Effectiveness of 980-mm Diode and 1064-nm Extra-Long-Pulse Neodymium-Doped Yttrium Aluminum Garnet Lasers in Implant Disinfection


Abstract

Objective: To evaluate the potential of 980-nm gallium aluminum arsenide (GaAlAs) and 1064-nm neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers to reduce bacteria after irradiation of implant surfaces contaminated with Enterococcus faecalis and Porphyromonas gingivalis and on irradiated implant surface morphology.

Background: Despite the frequency of implant success, some implant loss is related to peri-implantitis because of difficulty in eliminating the biofilm.

Methods: Implants (3.75 × 13 mm) with machined surfaces, surfaces sandblasted with titanium oxide (TiO2), and sand-blasted and acid-etched surfaces were exposed to P. gingivalis and E. faecalis cultures and irradiated with 980-nm GaAlAs or 1064-nm Nd:YAG lasers. After laser treatments, the number of remaining colony-forming units and implant surface morphology were analyzed using scanning electron microscopy (SEM).

Results: The Nd:YAG laser was able to promote a total contamination reduction on all implants irradiated. The results with the GaAlAs laser showed 100% bacteria reduction on the implants irradiated with 3 W. Irradiation with 2.5 W and 3 W achieved 100% of bacteria reduction on P. gingivalis–contaminated implants. Decontamination was not complete for the sand-blasted TiO2 (78.6%) and acid-etched surfaces (49.4%) contaminated with E. faecalis and irradiated with 2.5 W. SEM showed no implant surface changes.

Conclusion: The wavelengths used in this research provided bacteria reduction without damaging implant surfaces. New clinical research should be encouraged for the use of this technology in the treatment of peri-implantitis.

Introduction

Implantology has been the dental specialty that has evolved the most in the last 3 decades. Since the advent of osseointegration, the predictability of the results of prostheses over implants has led a growing number of dentists to practice that activity.

Innovations in surgical techniques, as well as in the shape and surface of implants and in prosthetic abutments, have brought better results to implantology. However, amid the numerous positive results, we find a few doubts, mainly related to the implant maintenance. Notwithstanding the excellent results obtained in implant rehabilitation, the emergence of an inflammatory pathology that affects the peri-implant tissues called peri-implantitis, which can cause bone loss and the implant’s failure, has been observed.

That pathology has been defined as an inflammatory process affecting the tissues that surround the implant, leading to loss of the supportive bone, and the bacterial biofilm being its major etiologic agent.

The process of bacterial colonization of the implant surface is complex and involves different stages and bacteria species,1 yet its pathogenic mechanism is similar to periodontitis.2

Just like periodontal disease, peri-implantitis is multifactorial, and many therapies are suggested for its treatment, among them the mechanical procedures of scaling and removal of the peri-implant biofilm, associated or not with local or systemic antimicrobial therapies. Previous work2,3 has found that the results obtained are not so positive owing to the difficulty in eliminating the biofilm, which contributes to maintaining the pathology, blocking local tissue repair.

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The main difficulty in the treatment of peri-implantitis is in obtaining effective decontamination of the implant surface owing to the difficulty of removing the biofilm and to the existence of implants on rough surfaces. These surfaces, although highly beneficial for the initial process of osseointegration, promote a larger accumulation of peri-implant biofilm. The literature describes local chemical (antiseptic solutions, antibiotics), systemic, or physical (scaling, ultrasound, plastic curettes) methods or a combination of these.

Insufficient bacteria elimination results in a decrease of the treatment's success rate, which ranges between 20% and 40%. Decontamination combined with regenerative techniques is fundamental for the remission of peri-implantitis. The use of lasers, in many wavelengths, has been described in dentistry, mostly for its interaction with tissues and its therapeutic and antimicrobial effects, being indicated in restorative and surgical procedures, particularly in endodontics and periodontics. The use of laser for decontaminating periodontal pockets has been shown to be effective and has encouraged research for determining or clarifying its effectiveness in the treatment of peri-implantitis. The microbiota of infectious periodontal processes is similar to that observed as the main cause of peri-implantitis, but important differences also exist, requiring research to study them and evaluate the clinic consequences.

Many wavelengths, energetic parameters, and types of equipment have been used and described in the literature aiming at determining an effective and secure protocol in the treatment of peri-implantitis that could provide more-satisfactory results.

This research aimed at evaluating the level of reduction in bacteria of Enterococcus faecalis and Porphyromonas gingivalis contaminating three different implant surfaces after the use of a light beam of 980-nm diode and 1064-nm neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers with different power, as well as assessing possible damage to implant surfaces using scanning electron microscopy (SEM).

**Material and Methods**

**Materials**

Titanium implants (n = 144) with profile and external dimensions of 3.75 mm diameter and 13 mm height were used. They were especially manufactured and machined in Branemark standard (Conexão Sistemas de Prótese, São Paulo, Brazil), with a format developed especially for this experiment, without an orifice for the adaptation of prosthetic components and with an extension of the top section for its adaptation and stabilization during irradiation (Fig. 1). The implants were divided into three groups according to their surface properties: machined, sand blasted with titanium oxide (TiO2), and sand blasted and submitted to sulfuric acid etching.

**Cells**

We used a pure culture of reference stock of P. gingivalis American Type Culture Collection (ATCC) 33277 and E. faecalis ATCC 29212 prepared in sterile brain heart infusion (BHI) (Laboratório DIFCO Ltda., São Paulo, Brazil) plus hemin (5 μg/mL) and menadione (1 μg/mL). For counting the colony-forming units (cfus), we used 5 mL of a peptonized water solution (1.25%) containing sodium chloride (2.5%).

The solid medium used for evaluating the number of cfus was the trypticase soy agar (TSA, Laboratório DIFCO Ltda.), supplemented with hemin (5 μg/mL) and menadione (1 μg/mL) and enriched with 10 mL of defibrinated lamb blood. The Petri dishes with blood-agar were divided into five groups and identified with different colors. Each dish was limited with four fields for the differentiation of the colony-forming units (cfus), we used 5 mL of a peptonized water solution (1.25%) containing sodium chloride (2.5%).

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implants previously contaminated with

P. gingivalis

in test tubes containing BHI broth. The test tubes containing
device using tweezers, which were sterilized and introduced
in test tubes containing BH1 broth. The test tubes containing
implants previously contaminated with P. gingivalis were
incubated under anaerobic conditions at 37°C for 3 days,
whereas those contaminated with E. faecalis were incubated
in anaerobiosis at 37°C for 18 h. At the end of the incubation
periods, we checked in which test tubes there occurred
cell growth (to reach approximately 5 \times 10^8 cfu), which
were separated to perform the series dilution, with the
purpose of analyzing and counting the number of cfu to
determine the reduction of the microbial population of the
irradiated implants. The methodology used for the microbiologic
analysis, as well as in the cultures, followed the guidelines of the Anaerobic Lab of the Microbiology Department of the Institute of Biomedical Sciences, University of Sao Paulo (ICB-USP).

Laser equipment and experimental drawing

Two types of laser equipment were used. The first was a surgical diode (980-nm gallium aluminum arsenide (GaA-
Lasers) laser type (model Smarty–A 900, DEKA M.E.L.A. s.r.l, Firenze, Italy), a laser system electronically controlled
through a maximum 10-W microprocessor, frequency up to
150 Hz, pulse length of 2 ms to 2 s, connectable to 200-, 300-,
and 600-μm fiber optics, and with a 3-mW laser guide. The second was a 1064-nm Nd:YAG laser (model Smartfile,
DEKA M.E.L.A. s.r.l), with a maximum power of 10 W, fre-
quency up to 150 Hz, and a pulse length of 1 ms. As a neg-
ative control, contaminated implants (n = 3/implant group/
bacteria, 18 implants total) were autoclaved. Contaminated
implants neither autoclaved nor irradiated were the positive
control (n = 3/implant group/bacteria, 18 implants total).

A device was developed for maintaining a constant dis-
tance between the laser’s fiber optic extremity and the implant
surface (in process for patenting (protocol No. 0031871),
presented by the Anaerobic Lab of the Microbiology De-
partment of ICB-USP) (Fig. 2). That device kept the implants
in continuous rotating movement around their own axes,
whereas the handle of the laser equipment had a vertical
movement of 15 mm amplitude, allowing irradiation to occur
throughout the implant surface.

The 980-nm diode laser was set in a continuous emission
mode for 5 min, whereas the 1064-nm Nd:YAG laser was
used in a pulsating mode, both keeping the fiber optics of
300 μm at a 3-mm distance, perpendicular to the irradiated
surface and with a diameter of focused beam of 0.3 mm. The
irradiations were performed continuously for 5 min at 2.5 W
(1143 J/cm²) or 3 W (1371 J/cm²). Irradiated implants (n = 3/
Surface morphology

For analysis of possible alterations on the implant surfaces after the laser irradiation, we used 18 uncontaminated implants (n = 3/power/type of laser, 36 implants) submitted to irradiation using two different sets of equipment. The energetic parameters were varied, as well as the contaminated implants irradiation, that is: 2.5 W and 3 W and control, continuous irradiation for 5 min and the three types of implant surfaces studied.

We obtained three microphotographs of each irradiated implant and a control, with enlargements of 200×, 500×, 1000×, referring to the regions of the implant threads. For that analysis, we used a scanning electron microscope (VEGA TS 5136 MM, Tescan, Brno, Czech Republic), totally computer controlled, working in high, medium, and low vacuum, with enlargements of up to 1,000× and with a reading speed of 600 ns to 10 ms per pixel.

Results

When using 3W, regardless of the type of irradiated implant surface, the contaminating bacteria, or the laser wavelength used, there was a complete reduction of the contaminating microorganisms (Tables 1 and 2). At 2.5 W with the 1064-nm Nd:YAG laser, bacteria reduction was 97.2% for the implants with the surface treated with acid etching (Table 2); with the diode laser, bacteria reduction was complete for P. gingivalis, regardless of the surface, whereas reduction of E. faecalis was 100%, for machined, 79% for sand blasted, and 50% for sand blasted and acid etched (Table 1).

The SEM analysis compared the nonirradiated implants (Fig. 3) with the 980-nm diode (Fig. 4) and 1064-nm Nd:YAG (Fig. 5) irradiated implants; no evident change occurred for 2.5 W or 3 W.

Discussion

In view of the results collected in the literature revision, we can say that peri-implant disease is similar to periodontal disease, the former usually being faster and more aggressive. Although many treatments have been proposed for the remission of both pathologies, there is not a defined protocol for the treatment of peri-implantitis. In addition, its prognostic in relation to periodontal disease is worse, because patients suffering from past periodontal disease have more chances to develop peri-implant disease.1,21

We found, in this study, that at 3W, both lasers decontaminated all surfaces no matter the type of bacteria tested, whereas at 2.5 W, the rough implants were partially decontaminated. It has previously been found that the Er:YAG laser does not decontaminate rough implants as well as smooth or machined implant surfaces.22 According to the methodology used, it was necessary to irradiate the implants for 5 min to cover the entire implant surface. For this reason, for each experiment a high value for the total energy (J/cm²) was used. Clinically, full implant irradiation is not necessary due to implant failure/loss, because it is no longer attached to bone.
The use of different types of lasers for the decontamination of periodontal pockets, bone surfaces, and root channels is a new field in peri-implantitis treatment. The reduction of microorganisms under the laser action, although confirmed by multiple studies, has some characteristics when used for the treatment of peri-implant disease, because in many cases the laser action may affect the implants’ titanium surface.\(^{23}\) The Nd:YAG laser is not indicated to peri-implantitis treatment due to important alterations on the titanium surface by laser.\(^{24,25}\) In the present study, the use of the 980-nm diode and the 1064-nm Nd:YAG lasers at 2.5 W and 3 W was not enough to produce any alteration on the implants’ surface, which were smooth or sand blasted using TiO\(_2\) and submitted to acid etching surface.

Even considering the thermal and superficial damage of the laser action on the implants, the prime objective is their decontamination for the regression of peri-implant disease. Parker et al. observed the reduction of bacteria using the diode laser.
laser, \(^1\) finding it quite effective. Castro et al.\(^{26}\) demonstrated in their in vitro study that the 980-nm diode laser did not change the titanium surface of dental implants, regardless of the energetic parameter used during the irradiation. Another benefit of the 980-nm diode and the 1064-nm Nd:YAG laser in the treatment of peri-implantitis is the possibility of its transmission through thin fiber optics, whose diameter may vary from 200 to 600 \(\mu m\). That allows them to be used in peri-implantitis without the need to open slashes through peri-implant furrows in initial processes like mucositis.

Because 980-nm the diode laser was capable of decontaminating the implants for the two contaminating agents proposed at 3 W, its use should be encouraged. \(E.\ faecalis\) optional anaerobic is resistant, whereas \(P.\ gingivalis\) is strict anaerobic, not so resistant, but quite pathogenic and capable of causing great destruction in the peri-implant tissue.

**FIG. 5.** SEM micrographs revealing the surface morphology of the 1064-nm neodymium-doped yttrium aluminum garnet irradiated implants. Machined (A, B), sand blasted with TiO\(_2\) (C, D), and sand-blasted and acid-etched surfaces (E, F). Laser power: 2.5 W/1143 J/cm\(^2\) (A, C, E) and 3.0 W/1371 J/cm\(^2\) (B, D, F).
The 1064-nm extra-long-pulse Nd:YAG laser eliminated the bacteria in all irradiated implants at 3 W. At 2.5 W, the bacteria were eliminated on all implants, except the one with the surface conditioned to the acid etching; whose reduction was 97.2%. During the assays, using the Nd:YAG laser, no implant surface was affected. Those facts are mostly due to the anti-bacterial power of the 1064-nm Nd:YAG laser, evidenced in endodontics27 and periodontal treatments28 because of the extra long pulse of the 1064-nm Nd:YAG, which has a duration of 1 μs, whereas the normal pulse used in all research described in the literature up to now is 100 μs. When extending the pulse, it became almost continuous like the diode, and we decreased the peak power of the 1064-nm Nd:YAG laser, this one being less absorbed by the titanium, not causing alterations on its surface. The reason for the poorer performance of the diode laser cannot be concluded with this methodology. Other research assessing thermal damages or other energetic parameters should be encouraged.

Conclusion

The 980-nm diode and the 1064-nm Nd:YAG lasers were effective in decontamination of P. gingivalis and E. faecalis without promoting surface alteration on the implants.

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Author Disclosure Statement

Fabio Gonçalves, Artemio Luiz Zanetti, Raquel Virgínia Zanetti, Francesco Savério Martelli, Mario Julio Avila-Campos, Luiz Fernando Tomazinho, and José Mauro Grangeiro state that competing financial interests exist in this work.

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