greater than that of the Nd:YAG laser [2]. Consequently, the Er:YAG laser wavelength appears to be a good choice for ablation of oral soft tissues and modification of dental hard tissues, including bone. With respect to root surfaces, the Er:YAG laser has been reported to remove the smear layer created by scaling and root planing with no apparent heat-induced damage, such as crazing, melting or carbonization of the surface.

The 1,064-nm wavelength of the Nd:YAG laser exhibits low absorption in water, is minimally absorbed by bone, cementum, dentin, calculus and enamel but is readily absorbed by pigmented soft tissues. In addition, the Nd:YAG wavelength is absorbed by hemoglobin and thereby is effective in coagulation and hemostasis during soft-tissue surgical procedures [2]. It is this proclivity for soft-tissue applications that has resulted in acceptance of the Nd:YAG laser for treatment of periodontal diseases.

When lasers are used in periodontics, mostly small spot sizes are used. The use of small spot sizes increases energy density. Dental surgical lasers generally use optical fiber tips (e.g. Nd:YAG) or sapphire, quartz tips (e.g. Er:YAG) with spot sizes ranging from 0.3 to 1 mm, which not only defines the laser-tissue interaction but also achieves a high level of precision when cutting or vaporizing the tissue [5].

The use of Nd:YAG laser for subgingival curettage (also laser troughing or sulcular debridement) as an adjunct to scaling and root planing is a popular application among general practitioners as an aid for disinfection. In periodontal treatments Nd:YAG is also used for laser-induced fibrin sealing of periodontal pockets (hemostasis). Variable pulse durations are effective – for laser troughing: 100-200 μ s pulse duration, and for fibrin clot formation: 150-650 μ s pulse duration [6]. The same power settings are used for both purposes, however, longer pulse durations are recommended for hemostasis [6].

Periodontal therapy may result not only in arresting the disease by controlling the microbial infection, but also includes the regeneration of the tissues that have been lost due to the disease. This includes de novo formation of connective tissue attachment and cementum (the surface layer of the root) and the restoration of alveolar bone. Usually surgical procedures such as different types of bone grafts, root surface demineralization, guided-tissue regeneration (GTR), or the application of growth factors have been employed with varying degrees of success [7]. The resulting healing is promoted through the formation of a long junctional epithelium or a new connective tissue attachment to the previously diseased root surface [1]. This applies to non-surgical and as well to the majority of surgical therapies.

In this paper, we report on a successful case of alveolar bone regeneration using only a non-surgical Nd:YAG laser procedure as reported already in [8].

II. MATERIALS AND METHODS

The Nd:YAG laser used was a Fidelis Plus combined Nd:YAG/Er:YAG dental laser system (now called LightWalker AT, manufactured by Fotona d.o.o., Slovenia). The Fotona laser system has been cleared by the US FDA for the following periodontal indications [9]:

a) Nd:YAG wavelength:

i) Laser-assisted new attachment procedure (cementum-mediated periodontal ligament new-attachment to the root surface in the absence of long junctional epithelium); ii) Sulcular debridement or soft-tissue curettage (removal of diseased or inflamed soft tissue in the periodontal pocket to improve clinical indices including gingival index, gingival bleeding index, probe depth, attachment loss, and tooth mobility), and iii) Implant recovery.

b) Er:YAG wavelength:

i) Sulcular debridement; ii) Removal of subgingival

calculi in periodontal pockets with periodontitis by closed or open curettage; iii) Apicoectomy surgery, and iv) Removal of granulated tissue.

In the periodontal treatment procedure, reported in this paper, only the Nd:YAG laser wavelength was used. The laser system was fitted with an R21 contact handpiece for Nd:YAG laser equipped with a 300 μm bare fiber, and a non-contact Nd:YAG fiber handpiece R24.

The treatment consisted of two Nd:YAG laser treatment steps:

1. During the first step, each of the periodontal pockets was lased using the R21 handpiece in direct contact with the affected tissue for 30 sec, following the protocol for treating soft and alveolar tissue: 1.75 W Nd:YAG laser power, a repetition rate of 15 Hz, and MSP pulse duration. These parameters were chosen based on the study published in [16].
2. During the second step, the apex area of each of the treated teeth was irradiated in a non-contact manner by circling the R24 handpiece over the tissue for 3 x 40 sec, using the following Nd:YAG laser parameters: 2.25 W laser power, a repetition rate of 15 Hz, and LP pulse duration.

The above treatment was repeated every 3-4 days for a total of 20 sessions.

The treated teeth were photographed and radiographically imaged, and pocket depths were measured before the treatment, at 2.5 months post-treatment (after the 14th session) and at 1 year after the treatment.

III. RESULTS

Figures 1, 2 and 3 show the photographs and radiographic images of the patient's teeth before the start of the treatment, and at 2.5 months and 1 year post-treatment, respectively.

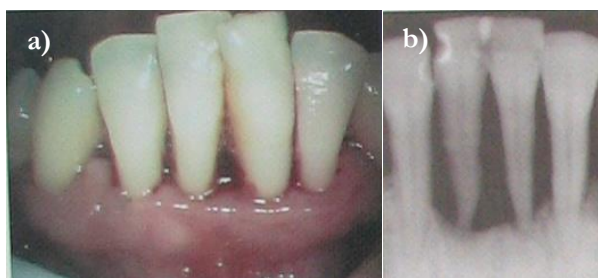


Fig. 1: Photograph (a) and radiographic image (b) of the treated teeth before the beginning of the treatment.

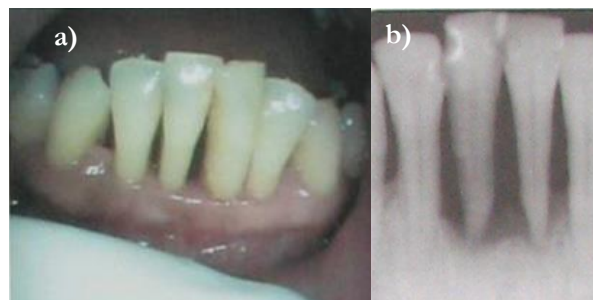


Fig. 2: Photograph (a) and radiographic image (b) of the treated teeth at 2.5 months after the start of the treatment. Post procedure bone regeneration can be observed.

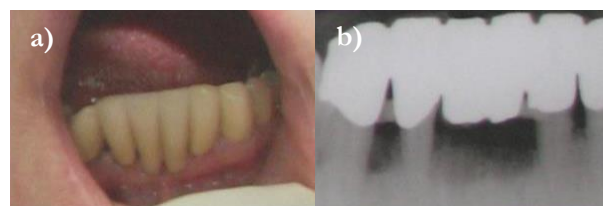


Fig. 3: Photograph (a) and radiographic image (b) of the treated teeth: 1 year following the complete treatment. Post-procedure bone regeneration can be observed. During the observation period the patient suffered an accident unrelated to the treatment, which resulted in the subluxation of both incisors, and was subsequently resolved by the bridge insertion.

Figure 4 depicts the measured pocket depths before, at 2.5 months and at 1 year after the beginning of the treatment.

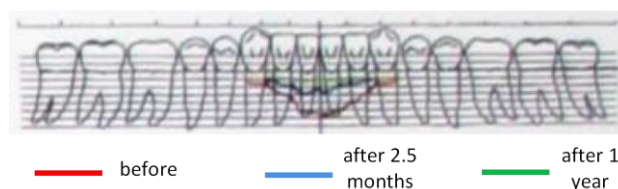


Fig. 4: Measured pocket depths before, after 2.5 months and at 1 year following the start of the treatment.

IV. DISCUSSION

Periodontal treatments using either Er:YAG or Nd:YAG laser have been demonstrated to stimulate faster bone healing and bone generation [8, 10 - 21, this study].

a) Nd:YAG laser for bone regeneration

One of the Nd:YAG laser protocols used as a conservative alternative to surgical therapy is a two-step Nd:YAG laser-assisted new attachment procedure [17]. In this procedure, also called the LANAP procedure, an Nd:YAG laser is used in the first step for the initial pocket de-epithelialization (sulcular debridement), and in the second step for final fibrin clotting (hemostasis) as a replacement for scalpel and sutures. An intermittent step of scaling and root

Table 1: Comparison of the protocol parameters and the devices used in the bone regeneration studies [8], [15], [16], [20] and this study, with the parameters used in FDA cleared periodontal procedures with Fotona Nd:YAG laser [9].

| Nd:YAG laser | Parameters used in [16] | Parameters used in [20] | Parameters used in [8, this study] | Parameters used in [15] | Parameters used in FDA cleared periodontal procedures [9] |
|----------------|-------------------------|---|------------------------------------|-------------------------------|---|
| Device | Smarty-A DECA Italy | Periolase, Millennium Dental Technol. USA | Fidelis/LightWalkerFotona Slovenia | Genius Dental, Genius Denmark | LightWalker Fotona, Slovenia |
| Wavelength | 1064 nm Nd:YAG | 1064 nm Nd:YAG | 1064 nm Nd:YAG | 1064 nm Nd:YAG | 1064 nm Nd:YAG |
| Spot size | 300 μ m fiber | 360 μ m fiber | 300 μ m fiber | NA | 300 - 360 μ m fiber |
| Power | 0.6-1.5 W | 4 W | 1.75 - 2.25 W | 4 W | 1.5 - 4.5 W |
| Energy | 60-150 mJ | 200 mJ | 115-150 mJ | 80 mJ | 60-200 mJ |
| Pulse duration | 100-300 μ s | 100-650 μ s | 100 - 650 μ s | 350 μ s | 100-650 μ s |
| Frequency | 10-15 Hz | 20 Hz | 15 Hz | 50 Hz | 10-50 Hz |
| Result | Bone regeneration | Bone regeneration | Bone regeneration | Bone regeneration | ✓ |

planing is performed using ultrasound instrumentation. In one of the reports, radiography demonstrated bone regeneration in both treated cases [18]. In another study [19], the major goal was to obtain human histology of the healing events over time. Five of 12 teeth showed histologic evidence of regeneration, including bone, cementum and periodontal ligament. One tooth showed new attachment without bone regeneration. Four healed with long junctional epithelium, while two splintered during histologic preparation. And in [20], histologic proof of new cementum and periodontal ligament was shown in six out of six, and new bone in four of six treated specimens [20].

In the above LANAP studies of the Nd:YAG laser promoted bone regeneration, a Periolase Nd:YAG laser (manufactured by Millennium Dental Technologies, USA) was used. However, bone regeneration is not limited to the Periolase device nor to the LANAP procedure. For example, in a study where a Smarty-A Nd:YAG laser (manufactured by DECA, Italy) with parameters as presented in Table 1 was used, it was shown that the laser treatment is as effective as surgical flap debridement in promoting bone regeneration [16]. Radiographic images taken at 2, 4, 6 and 12 months from treatment of the sites having undergone surgical or laser treatment, showed that the lack of bone support at each site before therapy tended to improve at the follow-up examinations, up to an appreciable recovery of the bone component [16].

In another study, made with a Genius Nd:YAG laser (manufactured by Genius, Denmark) using parameters as shown in Table 1, measurement of

standardized vertical bitewing X-rays indicated bone loss at 12-39 months (median 20 months) in scaling and root planing-treated sites 0.11 mm, and bone gain of 0.07 mm in scaling and root planing + Nd:YAG laser treated sites – the difference being significant [15].

Similarly, in this study and in [8], a Fotona Nd:YAG laser was successfully used to promote bone healing and regeneration.

Table 1 shows a comparison of the protocol parameters and the devices used in the bone regeneration studies [8], [15], [16], [20] and this study, with the parameters used in FDA cleared periodontal procedures [9] for the Fotona Nd:YAG laser.

It follows from the above that a certain degree of bone regeneration is expected to be promoted always when FDA-cleared parameters for Nd:YAG periodontal indications are being used. Note also that there is a relatively broad range of Nd:YAG laser periodontal treatment parameters with which bone regeneration has been observed to be stimulated. When it is taken into account that in references [8, this study], [16] and [20], different diameter fibers were used, and the corresponding power densities (power over fiber area, in W/mm²) are calculated, we obtain a better agreement between bone regeneration studies: up to 32 W/mm² for [8, this study], up to 21 W/mm² for [16], and up to 39 W/mm² for [20].

b) Er:YAG laser for bone regeneration

A promotion of bone regeneration was observed also in Er:YAG laser studies [10 - 14]. In Aleksic et al. [10], it was reported that Er:YAG stimulates proliferation of osteoblasts and enhances bone healing

Table 2: Comparison of the protocol parameters and the devices used in the bone regeneration studies [10-14], with the parameters used in FDA cleared periodontal procedures with Fotona Er:YAG laser [9].

| Er:YAG laser | Parameters used in [10] | Parameters used in [11] | Parameters used in [13] | Parameters used in [12] | Parameters used in [14] | Parameters used in FDA cleared periodontal procedures [9] |
|----------------|--------------------------------|-------------------------|-------------------------------|-------------------------|--|---|
| Device | VersaWave, Hoya Photonics, USA | Delight HOYA ConBio USA | KEY II, KaVo Germany | Delight HOYA Conbio USA | Powerlase/ LightWalker Fotona Slovenia | LightWalker Fotona, Slovenia |
| Wavelength | 2940 nm Er:YAG | 2940 nm Er:YAG | 2940 nm Er:YAG | 2940 nm Er:YAG | 2940 nm Er:YAG | 2940 nm Er:YAG |
| Spot size | 0.3 mm | 0.4 – 0.7 mm | 0.5 x 1.65 mm or 0.5 x 1.1 mm | 0.6 mm | 1 mm | 0.3 – 1 mm |
| Energy | 23 – 68 mJ | 30 – 350 mJ | 160 mJ | 30 – 62 mJ | 200 mJ | up to 200 mJ |
| Pulse duration | NA | 200 μ s | 250-500 μ s | NA | 50 μ s | 50 - 1000 μ s |
| Frequency | 10 – 30 Hz | 30 Hz | 10 Hz | 40 Hz | 15 Hz | up to 40 Hz |
| Result | Bone regeneration | Bone regeneration | Bone regeneration | Bone regeneration | Bone regeneration | ✓ |

and regeneration. In Pourzarandian et al. [11], histological and TEM examination showed faster initial bone healing after Er:YAG laser irradiation. Shwartz et al. [13] reported new cementum formation with Er:YAG laser, and Mizutani et al. [12], reported new bone formation using Er:YAG laser.

Bone regeneration has been observed also for a periodontal treatment using a Fotona Er:YAG laser. In [14], Cranska reported post-op bone regeneration following a peri-implantitis treatment. It should be noted that the management of peri-implant mucositis and peri-implantitis is similar to the treatment of conventional periodontal disease [1]. A major difference is that the implant is not surrounded by periodontal ligament and, therefore, the blood supply to the tissue around the implant is somewhat anatomically limited [1].

Table 2 shows a comparison of the protocol parameters and the devices used in the bone regeneration studies [10 -14], with the parameters used in FDA cleared periodontal procedures [9], for the Fotona Er:YAG laser.

It follows from the above that, as is the case with Nd:YAG laser periodontal treatments, a certain degree of bone regeneration is expected to be promoted whenever FDA-cleared parameters for Er:YAG periodontal indications are being used. Note also that there is a relatively broad range of Er:YAG laser periodontal treatment parameters with which bone regeneration has been observed to be stimulated.

c) Our clinical experience

In our clinic, we treated 8 patients diagnosed with periodontitis using the same treatment protocol as

presented in this paper. All treatments resulted in a positive clinical outcome, as evidenced by the gingival rehabilitation. Only the case of a patient who persisted and returned to the clinic for radiographic imaging of the resulting bone regeneration at 2.5 and 12 months post-op is presented here.

V. CONCLUSIONS

In agreement with previously published studies, our clinical experience confirms that alveolar bone regeneration can be promoted with an Nd:YAG dental laser. Using a two-step Nd:YAG laser protocol, growth of osteoblasts was stimulated and the alveolar bone was regenerated. As a result, a successful fixation and preservation of the teeth and their functionality was achieved without any surgical or other invasive method. This therapy is just another example of a successful use of the Nd:YAG laser in periodontics, providing that the patients follow very closely the dentist's instructions.

A review of the laser periodontal studies shows that there exists a relatively broad range of Nd:YAG and Er:YAG laser devices, laser parameters and treatment protocols with which there is at least some degree of bone regeneration achieved whenever FDA-cleared periodontal indications are treated with Nd:YAG and/or Er:YAG lasers. Further research is recommended to improve upon and to optimize the periodontal treatment protocols for the stimulation of bone regeneration.

The author of this study did not receive any compensation for this work from any manufacturer.

REFERENCES

1. Kinane DF, Stathopoulou PG, Papapanou PN. Periodontal diseases. *Nat Rev Dis Prim.* 2017;3:17038. doi:10.1038/nrdp.2017.38.
2. Cobb CM. Lasers and the treatment of periodontitis: the essence and the noise. *Periodontol 2000.* 2017;75(1):205-295. doi:10.1111/prd.12137.
3. Rose L, Mealey B, Genco R, Cohen D. *Periodontics: Medicine, Surgery, and Implants.* Philadelphia: Elsevier Mosby; 2004.
4. Parker S. Laser-tissue interaction. doi:10.1038/bdj.2007.24.
5. Manni J. *Basic Aspects of Medical and Dental Lasers.*; 2004.
6. Gregg RH 2nd, McCarthy D. Laser periodontal therapy for bone regeneration. *Dent Today.* 2002;21(5):54-59.
7. Schwarz F, Sculean A, Georg T, Becker J. Clinical evaluation of the Er:YAG laser in combination with an enamel matrix protein derivative for the treatment of intrabony periodontal defects: a pilot study. *J Clin Periodontol.* 2003;30(11):975-981. doi:10.1034/j.1600-051X.2003.00412.x.
8. Bozic Z, Alveolar Bone Regeneration using Nd:YAG Laser, 10th meeting of the International Society for Lasers in Dentistry (ISLD), Berlin 2006; Book of abstracts: 98.
9. 510(k) clearances : K070355, K101817 and K121508. ;https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPMN/pmn.cfm
10. Aleksic V, Aoki A, Iwasaki K, et al. Low-level Er: YAG laser irradiation enhances osteoblast proliferation through activation of MAPK/ERK. *Lasers Med Sci.* 2010;25(4):559-569. doi:10.1007/s10103-010-0761-5.
11. Pourzarandian A et al, Histological and TEM Examination of Early Stages of Bone Healing after Er:YAG Laser Irradiation, *Photomedicine and Laser Surgery* 2004, 4:342-350.
12. Mizutani K. et al, Periodontal Tissue Healing Following Flap Surgery Using an Er:YAG Laser in Dogs, *Lasers Surg Med* 2006; 38:314-324.
13. Schwartz F et al, Immunohistochemical Characterization of Periodontal Wound Healing Following Nonsurgical Treatment with Fluorescence Controlled Er:YAG Laser Radiation in Dogs, *Lasers Surg Med* 2007, 39:428-440.
14. J. P. Cranska: Use of Lasers to Treat Failing Dental Implants, *Dentistry Today*, Feb 01, 2016.
15. Qadri T, Javed F, Poddani P, Tuner J, Gustafsson A. Longterm effects of a single application of a water-cooled pulsed Nd:YAG laser in supplement to scaling and root planing in patients with periodontal inflammation. *Lasers Med Sci* 2011; 26: 763–766.
16. Mummolo S, Marchetti E, Di Martino S, Scorzetti L, Marzo G. Aggressive periodontitis: laser Nd:YAG treatment versus conventional surgical therapy. *Euro J Paediatr Dent* 2008; 9: 88–92.
17. Harris DM, Nicholson DM, McCarthy D, Yukna RA, Reynolds MA, Greenwell H, Finley J, McCawley TK, Xenoudi P, Gregg RH II. Change in clinical indices following laser or scalpel treatment for periodontitis: a split-mouth, randomized, multicenter trial. *Proc SPIE* 2014; 8929: 00. (*Lasers in Dentistry XX*): Feb. 18: 89290G-1-9
18. Gregg RH 2nd, McCarthy D. Laser periodontal therapy for bone regeneration. *Dent Today.* 2002;21(5):54-59.
19. Nevins ML, Camelo M, Schupbach P, Kim SW, Kim DM, Nevins M. Human clinical and histologic evaluation of laser-assisted new attachment procedure. *Int J Periodontics Restorative Dent* 2012; 32: 497–507.
20. Yukna RA1, Carr RL, Evans GH. Histologic evaluation of an Nd:YAG laser-assisted new attachment procedure in humans. *Int J Periodontics Restorative Dent.* 2007 Dec;27(6):577-87.
21. Qadri T, Javed F, Poddani P, Tuner J, Gustafsson A. A Short-Term Evaluation of Nd:YAG Laser as an Adjunct to Scaling and Root Planing in the Treatment of Periodontal Inflammation, *J Periodontol* 2010 Aug; 81(8):1161-1166.

The intent of this Laser and Health Academy publication is to facilitate an exchange of information on the views, research results, and clinical experiences within the medical laser community. The contents of this publication are the sole responsibility of the authors and may not in any circumstances be regarded as official product information by medical equipment manufacturers. When in doubt, please check with the manufacturers about whether a specific product or application has been approved or cleared to be marketed and sold in your country.