Implant-safe settings for SuperPulse 10,600 nm CO_2 laser-assisted, closed flap peri-implantitis treatment

Drs. Eric Linden and Peter Vitruk explore the peri-implantitis ablative laser treatment protocol

Introduction

The sulcular debridement laser settings[1,2] used in part 1 of this study (Linden and Vitruk[3]) were determined by four requirements for efficient decontamination of the implant surfaces by photo-thermal laser ablation[3]:

1. Laser energy is efficiently deposited into the target tissue (diseased tissue and bacterial biofilms with optical absorption and photothermal ablation properties dominated by water[4-7]).
2. Laser-generated heat inside the target tissue is confined to the irradiated volume and is not thermally conducted away into the implant (which acts as a highly efficient heat sink).
3. Laser-generated heat inside the target tissue is sufficient for vaporizing it.
4. Laser energy is efficiently reflected off the surfaces of the implant.

As was stated in Linden and Vitruk[3], the 10.6 µm (or 10,600 nm) CO_2 laser wavelength is highly reflected (>90%) from titanium, which makes the CO_2 laser the safest wavelength for peri-implantitis treatment (diode, Nd:YAG and Erbium laser wavelengths produce a 3-4 times greater rate of heating of the implant for a comparable amount of laser energy used in the treatment). The present article focuses on the fourth condition, and specifically explores the laser settings that (a) do not modify the implant surface and (b) do not result in elevated implant temperatures during the course of laser treatment.

CO_2 laser Perio Tip geometry and treatment settings

Laser tests reported here were performed with the LightScalpel LS-1005 Surgical/Dental SuperPulse 10,600 nm CO_2 laser. The sulcular debridement[1,2] and the peri-implantitis treatment protocols[3] utilize the 0.25 mm small aperture laser beam tip ("Perio Tip" PN LS9005-05 from LightScalpel LLC) with >90% optical transmission and a distal end design suitable for the intra-sulcus procedures. The OD of the Perio Tip's distal end is approximately 0.5 mm, and its tapered design allows for easy insertion into the deep pockets of up to 9 mm–10 mm. The Perio Tip was inserted into the LightScalpel dental angled laser handpiece PN LS9010-02.

Recent work on efficiency of the bacterial biofilms removal with 10,600 nm SuperPulse CO_2 laser justifies the safe and efficient use of 0.4 watts of average laser power configured as 4 watts SuperPulse (26.7 mJ pulses at 150 Hz) Gated with LightScalpel LS-1005 laser Repeat Mode M2-2 (10 msec @ 10 Hz).[7] Laser fluence during each individual SuperPulse is 54 J/cm², which greatly exceeds the ablation threshold of 3 J/cm² for water-rich soft tissue and bacterial biofilms.[3,5-7] The low average power of 0.4 watts minimizes the heat impact on the implant and the tissues while effectively vaporizing the epithelium, diseased tissue, and bacterial biofilms inside the perio pocket. The laser beam that exits the Perio Tip diverges at approximately 14°, which is important for delivering laser energy to the walls of the sulcus and the implant during the closed flap peri-implantitis treatment procedure.[3] Constant airflow through the hollow core of the Perio Tip pushes the sulcular debris and fluids (blood, saliva, irrigation) out of the way of the laser beam; airflow also prevents the clogging of the hollow tip.

CO_2 laser impact on implant surface

The surfaces of the Biomet ***3i*** NanoTite™ NIITP4310 and Biomet ***3i*** Osseotite™ IFNT510 (trade names and trademarks of Biomet) implants were treated as illustrated in Figure 1. The implant was centered on the rotating platform (31 seconds for a full revolution), and the laser Perio Tip delivered the laser energy from approximately a 0.5 mm–0.75 mm distance. The laser beam scanning velocity over the surface of the implant

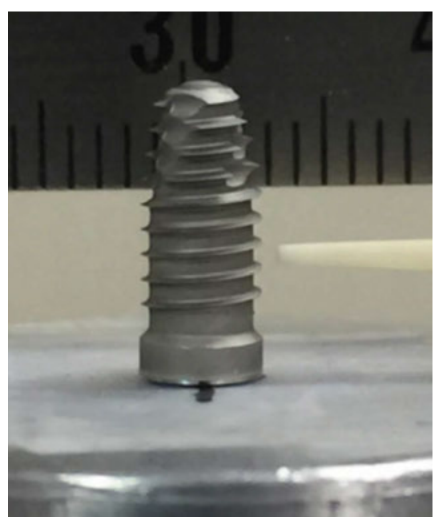
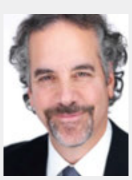


Figure 1: Implant centered on the rotating platform. 10,600 nm CO_2 laser beam from the Perio Tip (on the right) is directed at the implant surface



Eric Linden, DMD, MSD, is a periodontist specializing in the field of Laser Periodontal Surgery. He serves as Assistant Attending within the Section of Oral, Diagnostic and Rehabilitation Sciences, Division of Periodontics at Columbia University/Columbia Presbyterian Medical Center in New York. He teaches and lectures to the Postgraduate Periodontal and Implant residents and conducts research on lasers, implants, and the treatment of periodontal and implant disease. Dr. Linden is a Member of American Dental Association, American Academy of Periodontology (AAP), New Jersey Dental Association, Bergen County Dental Society, American Association of Dental Research, Northern Bergen County Dental Study Club (President), Northeast Society of Periodontists, and Institute for Advanced Laser Dentistry, New York County Dental Society, and Academy of LaserDentistry. Dr. Linden serves as a consultant on Editorial Board of Dentistry Today, and as a consultantfor the International Journal of Periodontics and Restorative Dentistry and is currently serving on theAAP Task force on establishing a framework for the treatment of peri-implantitis and establishing guidelines for the AAP worldwide membership.

Peter Vitruk, PhD, MInstP, CPhys, is a founder of LightScalpel, LLC. He is a member of the Institute of Physics, United Kingdom, and is the member of the Science and Research Committee, Academy of Laser Dentistry, USA. He is also on the faculty of the California Implant Institute and Global Laser Oral Health, both in the United States. Dr. Vitruk can be reached at 1-866-589-2722 or pvitruk@lightscalpel.com

was 0.4 mm/sec–0.5 mm/sec — such slow motion greatly amplifies the fluence on the implant surface (vs. approximately 1 mm–2 mm handspeed used in Linden and Vitruk[3]).

Figures 2 and 3 illustrate the SEM photographs of the NanoTite™ implant surface unaffected by the laser treatment. Figures 4 and 5 illustrate the typical EDS spectral analysis of the implant surface with no changes due to the laser treatment described, thus further reaffirming the unchanged integrity of the laser-treated implant surfaces. The SEM and EDS measurements (Figures 2-5) were performed at the Electron Microscope Laboratory, School of Dentistry, University of Missouri, Kansas City, Missouri.

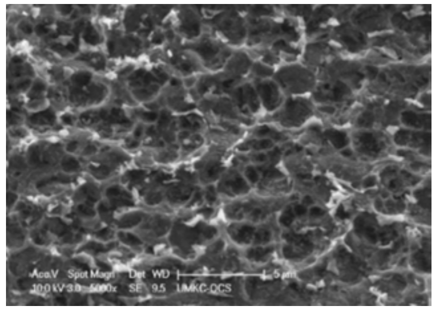


Figure 2: SEM x5,000 magnified surface of the laser-treated NanoTite™ implant

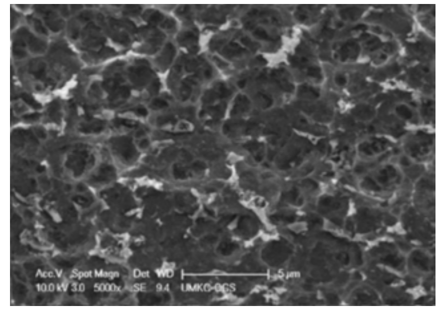


Figure 3: SEM x5,000 magnified surface of the NanoTite™ implant not treated with laser

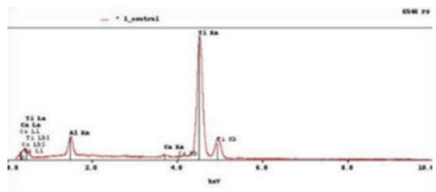


Figure 4: The EDS spectrum of the laser-treated NanoTite implant

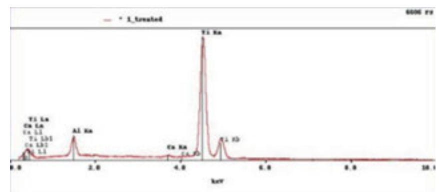


Figure 5: The EDS spectrum of the NanoTite implant not treated with laser

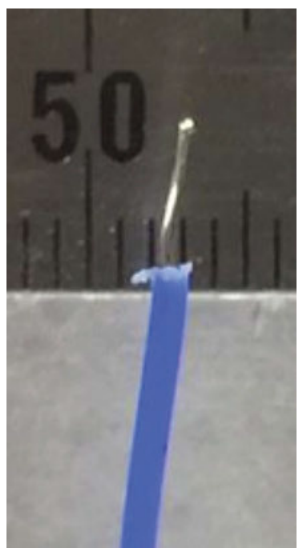


Figure 6: Thermocouple Tip is photographed against 1-mm mark scale

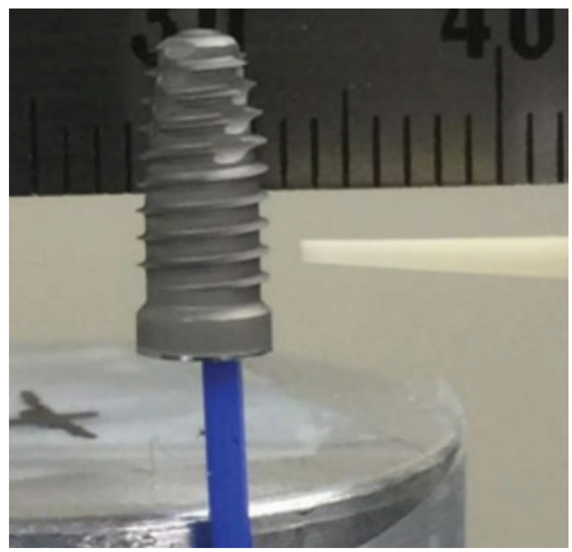


Figure 7: The implant is suspended on the Thermocouple Tip inserted into the NanoTite implant

Also worth noting is that due to a small aperture tip we used, the laser fluence in our studies greatly exceeded laser fluence in Cobb and Vitruk[7]. Despite the significantly higher fluence, both NanoTite™ and Osseotite™ type implant surfaces were unaffected by the laser treatment. The total laser fluence delivered was 320 J/cm^2 –360 J/cm^2 — a much greater total fluence than studied in Cobb and Vitruk[7] (6.3 J/cm^2– 113 J/cm^2) — due to a considerably smaller tip size of 0.25 mm. NanoTite™ implants feature the calcium phosphate crystals that form the sub-1-μm isles on the surface of titanium (see SEM images in Figure 2 and 3). Such sub-1-μm calcium phosphate crystals are efficiently heat-sunken by the titanium and are not able to heat up during CO_2 laser pulses from LightScalpel LS-1005.

Implant heating during CO_2 laser treatment

During the 31-second long laser treatment described above, a total of 12.4 joules of energy were directed at the implant. Some of the laser energy was reflected from the implant surface, and the rest of the energy was absorbed by the implant resulting in its heating. A series of implant temperature measurements (with Thermocouple Tip (Figure 6) and Meter manufactured by Control Company, model 4015, SN 101756285) were taken to quantify the rate of implant heating during the laser treatment.

Figure 7 illustrates the implant suspended on the tip of the thermocouple (inserted into the implant); such laser irradiation configuration represents an extreme case of an implant with severe bone loss around it. The laser Perio Tip is delivering laser energy to the implant from the side at a short distance from the implant surface. The thermocouple is inserted into the implant as shown in Figure 8. Laser treatment with settings described above (31 second duration, 0.4 watts average laser power), and with 1.5 cc/sec air purge (setting "High" for LightScalpel LS-1005) through the Perio Tip, resulted in a 3.1ºC temperature increase. The same laser settings, but without an air purge through the Perio Tip, resulted in a temperature increase of 10.6ºC.

To simulate the more realistic implant-tissue thermodynamic conditions (i.e., implant is not suspended in the air or is not thermally insulated), in the next set of measurements the Nanotite™ type implant was embedded in an approximately 22 mm x 22 mm x 8 mm block of soft poultry tissue at room temperature, as shown in Figure 8, or in the approximately 20 mm x 20 mm x 10 mm block of pork rib bone at room temperature, as shown in Figure 9. The laser Perio Tip delivered laser energy to the implant from the side at a short distance from the implant surface. The thermocouple was inserted into the implant, as shown in Figure 9. The laser treatment with settings described above (31 second duration, 0.4 watts average laser power), and with 1.5 cc/sec air purge (setting "High" for LightScalpel LS-1005) through the Perio Tip,

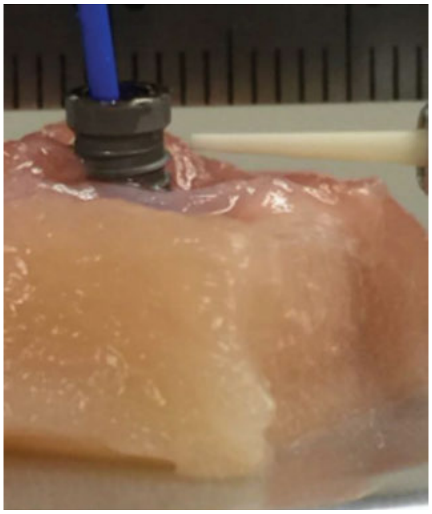


Figure 8: NanoTite™ implant embedded in a block of poultry soft tissue and irradiated by CO_2 laser

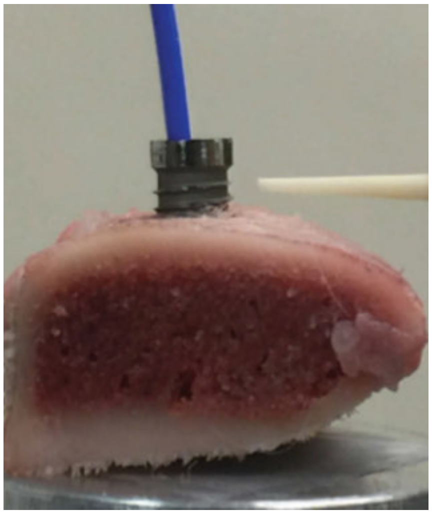


Figure 9: NanoTite™ implant embedded in a block of pork rib bone and irradiated by CO_2 laser

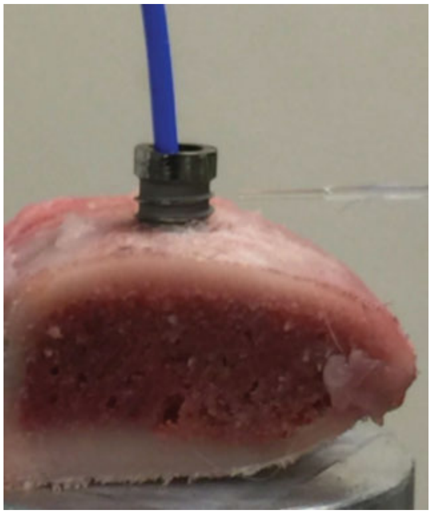


Figure 10: NanoTite™ implant embedded in a block of pork rib bone and irradiated by diode laser

resulted in, respectively, 0.8ºC and 1.2ºC temperature increase. The same laser settings, but without the air purge through the Perio Tip, resulted in a temperature increase of, respectively, 1.6ºC and 2.8ºC.

Based on the implant temperature measurements above, the air purge for the proposed treatment protocol was set to "High" to provide efficient cooling to the implant. The value of high air purge for implant cooling is even greater during open flap laser treatment with compromised heat transfer geometry from the implant into the surrounding bone and soft tissue.

Excessive implant heating during 810 nm laser treatment

To test the wavelength's impact on the implant's temperature change, the same implant (Figure 10) was irradiated by the 810 nm NIR diode laser light at often recommended perio settings of 1 watt,[8] which resulted in a temperature increase of 20.3ºC at 30 seconds and 28.7ºC at 60 seconds.[9] The clean, non-initiated tip of the diode laser delivered 810-nm laser energy to the implant from the side, at a short distance from the implant surface, as shown in Figure 10. The thermocouple was inserted into the implant as shown in Figure 10. The measured temperature increase is approximately 20 times greater than with the CO_2 laser settings above, which illustrates the potential dangers of the NIR diode perio protocols (i.e., severe implant overheating).

CO_2 laser treatment settings summary

The relatively low average 0.4 watt laser power at 10,600 nm in SuperPulse mode minimizes the heat load on the implants, and yet results in high laser fluence exiting the tip and high clinical efficacy of the single treatment protocol due to (1) small spot size and high beam divergence laser tip, and (2) zigzag passes of the tip within the sulcus during treatment.[3] As our measurements demonstrate, even at the slowest handspeed of 0.4 mm/sec–0.5 mm/sec, no damage to the implant surface was observed. Table 1 summarizes the recommended protocol settings proposed in Linden and Vitruk[3] for implant-safe and efficient SuperPulse 10,600 nm CO_2 laser-assisted, closed flap peri-implantitis treatment. IP

Table 1: Summary of the recommended protocol settings

	De-epithelization and Bacterial Decontamination	Coagulation
Laser tip	0.25 mm spot PN LS9005-05	0.4 mm spot PN LS9005-02
LightScalpel laser power setting	4 watts SuperPulse repeat gate pulsed M2-2	2 watts repeat gate pulsed F1-2
Average power	0.4 watt	0.4 watt
Air purge	"High"	"High"
Handspeed	1-2 mm/sec	1-2 mm/sec
Laser-ON duration in the pocket	< 30 seconds	< 30 seconds
Energy delivered during Laser-ON	< 12 Joules	< 12 Joules
Laser-OFF duration between laser treatments	10 seconds	10 seconds

Acknowledgments

The authors greatly appreciate Charles Cobb, DDS, MS, PhD, and Vladimir M. Dusevich, PhD, at the School of Dentistry, University of Missouri, Kansas City, Missouri, for providing the SEM and EDS measurements of implant surfaces, and Anna (Anya) Glazkova, PhD, and Olga Vitruk, BSc, at LightScalpel LLC for preparing this material for publication.

REFERENCES

1. FDA 510(k) Clearance K141658. LightScalpel LS-1005 & LS-2010 CO_2 Laser Systems
2. LightScalpel LS-1005 & LS-2010 CO_2 Laser Systems. *User Manual.* PN 00961.
3. Linden E, Vitruk P. SuperPulse 10.6 µm CO_2 laser-assisted, closed flap treatment of peri-implantitis. *Implant Practice US.* 2015;8(4):30-34.
4. Jacques SL. Optical properties of biological tissues: a review. *Phys Med Biol.* 2013;58(11):R37-61.
5. Vogel A, Venugopalan V. Mechanisms of pulsed laser ablation of biological tissues. *Chem Rev.* 2003;103(2):577-644.
6. Vitruk P. Oral soft tissue laser ablative and coagulative efficiencies spectra. *Implant Practice US.* 2014;7(6):22-27.
7. Cobb C, Vitruk P. Effectiveness of a super pulsed CO_2 laser for removal of biofilm from three different types of implant surfaces: an in vitro study. *Implant Practice US.* 2015;8(3):14-20.
8. Blayden J, Mott A. *Soft-Tissue Lasers in Dental Hygiene.* Ames, Iowa:Wiley-Blackwell;2013:87.
9. Lavere E, Sagor J, Mikulski L, Andreana S. Antimicrobial Effects of the 810 nm Diode Laser in the Treatment of Peri-Implantitis: An Ex Vivo Pilot Study. *J Laser Dent,* 2015;23(1):37-43.