CLINICAL STUDY

Evaluation of the Removal Bacteria on Failed Titanium Implants After Irradiation With Er:YAG

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Antonio *Scarano*, MD, MS, DDS,* *Gianna Nardi*, DH,[†] *Giovanna Murmura*, MD,*
Manuela Rapani, DDS,* and *Carmen Mortellaro*, MD, DDS^{‡§}

Peri-implantitis may occur because of biologic or mechanical factors. It can be treated by a variety of methods. The aim of the present study is to evaluate implant surface of failed oral titanium implants after being irradiated with erbium laser.

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Materials and Methods: These studies comprised 45 implants removed for peri-implantitis reasons. The implants were divided into 2 groups: group I (control), 22 nonirradiated implants; group II (test), 23 irradiated implants. Immediately after extraction, the implants in group II were irradiated with an erbium laser (PLUSER; Doctor Smile, Vicenza, Italy). The control and test implants were processed for SEM analysis.

Results: At higher magnification, no bacteria were found on test implant surface. At low magnification, there was variation in the number of fields of deposits among the nonirradiated implants and different portions on the same implants. At higher magnification, the deposits were identified as connective tissue in apical portion and bacteria or others in coronal portion of control implants.

Conclusions: In conclusion, erbium laser is recommended to be used for implant surface detoxification without surface alteration, using the experimental conditions.

Key Words: Detoxification, erbium laser, failure implant, peri-implantitis

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The use of oral implants in complete or partially edentulous patients has undoubtedly increased in dentistry over the last 30 years. This has also led to different complications such as surgical trauma, inadequate bone volume, a lack of primary stability, intrabony infection or bacterial contamination of the receptor zone. Peri mucositis, peri-implantitis, and occlusal overload could also be issues¹ that could lead to implant failure. Pontoriero et al² in 1994 show a cause–effect relationship between bacterial plaque accumulation and the development of inflammatory changes in peri-implant soft tissues.² The term peri-implant

disease is collectively used to describe biological complication in implant dentistry, including peri-implant mucositis and peri-implantitis.

The Sixth European Workshop in Periodontics held in 2008 defined peri-implant diseases as follows: peri-implant mucositis is the presence of inflammation of the peri-implant mucosa without signs of loss of bone support, whereas peri-implantitis, in addition to inflammation of the mucosa, is characterized by a loss of bone support.^{3,4}

The diagnosis of peri-implant infections are based on peri-implant probing depth (PD), evaluation of peri-implant keratinized mucosa, presence of bleeding on probing and suppuration, radiographic evaluation, evaluation of implant mobility, and analysis of peri-implant sulcus fluid.⁵ The peri-implant disease treatments proposed are based on the results of the treatment of periodontitis.⁶

Both surgical and nonsurgical techniques have been developed to reduce bacterial colonization, eliminate the bacterial microbiota, and introduce an ecology capable of suppressing the subgingival anaerobic flora.⁷ Mombelli⁸ suggested that bactericidal treatment such as detoxifying the implant surface, reducing or removing periodontal pockets, restoring bone tissues and re-osseointegration, and reinforcing oral hygiene should be considered for treating bacteria-contaminated implants.

The detoxifying techniques are divided as follows: mechanical detoxification using a plastic curet, rubber cups, ultrasonic scaler, or air-powder abrasives⁹; chemical detoxification using citric acid, chlorhexidine, tetracycline, hydrogen peroxide, or stannous fluoride^{9,10}; laser-based treatments.¹¹ However, mechanical and chemical methods may lead to implant surface changes viewed on scanning electron microscopy, without effectively detoxifying the surfaces.¹² On the other hand, laser-based methods are highly effective in sterilization and detoxification.

Many authors have suggested its use for the treatment of peri-implant infections based on its advantages such as easy handling, and hemostatic and bactericidal effects against periodontopathic pathogens while reducing bleeding, swelling, and pain. Different laser techniques have been developed to improve treatment outcomes, such as diode laser, neodymium-doped: yttrium-aluminum-garnet (Nd:YAG), erbium-doped: yttrium-aluminum-garnet (Er:YAG), erbium, chromo-doped: Yttrium-scandium-gallium-garnet (Er,Cr:YSGG) laser, Kalium-Titanyl-Phosphate (KTP), and anhydride carbon laser (CO₂). Only the CO₂ laser, the diode laser, and the Er:YAG laser may be suitable for the irradiation of titanium surfaces because the implant body temperature did not increase significantly during its application. But neither CO₂ nor diode lasers were effective in removing plaque biofilms from titanium implants.^{13,14}

Different studies demonstrated that the Er:YAG laser, emitting at a wavelength of 2.94 μm, seemed to be capable of effectively removing plaque and calculus from both smooth and rough implant surfaces without injury.^{15,16} The aim of the present study is to evaluate implant surface of failed oral titanium implants after irradiation with erbium laser.

AQ4 From the *Department of Medical, Oral and Biotechnological Sciences, University of Chieti-Pescara, Chieti; [†]Department of Oral and Maxillofacial Sciences, Sapienza University of Rome, Rome; [‡]University of Eastern Piedmont, Novara; and [§]Oral Surgery Unit, Regina Margherita Pediatric Hospital, Turin, Italy.

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AQ5 Address correspondence and reprint requests to Antonio Scarano, MD, MS, DDS, Via dei Frentani 98/B, 66100 Chieti, CH, Italy;
E-mail: ascarano@unich.it

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METHODS

Implants

This study comprised 45 implants removed for peri-implantitis reasons in the Oral Surgery Division of the Dental Clinic at the University of Chieti-Pescara, Italy. The criteria needed for inclusion were the presence of ≥ 1 screw-type implant with a PD > 6 mm and signs of acute peri-implantitis (ie, bleeding on probing, suppuration), no implant mobility, presence of keratinized peri-implant mucosa, and a good level of oral hygiene.

AQ8 The implants were divided into 2 groups: group I (control), 22 nonirradiated implants, and group II (test), 23 irradiated implants. Immediately after extraction, the implants in group II were irradiated with an erbium laser (PLUSER). The control and test implants were rinsed briefly in normal saline solution to remove the adherent blood and immediately put in 2.5% glutaraldehyde in 0.1 mol/L sodium cacodylate buffer pH 7.4 for 4 hours. Then, they were dehydrated with increasing concentrations of ethanol solutions

AQ9 (50-70-90-100%) and left for 12 hours in 113 Freon (Trichlorotrifluoroethane) as a transition fluid to critical point drying bomb Polaron. The chambers were, finally, glued to aluminum stubs and coated with 20 to 30 nm of gold. The implant's surface was examined under a Leo 435VP Scanning Electron Microscopy (SEM LEO, Cambridge, England) operating at 20 to 30 KV with tilt angles ranging from 10 to 45 degrees.

AQ10 SEM evaluations were performed by 3 independent observers who expressed an estimate of bacterial amount of 3 different areas. Five areas of 100 to 130 microns in diameter were evaluated for each implants, and an image in JPEG format was created. Ten digital images have been used per region. The same images were evaluated by the 3 observers. Each image was evaluated twice, 2 days apart by each of the examiners. Intraexaminer and interexaminer duplicate measurements showed no significant differences ($P = 0.743$). Percentage of surface covered by bacteria or other tissues was carried out on the JPEG images using a PC (Intel Pentium III 1200 MMX). This PC was associated with a histometry software package with image capturing capabilities (Image-Pro Plus 4.5; Media Cybernetics Inc, Immagini & Computer Snc, Milano, Italy). The surface covered by connective tissue or bacterial deposits and their distributions on each control implant and test implant were analyzed by the Statistical Package for Social Science version 7.5 for Windows.

Statistical Evaluation

The differences in the percentages of surfaces covered by bacteria in the 2 groups were evaluated with the analysis of variance. The percentage of surface covered by bacteria was expressed as a mean $\pm$ standard deviation. Statistically significant differences were set at $P < 0.05$.

Laser Irradiation

AQ11 The implants were irradiated with an erbium laser (PLUSER) emitting pulsed infrared radiation at a wavelength of $2.940 \mu\text{m}$ with a truncated cone tip. Erbium laser has variable pulse frequency (20 pps) and pulse energy 75 mj (1.5 W). The laser beam was guided along the implant surfaces under water irrigation with a special designed handpiece (STH1 PLUSER; Doctor Smile) and a cone-shaped glass fiber tip emitting a radial and axial laser beam (RAL Tip; Doctor Smile). The fiber tip was guided in a circular motion from coronal to apical parallel to the implant surface in contact mode. The laser was applied to 3 points of the implants, and each irradiated surface area was $2 \times 2 \text{ mm}^2$. The frequency was fixed at 10 Hz, and the laser was operated in the near-contact mode. In this mode, the tip of the hand piece was at a distance of 0.5 mm from the

FIGURE 1. (A) At low magnification, a field of deposits among the surface same implants. Monolayer adhesion of streptococci on all samples was observed. (B) At higher magnification, the deposits were identified as cocci, rods, and filaments, and spirochete bacteria were identified on surface implants. (C) No bacteria were found on surface implant after treated with erbium Yag laser. (D) Previous image at higher magnification.

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implant surfaces, and the optical fiber was perpendicular to the surface of the subject to maximize the effects. The laser was applied in an up-down and right-left motion for 1 minute. After irradiation, the specimens were dried with air syringes.

RESULTS

Control Implant

Different degrees of organic residues, appearing mainly as dark stains, were detected on most of the retrieved implants. At low magnification, there was variation in the number of fields of deposits among the implants and different portions on the same implants (Fig. 1A). At higher magnification, the deposits were identified as connective tissue in apical portion and bacteria or others in coronal portion. There were fibroblasts and their extracellular matrices forming the connective tissue on implants surface. Several bacterial forms including cocci, rods, and filaments were identified on implants (Fig. 1B). Spirochete bacteria were observed in apical portion of implants. Connective tissue, bone, or other tissues are found on apical portion—examined fields of the implant surfaces. The coronal area covered by bacteria was $63.3\% \pm 2.9$.

Test Implant

At low magnification, there was variation in the number of fields of deposits among the implants and different portions on the same implant. The absence of deposits on some parts of the implant surface was also evident in implant surface treated with Er:YAG (Fig. 1C). At higher magnification, the deposits were identified as connective tissue, bone, or other tissues. Into any area of implant were not found bacteria (Fig. 1D). Connective tissue, bone, or other tissues are found on apical portion—examined fields of the implant surfaces. The coronal area covered by bacteria was $0.3\% \pm 1$

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Statistical Analysis

The test implant surface covered by bacteria was significantly lower than that of control implant, and the P value was ($P = 0.001$).

DISCUSSION

This study observed the detoxifying effect of erbium YAG laser on implant surfaces retrieved from patients affected by peri-implantitis. The most common biological peri-implant complications are peri-implant disease. These inflammatory conditions affecting tissues surrounding dental implant can be classified into peri-implant mucositis and peri-implantitis.^{3,4} Fransson et al¹⁷ reported a 27.8% prevalence of peri-implantitis, whereas Roos-Jansåker et al¹⁸ suggested that $\geq 56\%$ of the subjects exhibited sites with peri-implantitis. One of the main etiological factors of peri-implant disease is the accumulation of dental plaque. Therefore, the ultimate goal of peri-implantitis treatment is to remove the dental plaque and decontaminate implant surface. Different mechanical and chemical techniques have been developed to achieve this but without satisfactory results.^{9–11} Now, the laser is a widely used technique for decontamination of implant surfaces. Particularly, the erbium laser possesses bactericidal decontamination effectiveness and seemed to be capable of effectively removing plaque and calculus by a hydrokinetic process without injuring titanium and prevents a temperature increase.¹⁷ One of the problems raised during implant surface decontamination is the control of the temperature on implant-bone interface. Therefore, erbium laser was used in this study. Eriksson and Albrektsson¹⁹ reported that a temperature threshold levels for heat-induced bone tissue injury is 47°C. The use of water coolant minimizes heat generation by cooling the irradiated area and absorbing excessive laser energy. In addition, a water spray facilitates hard tissue ablation by keeping the target moist.²⁰ In this study, the laser beam was irradiated under maximum water irrigation to minimize thermal influence.

Although the erbium laser hydrokinetic laser system is widely used for dental purposes, information about its potential application for surgical peri-implantitis treatment is little known in the literature. In the present study, an erbium laser was used to decontaminate the implant surface. An erbium laser was highly efficient and effective in removing contaminants from the implant body without overheating or altering the surface characteristics of the roughened titanium surface.¹⁸ The absence of any measurable changes to the titanium surface and the lack of an organic smear layer create the ideal environment for the regrowth of bone and potential reintegration of the exposed or contaminated area of the implant body. Kreisler et al⁹ reported mean bacterial reductions of 98% on various implant surfaces contaminated with an Er: Yag laser at pulse energy of 60 and 120 mJ and a 10 Hz. Also no implant surface damage was shown on S.E.M. evaluation. In addition, Schwarz et al¹³ reported no significant alteration of HA-coated implant surface at pulse energy of 100 mJ, 10 Hz, and 2 minutes. Based on previous studies,²¹ laser irradiation at 100 mJ/pulse and 10 Hz for 1 minute is suggested as a standard for detoxification of implant surfaces. In this experiment, the pulse energy and application time were in accordance with the literature for detoxification of implant surface without surface alteration. In SEM, implant surface was not altered by Er: Yag laser irradiation under experimental condition. In conclusion, Er: Yag laser is recommended to be used for implant surface detoxification without surface alteration, using the experimental conditions. As in this study, only the detoxifying effect and topographic characterization was studied. Further studies based on the laser effects are necessary.

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