

The International Journal of Periodontics & Restorative Dentistry

 $^{\odot}$ 2020 by quintessence publishing CO, Inc. Printing of this document is restricted to personal use only. No part may be reproduced or transmitted in any form without written permission from the publisher.

805

Human Histologic Evaluations of the Use of Er,Cr:YSGG Laser to Decontaminate an Infected Dental Implant Surface in Preparation for Implant Reosseointegration



Myron Nevins, DDS¹/Stefano Parma Benfenati, DDS² Primo Galletti, MD, DDS³/Andrei Zuchi, DDS⁴ Cosmin Sava, DDS⁵/Catalin Sava, DDS⁵/Mihaela Trifan, DDS⁶ Andriano Piattelli, MD, DDS, DrHC⁷/Giovanna Iezzi, DDS, PhD⁷ Chia-Yu Chen, DDS, DMSc¹/David M. Kim, DDS, DMSc¹ Isabella Rocchietta, DDS, MSc⁸

This investigation was designed to evaluate the reestablishment of bone-toimplant contact on infected dental implant surfaces following decontamination with an erbium, chromium:yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser and reconstructive therapy. Three patients presenting with at least one failing implant each were enrolled and consented to treatment with the Er,Cr:YSGG laser surface decontamination and reconstruction with a bone replacement allograft and a collagen membrane. The laser treatment was carried out at a setting of 1.5 W, air/water of 40%/50%, and pulse rate of 30 Hz. At 6 months, all three patients returned for the study. En bloc biopsy samples of four implants were obtained and analyzed. Two patients had excellent clinical outcomes, while one patient with two adjacent failing implants experienced an early implant exposure during the follow-up period. There was histologic evidence of new bone formation with two implant specimens and less bone gain with the others. Despite the small sample size, these were optimistic findings that suggested a positive role of Er,Cr:YSGG laser in debridement of a titanium implant surface to facilitate subsequent regenerative treatment. This investigation provides histologic evidence as well as encouraging clinical results that use of the Er,Cr:YSGG laser can be beneficial for treatment of peri-implantitis, but further long-term clinical studies are needed to investigate the treatment outcome obtained. Int J Periodontics Restorative Dent 2020;40:805-812. doi: 10.11607/prd.5139

¹Division of Periodontology, Department of Oral Medicine, Infection, and Immunity, Harvard School of Dental Medicine, Boston, Massachusetts, USA.

²Master's Program in Periodontology, Dental School, University of Turin, Italy; Surgery and Oral Pathology, University of Parma, Parma, Italy.

³Private practice, Ferrara, Italy.

⁴Dental Evo Periodontology & Implantology Clinic, Bucharest, Romania.

⁵Private practice, Bistriţa, Romania.

⁶Private practice, Bucharest, Romania.

⁷Department of Medical, Oral and Biotechnological Sciences, University of Chieti-Pescara, Chieti, Italy.

⁸Department of Periodontology, UCL Eastman Dental Institute, University College London, London, England.

Correspondence to: Dr David M. Kim, Harvard School of Dental Medicine, Department of Oral Medicine, Infection, and Immunity, 188 Longwood Ave, Boston, MA 02115, USA. Email: dkim@hsdm.harvard.edu

Submitted May 12, 2020; accepted June 18, 2020. ©2020 by Quintessence Publishing Co Inc. Presently, implant therapy is commonly preferred over alternative removable and fixed prosthetic options because implant-supported restorations offer a satisfactory solution to achieve functional mastication, esthetics, and phonetics. With the growing numbers of implants placed each year, implant-related complications have surfaced, and the prevalence of peri-implantitis is of great concern to clinicians. Periimplantitis occurs in 28% to 56% of patients.1 This represents an important aspect of implant dentistry that requires multiple treatment modalities in order to ensure long-term success of dental implants.

With a considerable body of evidence supporting the causeand-effect relationship between microbial plaque colonization and the pathogenesis of peri-implant infections, various treatment protocols have been proposed in an effort to decontaminate the implant surface to facilitate regeneration of lost peri-implant tissue.² For the management of peri-implantitis around titanium implants, nonsurgical and surgical approaches generally consist of mechanical debridement, the use of antiseptics, local or systemic antibiotics, and regenerative or resective procedures.3 The use of lasers, in particular, has shown promising results.⁴ In a preclinical canine study conducted by Nevins

806

et al, the erbium:yttrium-aluminumgarnet (Er:YAG) laser has been shown to effectively arrest inflammatory process around contaminated implants and to promote new bone-to-implant contact (BIC).⁵

The erbium, chromium: yttriumscandium-gallium-garnet (Er,Cr:YSGG) laser has a wavelength of 2,780 nm. The Er,Cr:YSGG laser energy allows for microablation of tooth structure bone or soft tissue. The Er.Cr:YSGG laser has been also been used for surgical treatment of peri-implant disease as well as nonsurgical use.^{6,7} In a case report by Azzeh, Er,Cr:YSGG laser was used at different settings in combination with open flap and regenerative procedures to treat peri-implantitis.⁶ At 18 months after surgery, there was osseous regeneration and reduction of probing depth for those treated implants.

The objective of this proof-ofprinciple study was to provide a short-term observation of the effectiveness of using Er,Cr:YSGG laser to decontaminate titanium implant surfaces to facilitate the reestablishment of BIC. The goal was to evaluate the hard and soft tissue adaption to a previously failing implant following surface irradiation with Er,Cr:YSGG laser and a regenerative procedure.

Materials and Methods

This was a prospective proof-ofprinciple human histologic study investigating the use of the Er,Cr:YSGG laser to decontaminate the surface of a compromised dental implant to achieve reestablishment of BIC. Three patients were enrolled and signed an informed consent form based on the Helsinki Declaration of 1975, as revised in 2013. The inclusion criteria for patients and sites were: (1) being between 20 and 70 years of age and having failing dental implants; (2) willingness to sign an informed consent, participate, and return for follow-up visits; (3) nonsignificant medical history and currently not on medications that might complicate results (American Society of Anesthesiologists classifications ASA 1 and ASA 2); (4) nonsmoking; (5) not pregnant.

Implant Debridement and Reconstructive Surgery

Pre- and postsurgical clinical examinations were performed in concert with an evaluation of oral hygiene during each patient visit. All treatments were performed under local anesthesia in sterile conditions. After removal of dental implant crowns and abutments, a cover screw was placed. Sulcular incisions were made around the dental implant with subsequent reflection of full mucoperiosteal flaps. Vertical incisions were used as necessary for visibility. Granulomatous tissues were removed. The Er.Cr:YSGG laser (Waterlase, Biolase) was used to debride the implant surface. The RFPT5 tip with a primarily radial emission, with a portion of straight laser energy and a tip size of 500 µm was used. The energy settings were 1.5 W, air/ water of 40%/50%, and pulse rate of 30 Hz. Following debridement, the surrounding bone was decorticated

with small carbide burs. Freezedried bone allograft that was hydrated with recombinant human platelet-derived growth factor-BB (GEM 21S, Lynch Biologics) was utilized to cover treated implant threads, and a collagen barrier membrane (OSSIX Plus, Datum Dental) was used to contain the bone grafting material. The flaps were adapted for a tension-free primary wound closure with interrupted and horizontal mattress sutures using a combination of resorbable and nonresorbable sutures (Fig 1).

Postoperative instructions and medications were prescribed, including chlorhexidine mouth rinse bid for 4 weeks, oral antibiotics (500 mg amoxicillin) every 8 hours for 7 days, and anti-inflammatory analgesics for pain relief as needed (600 mg ibuprofen every 6 hours). Patients were seen for follow-up care and oral hygiene instructions at 1, 2, 4, 8, and 12 weeks and every 4 weeks thereafter until the biopsy.

Implant Biopsy

Radiographs were updated 6 months before the en bloc biopsy of the studied implants. Each study implant and the surrounding bone were removed en bloc as described previously.⁸ Biopsy sample sites were reconstructed with regenerative procedures in preparation for implant placement and subsequent prosthetic reconstruction with implantsupported prostheses (Fig 2). Biopsy samples were stored in 10% formalin.

The International Journal of Periodontics & Restorative Dentistry

^{© 2020} BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.



Fig 1 Implant debridement surgery. (a) An implant in the area of the mandibular left first molar presented with circumferential bone loss. (b) Implant surface debridement was performed with the Er,Cr:YSGG laser following the described protocol. (c) The surrounding bone was decorticated. (d) Freeze-dried bone allograft hydrated with recombinant human platelet-derived growth factor-BB was used to cover the exposed threads. (e) A collagen membrane was used to contain the bone graft material. (f) Tension-free primary closure was achieved.



Fig 2 Biopsy sample and site reconstruction. (a) En bloc biopsy sample harvesting was performed at 6 months. (b) Guided bone reconstruction was performed, and (c) tension-free primary closure was achieved.

Light Microscopy

Fixed samples were prepared for the nondemineralized ground sections, prepared according to the technique of Donath and Breuner.⁹ The core specimens were processed by dehydration in a graded series of alcohols over a period of at least 9 days at standard temperature and pressure while constantly shaking. Then, the specimens were infiltrated with a graded series of alcohols and Technovit 7200 VLC embedding resin (Kulzer) over a period of at least 12 days at standard temperature and pressure while constantly shaking. When finished, specimens were placed in three consecutive containers of 100% Technovit 7200 VLC for 24 hours each at standard temperature and pressure while constantly shaking.

Following dehydration and infiltration, specimens were embedded in Technovit 7200 VLC and polymerized using 450 nm of light for 10 hours, never exceeding 40°C.

Polymerized blocks were sliced longitudinally along either the

Volume 40, Number 6, 2020

© 2020 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.



Fig 3 Preoperative (a) clinical view, revealing circumferential bone loss, and (b) radiograph, demonstrating bone loss around the mandibular left first molar site implant. (c) Reentry at 6 months revealed excellent healing, with bone covering the previously exposed implant surface. (d) Bone gain was seen in the postoperative radiograph. (e) Histologic view of the implant. BIC was achieved on both the buccal and lingual coronal aspects. On the buccal side, some remnants of bone replacement graft could still be observed. B = buccal; L = lingual.

buccolingual or mesiodistal directions of the implants (depending on grafted sites) using an Exakt cutting unit. This involved preparing a section of approximately 150 µm using the cutting/grinding instrument and then finishing the section to 30 to 50 µm using the microgrinding unit. A final polish was used with 0.1-µm diamond polishing paste.

The sections were stained with Sanderson Rapid Bone Stain (methylene blue and potassium permanganate stain). Sections were enclosed by cover slips for analysis by means of both bright-field and polarized light microscopic evaluation.

Results

Three patients with failing implants identified for implant removal and histologic analysis were enrolled in the study. The patients underwent en bloc biopsy sample harvesting of the study implants (n = 4). All sites healed uneventfully, and patients reported no unexpected adverse events except for one premature implant screw exposure. The implants are presented as case examples.

Case I

The first biopsy specimen was an implant from the mandibular left

first molar area that presented with circumferential bone loss, evident both radiographically and clinically (Figs 3a and 3b). After 6 months, radiographic and clinical bone gain could be observed (Figs 3c and 3d). Histologically, BIC could be observed on both the buccal and lingual aspects. A few remnants of bone replacement graft bone were observed at the buccal coronal portion (Fig 3e).

Case II

The second biopsy specimen was an implant from the maxillary left second premolar site that presented with an extensive buccal bone loss

The International Journal of Periodontics & Restorative Dentistry

Fig 4 (a) Preoperatively, extensive bone loss—almost to the apex of the implant on the buccal aspect—was seen surrounding the implant at the maxillary left second premolar site. (b) Preoperative bone loss was seen radiographically around the implant. (c) Reentry at 6 months revealed excellent healing, with bone covering the previously exposed implant surface. (d) Radiographic view of the postoperative bone gain. (e to g) Histologic view of the implant biopsy sample from the maxillary left second premolar site. The yellow lines mark the first BIC on both the buccal and palatal aspects. It could be observed that at the most coronal portion, there was no BIC and residual bone graft materials could still be observed, with some vital bone interposed between them. Moving to the middle portion, BIC was achieved on both the buccal and palatal aspects. On the buccal side, residual bone grafts could still be observed. B = buccal; P = palatal.















approaching the apex (Figs 4a and 4b). Six months after the surgical procedure, a remarkable bone gain could be observed radiographically and clinically (Figs 4c and 4d). Histologically, on the buccal aspect, BIC was first observed in the middle portion. At the most coronal portion, the area was largely occupied by residual bone graft materials with some vital bone surrounding the granules. At the middle sections, although residual bone grafts were still observed, direct BIC was also evident (Fig 4e to 4g).

© 2020 BY QUINTESSENCE PUBLISHING CO, INC. PRINTING OF THIS DOCUMENT IS RESTRICTED TO PERSONAL USE ONLY. NO PART MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM WITHOUT WRITTEN PERMISSION FROM THE PUBLISHER.

Volume 40, Number 6, 2020



Fig 5 (a) Extensive bone loss was seen preoperatively at the mandibular left second premolar and first molar implants, also visible (b) radiographically. (c) At the 6-month follow-up, premature exposure of the molar implant was observed, and probing revealed a 5-mm pocket depth on the buccal aspect. Notice that the premolar implant could also be observed underneath the thin mucosal tissue. (d) Reentry at 6 months revealed a minor improvement for the premolar implant, while almost no gain was observed for the molar implant. (e and f) Histologic view of the implant biopsy samples from the mandibular left second premolar and first molar sites, respectively. (e) Biopsy of the second premolar implant revealed that BIC was achieved on both the buccal and lingual sides at the middle portions. The slight clinical improvement observed could be corroborated by the bone apposition coronal to the first BIC. (f) No signs of bone gain were observed for the first molar implant. The top red line indicates the most-deal bone level, at the implant shoulder. The bottom red line indicates the first real BIC.

The International Journal of Periodontics & Restorative Dentistry

Case III

The third patient contributed two implant biopsy samples: a mandibular left second premolar and a first molar. Both implants presented with extensive bone loss extending to the middle thirds (Figs 5a and 5b). During the follow-up period, there was premature implant exposure of the first molar implant and the probing depth was around 5 mm on the buccal aspect (Fig 5c). At reentry (6 months later), some minor improvement could be observed for the premolar implant while the molar implant had little to no bone gain (Fig 5d). Histologically, direct BIC on previously exposed surfaces could not be observed for either premolar or molar implants (Figs 5e and 5f). The clinical bone apposition observed for the premolar implant corroborated histologically, as bone could be seen coronal to the first BIC (Fig 5e).

Discussion

Peri-implantitis is a plaque-associated pathologic condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.¹⁰ A recent systematic review by Derks and Tomasi found that the weighted mean prevalence of peri-implantitis was 22% (95% Cl: 14% to 30%).¹¹ This is indeed a disappointing discovery for the patients and calls for an important decision. Depending on the severity of disease, treatment decisions can include supportive nonsurgical therapy, surgical treatment with either resective or regenerative approaches, or removal of the failing implant. When possible, patients desire an ideal therapy that should arrest the disease and promote the regeneration of substantial lost BIC.

A major impediment for a successful treatment outcome is the difficulty in decontaminating the titanium implant surface. A contemporary threaded implant design with a rough surface presents a challenge for thorough decontamination. A previous case series with Er:YAG laser together with a grafting procedure has shown pocket depth reduction and defect fill at 1 year.¹² The Er,Cr:YSGG laser, operating at a wavelength of 2,780 nm, is suitable for both soft and hard tissue ablation. Several in vitro studies have demonstrated the effectiveness of the laser in removing Porphyromonas gingivalis contamination and calcified deposits without causing surface damage.^{13–15} Furthermore, the irradiated surface seemed to promote a biologic response related to fibroblast osteoblast adhesion.16,17

The results are encouraging and attest to the Er,Cr:YSGG laser's ability to effectively remove surface contamination and facilitate subsequent regenerative treatment. It is widely acknowledged that outcomes of peri-implantitis surgical therapy are heavily influenced by the configuration of the peri-implant bone defect.¹⁸ Both the first and second cases presented were singleimplant sites with supporting bone architecture available from adjacent natural teeth. Comparing the two cases, the second case had a large amount of residual bone graft due to the initial large defect size, and true regeneration started closest to areas with innate bone bed. Given a longer healing period, the authors speculate that the second case could eventually achieve direct BIC to the coronal portion.

For the third case, the longspan area was in itself challenging for any regenerative surgical procedure. The unfavorable soft tissue condition also made achieving tension-free primary closure difficult, which may have contributed to early implant exposure, leading to an unfavorable result. Despite these challenges, the implant did not bleed upon probing at reentry, and no infection was observed. Without effective surface debridement by the Er,Cr:YSGG laser, the sites would continue to show inflammation or purulent discharge.

The small sample size and short-term follow-up are two major limitations in the present study. Nevertheless, the true regenerative outcomes, confirmed by histologies in two of the present cases, are proof that the Er,Cr:YSGG laser can be a viable option for treatment of periimplantitis.

Conclusions

This proof-of-principle human histologic investigation provided evidence that reestablishment of BIC on a previously contaminated implant surface could be achieved following surface treatment with

Volume 40, Number 6, 2020

the Er,CR:YSGG laser. When faced with the challenge of treating periimplantitis, the laser should be considered a viable treatment option by clinicians.

Acknowledgments

A grant from BIOLASE funded the study. The authors declare no conflicts of interest.

References

- Lindhe J, Meyle J, Group D of European Workshop on Periodontology. Periimplant diseases: Consensus report of the Sixth European Workshop on Periodontology. J Clin Periodontol 2008;35 (8 suppl):s282–s285.
- Khoshkam V, Suárez-López Del Amo F, Monje A, Lin GH, Chan HL, Wang HL. Long-term radiographic and clinical outcomes of regenerative approach for treating peri-implantitis: A systematic review and meta-analysis. Int J Oral Maxillofac Implants 2016;31:1303–1310.
- Papathanasiou E, Finkelman M, Hanley J, Parashis AO. Prevalence, etiology and treatment of peri-implant mucositis and peri-implantitis: A survey of periodontists in the United States. J Periodontol 2016;87:493–501.

- Natto ZS, Aladmawy M, Levi PA Jr, Wang HL. Comparison of the efficacy of different types of lasers for the treatment of peri-implantitis: A systematic review. Int J Oral Maxillofac Implants 2015;30:338–345.
- Nevins M, Nevins ML, Yamamoto A, et al. Use of Er:YAG laser to decontaminate infected dental implant surface in preparation for reestablishment of boneto-implant contact. Int J Periodontics Restorative Dent 2014;34:461–466.
- Azzeh MM. Er,Cr:YSGG laser-assisted surgical treatment of peri-implantitis with 1-year reentry and 18-month follow-up. J Periodontol 2008;79:2000–2005.
- Al-Falaki R, Cronshaw M, Hughes FJ. Treatment outcome following use of the erbium, chromium:yttrium, scandium, gallium, garnet laser in the non-surgical management of peri-implantitis: A case series. Br Dent J 2014;217:453–457.
- Nevins M, Parma-Benfenati S, Quinti F, et al. Clinical and histologic evaluations of SLA dental implants. Int J Periodontics Restorative Dent 2017;37:175–181.
- Donath K, Breuner G. A method for the study of undecalcified bones and teeth with attached soft tissues. The Säge-Schliff (sawing and grinding) technique. J Oral Pathol 1982;11:318–326.
- Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: Consensus report of Workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions. J Periodontol 2018;89(suppl 1):s313-s318.

- Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. J Clin Periodontol 2015;42(suppl 16):s158–s171.
- Clem D, Gunsolley JC. Peri-implantitis treatment using Er:YAG laser and bone grafting. A prospective consecutive case series evaluation: 1 year posttherapy. Int J Periodontics Restorative Dent 2019;39: 479–489.
- Strever JM, Lee J, Ealick W, et al. Erbium, chromium:yttrium-scandium-galliumgarnet laser effectively ablates singlespecies biofilms on titanium disks without detectable surface damage. J Periodontol 2017;88:484–492.
- Takagi T, Aoki A, Ichinose S, et al. Effective removal of calcified deposits on microstructured titanium fixture surfaces of dental implants with erbium lasers. J Periodontol 2018;89:680–690.
- Alagl AS, Madi M, Bedi S, Al Onaizan F, Al-Aql ZS. The effect of Er,Cr:YSGG and diode laser applications on dental implant surfaces contaminated with Acinetobacter baumannii and Pseudomonas aeruginosa. Materials (Basel) 2019;12: 2073.
- Romanos G, Crespi R, Barone A, Covani U. Osteoblast attachment on titanium disks after laser irradiation. Int J Oral Maxillofac Implants 2006;21:232–236.
- Yao WL, Lin JCY, Salamanca E, et al. Er,Cr:YSGG laser performance improves biological response on titanium surfaces. Materials (Basel) 2020;13:756.
- Schwarz F, Sahm N, Schwarz K, Becker J. Impact of defect configuration on the clinical outcome following surgical regenerative therapy of peri-implantitis. J Clin Periodontol 2010;37:449–455.

The International Journal of Periodontics & Restorative Dentistry