Is Laser Disinfection an Effective Adjunctive Treatment to Bone Augmentation for Peri-Implantitis? A Review of Current Evidence

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Focused Clinical Question:

In patients with endosseous dental implants that demonstrate peri-implantitis, does surgical bone augmentation with adjunctive laser implant surface disinfection have an effect on implant survival rates, and do these rates differ based on laser treatment modality?

Clinical Scenario:

A 55-year-old female presents 10 years after implant placement at sites #18 and #20 (Fig. 1). She demonstrates a 9-mm probing depth mesially and distally at implant #20. Bleeding on probing is present at all six sites around implant #20. The patient has not noted any discomfort, and suppuration has not been noted on clinical examination. Her medical history is significant for osteoarthritis, gastroesophageal reflux disease, and anxiety. She reports taking ibuprofen as needed for pain, 150 mg ranitidine twice daily, and 20 mg citalopram daily. The patient is concerned about the possibility of implant loss and states that she wants to save and treat the implant, if possible. During flap reflection, a circumferential defect at implant #20 is noted intrasurgically (Fig. 2).

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Key Words: Alveolar bone grafting; dental implants; lasers; peri-implantitis; periodontal diseases; review.

Background

A large number of dental implants are placed currently, and although they have been shown to be a predictable treatment modality to replace missing teeth,[1] reports indicate that up to 12% to 43% of dental implants will develop clinical signs and symptoms of peri-implantitis and crestal bone loss over 5 or more years after functional loading.[2,3] Treatment strategies for management and treatment of peri-implantitis have been varied, and there is little evidence of treatment efficacy.[4] A consensus report of the 6th European Workshop on Periodontology stated that non-surgical therapy of peri-implantitis has not been found to be effective.[5] Conversely, surgical outcomes with guided bone regeneration (GBR) have demonstrated improved clinical and radiographic outcomes for peri-implantitis treatment.[6-9] The adjunctive use of laser and photodynamic therapy (PDT) has also been considered to improve implant surface decontamination with both surgical and non-surgical therapy.[10-12]

Search Strategy

The following terms were searched in the PubMed database (in which mh is the MeSH term, tw is the text word, pt is the publication type, and sb is the subset): Peri-Implantitis OR peri-implantitis OR perimplantitis OR peri-implant OR peri-implant OR perimplant OR (Dental Implantation OR Dental Implants) AND (Prosthesis-Related Infections OR Alveolar Bone Loss OR Periodontal Diseases OR Periodontitis OR Gingivitis OR Pericoronitis OR infection OR infections OR microbiology OR Bacteria OR Dental Plaque OR Mucositis OR Stomatitis OR Periodontal Debridement OR Debridement OR debrid* OR Dental Scaling OR Dental Air Abrasion OR "air abrasive" [tw] OR Dental Disinfectants OR Dental Etching OR Dental Prophylaxis OR Disinfection OR Disinfectants OR disinfect* OR Decontamination OR decontaminat* OR Prosthesis Failure OR Dental Restoration Failure) AND Laser Therapy OR Lasers OR laser OR Er-YAG OR eryag [tw] OR erl [tw] OR Nd-YAG OR ndyag [tw] OR photodynamic OR Photochemotherapy OR semiconductors OR diode OR co2 OR "co 2" [tw] OR Carbon Dioxide AND (cohort studies [mh] OR meta-analysis [pt] OR meta-analysis as topic [mh] OR randomized controlled trial [pt] OR randomized controlled trials as topic [mh] OR systematic [sb] OR cohort [tw] OR "meta analysis" [tw] OR "randomized controlled" [tw] OR systematic [tw]).

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Search Outcome

Ninety-six abstracts were hand reviewed, and 19 full-text articles were reviewed. Four articles are included in this review. Original human participant case series, cohort, and randomized controlled trials were included. Papers were eliminated for the following reasons: 1) study design; 2) lack of published data on peri-implantitis treatments; 3) non-unique patient populations; and 4) surgical access only with laser debridement. Data for guided tissue regeneration (GTR) with laser implant surface debridement were extracted from datasets if the following were true: 1) additional treatment modalities were included in the manuscripts; 2) findings were reported; and 3) those specific data are reported in this report. The findings of the relevant current literature[13-16] are reviewed in Table 1.

Discussion

Commercially available lasers that have been used for implant surface disinfection include carbon dioxide (CO_2), diode, erbium:yttrium-aluminum-garnet (Er:YAG), and neodymium:yttrium-aluminum-garnet (Nd:YAG). Current evidence demonstrates inconsistent data regarding laser reduction of bacterial loads on tooth surfaces beyond that achieved with non-surgical periodontal therapy alone.[17,18] However, in vitro and in vivo trials have demonstrated elimination of bacterial smear layer and viable bacteria with the use of laser therapy.[19-22] Although non-surgical treatment of peri-implantitis with the adjunctive use of laser treatment was not found to be effective in a previous review,[5] surgical access with surface debridement and bone augmentation has been shown to be effective.[6,7] Variability within the treatment outcomes may be influenced by implant surface characteristics, bone graft substitute qualities, and defect characteristics.[8,23]

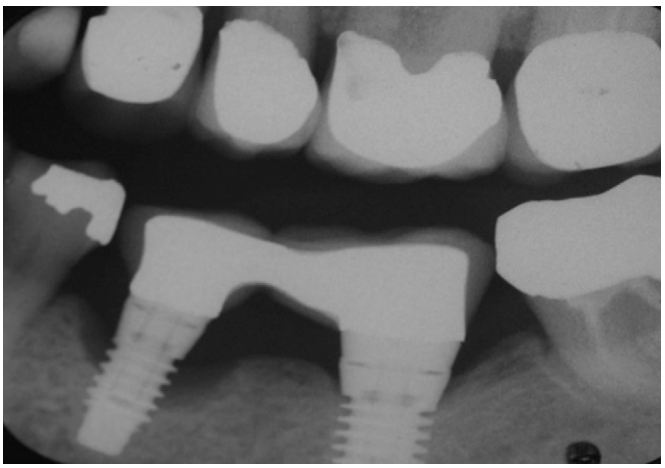

FIGURE 1 Bitewing radiograph demonstrating radiographic bone loss of 40% to 60% of implant length at both the mesial and distal surfaces of implant #20.

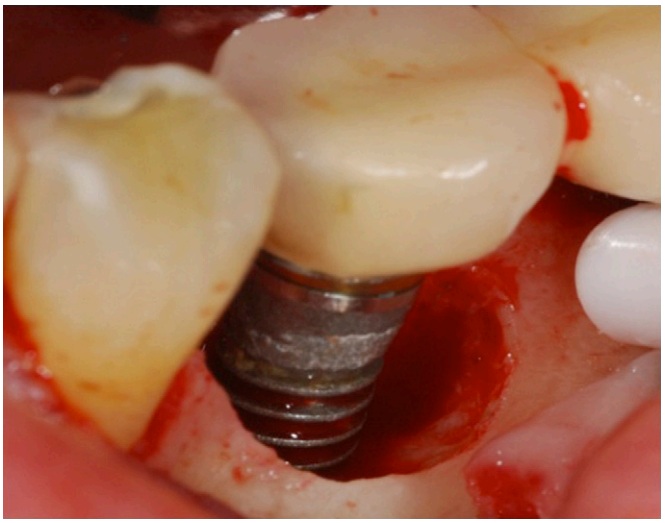

FIGURE 2 Intrasurgical clinical photograph taken after debridement demonstrating a circumferential bony defect at implant #20.

One article reviewed[16] was a randomized controlled trial, but the manuscript only presented clinical data at baseline and follow-up. Surgical reentry data were available in one article reviewed,[14] although patient assignment to treatment groups was not stated to be randomized in this study. A total of 86 implants were treated with GBR and laser implant surface decontamination in all articles reviewed, and the total follow-up time ranged from 0 to 60 months. Considerable heterogeneity exists in evaluation procedures for resolution of peri-implantitis in the articles reviewed, and none of the articles evaluated microbiologic outcomes. All articles reviewed demonstrated an improvement in clinical and/or radiographic outcomes from baseline to follow-up for ailing implants treated with laser and GBR protocols. Furthermore, the two studies that demonstrated comparative results for implants treated with GBR without laser debridement demonstrated improved clinical and/or radiographic outcomes for the laser decontamination group when compared with standard decontamination.[14,16] Because the articles reviewed used varied laser protocols, including CO_2,[14,15] Er:YAG,[16] and soft light laser at 906 nm,[13] no meaningful conclusions can be made about the effectiveness of individual laser types for decontamination purposes from these studies. In vitro and animal studies have suggested that low-level laser with dye may improve implant surface disinfection.[12,24,25] Furthermore, in vitro studies have shown that diode, CO_2, Er:YAG, and Nd:YAG lasers at appropriate wavelength settings may be sufficient to reduce and/or eliminate surface bacteria without damaging implant surface characteristics if appropriate published parameters are used.[26,27]

Implant failure has been classified into clinically distinct types with differing microbiota based on the underlying etiology.[28] Early implant failure may be associated with lack of primary stability, surgical trauma, or postoperative infection, whereas late failure has been shown to be associated with occlusal overload and peri-implantitis.[29,30] In one article reviewed,[15] 15 of the 19 implants treated demonstrated bone loss before Phase II uncovery procedures and prosthetic restoration. These implants may represent a different subset of microbiota than those with late and/or infection-related failures and may respond differently to therapy. Evaluation of specific microbiota associated with peri-implantitis, specifically *Tannerella forsythia*, *Campylobacter*

TABLE 1 Adjunctive Laser Use With Bone Grafting Around Implants: A Summary of the Published Literature

Reference	Implant Data	Laser Type	Study Type (Level of Evidence)	Methods	Key Results	Comments
Haas et al., 2000[13]	24 flame-sprayed cylindrical implants.	Soft light laser at 906 nm for 1 minute after toluidine blue O (100 μg/mL) treatment for 1 minute; preprocedural saline rinse.	Case series	Patients with peri-implantitis were defined by an infrabony pocket of ≥6 mm and progressive bone loss over the past 12 months. Sites were accessed surgically, and the implant surfaces were treated with toluidine blue O (100 μg/mL), soft light laser at 906 nm, and bone augmentation with autogenous bone and ePTFE membrane. Membrane removal was scheduled 3 months after placement but was removed immediately if exposed and demonstrating signs of inflammation. Radiographic bone gain was evaluated at 9.5 months postoperatively.	Two implants failed and were explanted. Mean defect depth decreased statistically significantly from preoperative levels. Defect depths preoperatively were 5.5 ± 2.0 mm, and a statistically significant mean bone gain of 2.0 ± 1.9 mm was seen over the study period. Early membrane retrieval was associated with decreased bone gain.	A large percentage of membranes were exposed early, and this may have altered treatment effectiveness. Furthermore, there was no control group that did not receive adjunctive implant laser disinfection, so the additive benefit of laser treatment is unable to be determined.
Deppe et al., 2007[14]	32 implants; 17 received bone augmentation and laser debridement, 15 received traditional disinfection and bone augmentation. Resective surgical treatment with or without laser disinfection was performed in the other groups. Two implant types were included.	CO_2 laser at 10.6 μm wavelength and a maximum of 7 W. No irrigation was noted.	Case series	Patients who were identified with progressive vertical bone loss, PD ≥5 mm, or BOP received surgical access, bone augmentation treatment using β-tricalcium phosphate and autogenous bone with laser or traditional (cotton pellet, saline, plastic curet) implant surface decontamination. Non-resorbable membranes were used. Surgical reentry and 5-year follow-up were performed.	Implants receiving laser decontamination demonstrated statistically significant improvements in CAL when compared with those receiving conventional disinfection at reentry. Statistically significantly more vertical bone height (DIB) was demonstrated in laser-debrided implants at surgical reentry.	All implants were treated with air-powder abrasive disinfection, and, in 22, adjunctive CO_2 laser treatment was performed. Although the differences between laser-debrided and non-debrided groups receiving bone augmentation are clinically significant, both bone augmentation treatment modalities demonstrated more vertical bone height and CAL gain than implants receiving resective therapy.

TABLE 1 (Continued) Adjunctive Laser Use With Bone Grafting Around Implants: A Summary of the Published Literature

Reference	Implant Data	Laser Type	Study Type (Level of Evidence)	Methods	Key Results	Comments
Romanos and Nentwig, 2008[15]	19 implants; all received laser debridement and grafting with either autogenous or xenograft material. Multiple implant types were included.	CO_2 laser at 2.84 ± 0.83 W for 1 minute. No irrigation was noted.	Case series	Patients were identified with deep infrabony defects, bone loss over two thirds of the implant length, and no implant mobility. Four implants were identified after restoration and 15 after initial placement before implant uncovery. Surgical access and debridement was performed, and a CO_2 laser was used to disinfect implant surfaces. Grafting was performed with autogenous or xenograft bone material. Resorbable collagen membranes were used. Implants were observed up to 27 months, and radiographic analysis was performed.	Statistically significant improvements were seen in the sulcus bleeding index and PD postoperatively compared with preoperatively, despite no significant differences in plaque index and width of keratinized gingiva at surgical sites. The number and extent of peri-implant defects with vertical bone loss improved postoperatively as well.	This treatment protocol proved to be effective in increasing radiographic bone fill and decreasing PD in implants with vertical bone loss. The majority of these implants must be considered early failures because they were not exposed to the oral environment before peri-implantitis diagnosis and treatment. Also, this study did not include a control group, so the effect of the CO_2 laser used for surface disinfection compared with the effectiveness of augmentation procedures is unknown.
Schwarz et al., 2012[16]	26 implants; all received flap access and surgical debridement. Patients were then randomly assigned to receive adjunctive debridement with Er:YAG laser or standard disinfection before bone augmentation. Various implant types were included.	Er:YAG laser with pulse radiation at 2.940 nm with 100 mJ/pulse and 10 Hz. Continuous water irrigation was used.	Randomized controlled trial	Patients who were identified with infrabony and supracrestal defects with PD >6 mm and infrabony component >3 mm were defined as having peri-implantitis. All patients received surgical access and degranulation of the surgical sites and then were randomized to receive implant surface decontamination with either Er:YAG laser or standard disinfection protocols (cotton pellet, saline, plastic curet). All participants then received bone augmentation	Statistically significant differences were seen at 12-month follow-up within each group from baseline for BOP, PD, mucosal recession, and CAL. At 24 months, intragroup differences in BOP were seen. There were no statistically significant differences between groups at either time point.	Site-level analysis demonstrates a high level of heterogeneity in the responses to both treatment modalities. All patients received additional peri-implantitis treatment after the 24-month observation period was over.

TABLE 1 (Continued) Adjunctive Laser Use With Bone Grafting Around Implants: A Summary of the Published Literature

Reference	Implant Data	Laser Type	Study Type (Level of Evidence)	Methods	Key Results	Comments
				grafting with xenograft bone graft and resorbable collagen membrane. Clinical follow-up was performed to 24 months.		

ePTFE = expanded polytetrafluoroethylene; PD = probing depth; DIB = distance from implant platform to first implant bone contact radiographically.

spp., and *Parvimonas micra*, and evaluation of loss of radiographic lamina dura[31] in future investigations may allow for more certainty in the diagnosis of late implant failure, i.e., true peri-implantitis.

GBR alone has been used in both animal and human models to treat peri-implant defects.[8,9,32-37] Furthermore, bone replacement grafting has demonstrated differing success on various implant surface types.[37] Bone substitute materials, defect morphology, and implant surface characteristics may all influence clinical outcomes of peri-implantitis treatment with GBR. Participants in the studies reviewed received grafting with autogenous bone, xenograft, and alloplast materials, and numerous implant surface types were included in the treated implant group. The heterogeneity of implant systems and surface types, bone replacement graft materials used, and possible varied etiologies for peri-implant bone loss are confounders when evaluating the current literature.

One study included in this review demonstrated long-term follow-up with a randomized controlled trial design.[9] Previous data were published on the short-term (6-month) results after Er:YAG laser surface decontamination.[23] Although 6-month data demonstrated higher reduction in bleeding on probing (BOP) and clinical attachment level (CAL) at the laser disinfected sites, at 24 months, there were no statistically significant differences between the groups, and neither group demonstrated CAL levels that differed from baseline findings. These results may indicate that adjunctive laser disinfection may result in short-term decontamination and improved clinical findings, but the longevity of these effects may not allow long-term improvements at implants with peri-implantitis.

There have also been adverse events associated with implant treatment with lasers. Nd:YAG lasers have been shown in some studies to boil additive implant surfaces, yielding porosities, which could serve as a niche for additional bacterial proliferation.[38,39] Additionally, the use of CO_2 lasers at pulsed and continuous settings has been demonstrated to raise the temperature of implants in vitro 9.5°C to 12.2°C, respectively.[40] This type of increase in temperature from physiologic 37°C could yield local circumimplant temperatures in the range of bone necrosis. Furthermore, variability in wavelength, pulse, and irrigation have been shown to have demonstrative effects on decontamination effectiveness and alterations to surface chemistry.[41] Some of the risks of laser therapy may be mitigated by the use of PDT, which uses low-level laser therapy to perform surface decontamination. A recent in vitro study indicated that PDT may be more efficient than standard laser disinfection protocols without many of the associated risks.[12] Therefore, it is very important to note the time, wavelength, presence of cooling, and power of lasers used for peri-implantitis treatment when adapting a published laser treatment protocol for clinical application. ■

Clinical Bottom Line

Adjunctive use of laser disinfection protocols with GTR for the treatment of peri-implantitis may improve clinical and radiographic findings up to 5 years after therapy. Significant heterogeneity exists in implant decontamination protocols. Care must be taken to develop standardized, ideal laser decontamination protocols that fully characterize the wavelength, time, power, and presence of cooling that may yield ideal results for peri-implantitis treatment. Additional longitudinal studies are necessary to allow for the development of standardized protocols for surgical treatment of peri-implant bone loss and clinical inflammation.

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References

1. Buser D, Ingimarsson S, Dula K, Lussi A, Hirt HP, Belser UC. Long-term stability of osseointegrated implants in augmented bone: A 5-year prospective study in partially edentulous patients. *Int J Periodontics Restorative Dent* 2002;22:109-117.
2. Zitzmann NU, Berglundh T. Definition and prevalence of peri-implant diseases. *J Clin Periodontol* 2008;35(Suppl. 8):286-291.
3. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2002;29(Suppl. 3):197-212, discussion 232-233.
4. Esposito M, Grusovin MG, Worthington HV. Treatment of peri-implantitis: What interventions are effective? A Cochrane systematic review. *Eur J Oral Implantology* 2012;5(Suppl.):S21-S41.
5. Lindhe J, Meyle J; Group D of European Workshop on Periodontology. Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. *J Clin Periodontol* 2008;35(Suppl. 8):282-285.
6. Schwarz F, Bieling K, Bonsmann M, Latz T, Becker J. Nonsurgical treatment of moderate and advanced periimplantitis lesions: A controlled clinical study. *Clin Oral Investig* 2006;10:279-288.
7. Roos-Jansåker AM, Renvert H, Lindahl C, Renvert S. Surgical treatment of peri-implantitis using a bone substitute with or without a resorbable membrane: A prospective cohort study. *J Clin Periodontol* 2007;34:625-632.
8. Roos-Jansåker AM, Lindahl C, Persson GR, Renvert S. Long-term stability of surgical bone regenerative procedures of peri-implantitis lesions in a prospective case-control study over 3 years. *J Clin Periodontol* 2011;38:590-597.
9. Schwarz F, Sahm N, Becker J. Impact of the outcome of guided bone regeneration in dehiscence-type defects on the long-term stability of peri-implant health: Clinical observations at 4 years. *Clin Oral Implants Res* 2012;23:191-196.
10. Renvert S, Lindahl C, Roos Jansåker AM, Persson GR. Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: A randomized clinical trial. *J Clin Periodontol* 2011;38:65-73.
11. Muthukuru M, Zainvi A, Esplugues EO, Flemmig TF. Non-surgical therapy for the management of peri-implantitis: A systematic review. *Clin Oral Implants Res* 2012;23(Suppl. 6):77-83.
12. Marotti J, Tortamano P, Cai S, Ribeiro MS, Franco JE, de Campos TT. Decontamination of dental implant surfaces by means of photodynamic therapy. *Lasers Med Sci* 2013;28:303-309.
13. Haas R, Baron M, Dörtbudak O, Watzek G. Lethal photosensitization, autogenous bone, and e-PTFE membrane for the treatment of peri-implantitis: Preliminary results. *Int J Oral Maxillofac Implants* 2000;15:374-382.
14. Deppe H, Horch HH, Neff A. Conventional versus CO2 laser-assisted treatment of peri-implant defects with the concomitant use of pure-phase beta-tricalcium phosphate: A 5-year clinical report. *Int J Oral Maxillofac Implants* 2007;22:79-86.
15. Romanos GE, Nentwig GH. Regenerative therapy of deep peri-implant infrabony defects after CO_2 laser implant surface decontamination. *Int J Periodontics Restorative Dent* 2008;28:245-255.
16. Schwarz F, John G, Mainusch S, Sahm N, Becker J. Combined surgical therapy of peri-implantitis evaluating two methods of surface debridement and decontamination. A two-year clinical follow up report. *J Clin Periodontol* 2012;39:789-797.
17. American Academy of Periodontology statement on the efficacy of lasers in the non-surgical treatment of inflammatory periodontal disease. *J Periodontol* 2011;82:513-514.
18. Cobb CM. Lasers in periodontics: A review of the literature. *J Periodontol* 2006;77:545-564.
19. Haas R, Dörtbudak O, Mensdorff-Pouilly N, Mailath G. Elimination of bacteria on different implant surfaces through photosensitization and soft laser. An in vitro study. *Clin Oral Implants Res* 1997;8:249-254.
20. Dörtbudak O, Haas R, Bernhart T, Mailath-Pokorny G. Lethal photosensitization for decontamination of implant surfaces in the treatment of peri-implantitis. *Clin Oral Implants Res* 2001;12:104-108.
21. Ishikawa I, Aoki A, Takasaki AA, Mizutani K, Sasaki KM, Izumi Y. Application of lasers in periodontics: True innovation or myth? *Periodontol 2000* 2009;50:90-126.
22. Takasaki AA, Aoki A, Mizutani K, et al. Application of antimicrobial photodynamic therapy in periodontal and peri-implant diseases. *Periodontol 2000* 2009;51:109-140.
23. Schwarz F, Sahm N, Iglhaut G, Becker J. Impact of the method of surface debridement and decontamination on the clinical outcome following combined surgical therapy of peri-implantitis: A randomized controlled clinical study. *J Clin Periodontol* 2011;38:276-284.
24. Hayek RR, Araújo NS, Gioso MA, et al. Comparative study between the effects of photodynamic therapy and conventional therapy on microbial reduction in ligature-induced peri-implantitis in dogs. *J Periodontol* 2005;76:1275-1281.
25. Deppe H, Horch HH, Henke J, Donath K. Peri-implant care of ailing implants with the carbon dioxide laser. *Int J Oral Maxillofac Implants* 2001;16:659-667.
26. Gonçalves F, Zanetti AL, Zanetti RV, et al. Effectiveness of 980-mm diode and 1064-nm extra-long-pulse neodymium-doped yttrium aluminum garnet lasers in implant disinfection. *Photomed Laser Surg* 2010; 28:273-280.
27. Tosun E, Tasar F, Strauss R, Kıvanc DG, Ungor C. Comparative evaluation of antimicrobial effects of Er:YAG, diode, and CO_2 lasers on titanium discs: An experimental study. *J Oral Maxillofac Surg* 2012; 70:1064-1069.
28. Rosenberg ES, Torosian JP, Slots J. Microbial differences in 2 clinically distinct types of failures of osseointegrated implants. *Clin Oral Implants Res* 1991;2:135-144.
29. Sakka S, Baroudi K, Nassani MZ. Factors associated with early and late failure of dental implants. *J Investig Clin Dent* 2012;3:258-261.
30. Snauwaert K, Duyck J, van Steenberghe D, Quirynen M, Naert I. Time dependent failure rate and marginal bone loss of implant supported prostheses: A 15-year follow-up study. *Clin Oral Investig* 2000;4:13-20.
31. Tabanella G, Nowzari H, Slots J. Clinical and microbiological determinants of ailing dental implants. *Clin Implant Dent Relat Res* 2009; 11:24-36.
32. Grunder U, Hürzeler MB, Schüpbach P, Strub JR. Treatment of ligature-induced peri-implantitis using guided tissue regeneration: A clinical and histologic study in the beagle dog. *Int J Oral Maxillofac Implants* 1993; 8:282-293.
33. Schüpbach P, Hürzeler MB, Grunder U. Implant-tissue interfaces following treatment of peri-implantitis using guided tissue regeneration: A light and electron microscopic study. *Clin Oral Implants Res* 1994;5: 55-65.
34. Behneke A, Behneke N, d'Hoedt B. Treatment of peri-implantitis defects with autogenous bone grafts: Six-month to 3-year results of a prospective study in 17 patients. *Int J Oral Maxillofac Implants* 2000;15:125-138.
35. Casati MZ, Sallum EA, Nociti FH Jr., Caffesse RG, Sallum AW. Enamel matrix derivative and bone healing after guided bone regeneration in dehiscence-type defects around implants. A histomorphometric study in dogs. *J Periodontol* 2002;73:789-796.
36. Aghazadeh A, Rutger Persson G, Renvert S. A single-centre randomized controlled clinical trial on the adjunct treatment of intra-bony defects with autogenous bone or a xenograft: Results after 12 months. *J Clin Periodontol* 2012;39:666-673.
37. Roccuzzo M, Bonino F, Bonino L, Dalmasso P. Surgical therapy of peri-implantitis lesions by means of a bovine-derived xenograft: Comparative results of a prospective study on two different implant surfaces. *J Clin Periodontol* 2011;38:738-745.
38. Block CM, Mayo JA, Evans GH. Effects of the Nd:YAG dental laser on plasma-sprayed and hydroxyapatite-coated titanium dental implants: Surface alteration and attempted sterilization. *Int J Oral Maxillofac Implants* 1992;7:441-449.
39. Romanos GE, Everts H, Nentwig G. Alterations of the implant surface after CO_2- or Nd:YAG-laser irradiation: A SEM examination. *J Oral Laser Applications* 2001;1:29-33.
40. Oyster DK, Parker WB, Gher ME. CO_2 lasers and temperature changes of titanium implants. *J Periodontol* 1995;66:1017-1024.
41. Romanos GE, Gutknecht N, Dieter S, Schwarz F, Crespi R, Sculean A. Laser wavelengths and oral implantology. *Lasers Med Sci* 2009;24:961-970.