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Evaluation of thermal damage in dental implants after irradiation with 980nm diode laser. An in vitro study

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Abstract

Purpose: *The aim of this study was to analyze the thermal damage in dental implants after irradiations with a 980nm diode laser, normally used for the decontamination.*
Material and Methods: *Five Titanium Plasma Sprayed dental implants were irradiated with a 980nm diode laser at different parameters. Temperature increase on implant surface was evaluated by a Mid-Wavelength Infrared thermal-camera (Merlin®, FLIR, USA). Temperature increase (ΔT) was compared to environmental temperature (27°C) and recorded in three points: "A" (laser spot), "B" (3mm apically to the laser spot) and "C" (2mm horizontally to the laser spot). Finally, a morphological evaluation at optical stereomicroscopy was performed.*
Results: *When 0.6W power was applied, a moderate increase of temperature in point A (5.5°C-15.0°C), a slight increase in point B (0.1°C-6.2°C) and point C (0.1°C-5.7°C), were registered after 30" of irradiation. In the samples treated at 6W, in "point A" an impressive ΔT increase was immediately recorded (over 70°C). In "point B" was recorded a slight ΔT after 2 sec. irradiation (range 2.3°C-6.0°C), a moderate ΔT after 4 sec. irradiation (16.4°C) and a consistent ΔT after 8-10 sec. irradiation (range 36.6°C-46.2°C). In "point C" ΔT values were very similar to those collected in "point B". Optical stereomicroscopy examination at a magnification of 32x did not show any surface alteration or damage after whichever laser irradiation independently from irradiation time and power output .*
Conclusions: *980nm diode laser, used at controlled parameters, can be used in the decontamination of dental implants, without causing any thermal damage or increase.*

Keywords: *diode laser, periimplantitis; temperature increase.*

Introduction

Focusing on indications, anatomical and intra-individual limiting factors, insertion of dental implants represents a "safe" treatment option. However, in the last decades, increasing evidence raised on the presence of peri-implant inflammations representing one of the most frequent complications affecting both the surrounding soft and hard tissues and can lead to the loss of the implant. Peri-implantitis appears as a mixed anaerobic infection dominated by Gram negative bacteria, resulting in soft tissues inflammation and bone damage [1, 2].

In order to aid osseointegration and enhance the bone-implant contact, most titanium implants present a rough surface that improves the colonization of bone cells. By contrast, bacterial biofilm finds as favorable a rough microenvironment than a smooth one. When an implant is infected, it is very difficult to achieve a decontamination of a rough infected implant surface by the use of standard procedures [3] and, for this purpose, several techniques have been tested.

Metal instruments (ultrasonic scalers, steel and titanium curettes), can cause further increase in surface roughness and fail to kill bacterial implants [4,5]. So, an improvement in clinical and microbiological parameters was described following the decontamination by surgical open flap and teflon curettes and abrasive sodium carbonate air-powder [6]. At last, a limited evidence of the use of systemic antibiotics in the treatment of peri-implantitis was reported [7].

The aim of a cleaning procedure is to disinfect the implant without changing the surface structure and damaging the surrounding soft and hard tissues.

In the last years, lasers were proposed in most branches of dentistry. In periodontology and implantology, thanks to the antibacterial properties, some wavelengths, such as Nd:YAG (1064nm), Er:YAG (2940nm) and diode (808 and 980nm), have been used for the decontamination of periodontal or periimplant pockets. Disinfection and cleaning of implant surfaces by laser devices have been widely described [8-12]. However, in some cases, laser irradiation may cause morphological alterations and heating of implant surfaces since its thermal effect [13-16], so, controlled parameters should be applied. Power output, exposure time and operation mode are the main factors affecting the thermal damage of implant surface.

Except few studies using thermocouple device, no information about potentially excessive heat generation at the implant-bone interface has been published [17-19].

In this “in vitro” study the temperature increase in dental implants irradiated by a 980nm GaAlAs at different parameters, was evaluated using a Mid-Wavelength Infrared (MWIR) thermal-camera. The assessment of thermal damage was completed with a morphological analysis by optical microscopy at 32x and 50x.

Materials and Methods

Five Titanium Plasma Sprayed (TPS) dental implants (Straumann®, Basel, Swiss, diameter 4.1mm, height 14mm) were used in the present study. Each implant was divided into four symmetrical areas resulting in 20 test surfaces.

A GaAlAs laser 980nm (Smarty A900®, DEKA, Florence, Italy) was used on 16 surfaces (four implants), while 4 surfaces (1 implant) served as control. The laser was used in no contact mode at a distance of 1mm, with an optic fiber of 300μm, in Continuous Wave (CW). Two power settings were considered, 0.6W (power recommended by the company for the treatment) and 6W (a frankly high parameter, to have a net of comparison), for 30 seconds.

During every irradiation, implants were handled with latex gloves.

Each implant was identified with an alphabetical letter (from A to E). On the neck of each implant a working area was limited by a hemispherical cavity marked on the border between the neck and titanium plasma using a ball-shaped diamond bur (INTENSIV ISO 10, Switzerland). For each treated area, an evaluation of the temperature increase and morphological alteration was performed.

To evaluate the temperature increase, a MWIR thermo-camera was used. Its wavelength range allows to have a better spatial resolution when used to analyze some little objects such as dental implants. It is a more accurate device than thermocouples. Moreover, it does not demand a special sample preparation and does not need any contact with the sample during the test. It is a high precision instrument that can observe instantaneous temperature with a resolution of 20mK [20]. Furthermore, MWIR thermal-camera can notice not only the instantaneous temperature achieved on the specific point of laser irradiation, but also on the whole implant surface.

Data were collected by a software (MATLAB®, Torino, Italy), to create the "temperature map" assembled for the video output. This code allows for proper calibration of the data recorded by the camera.

During the irradiation, the apical parts of implants were inserted into a clamp placed in front of the objective focus of the thermo-camera and laser fiber was placed on a support at about 1 mm of distance from implant surface. Thermal-camera was connected with a Personal Computer that recorded thermal maps at a frame rate of 50Hz during all the experiment duration.

Temperature increase was recorded starting from the environmental temperature (T_0: 27°C), without any cooling system. For each parameters, five measurements were obtained. ΔT was recorded in three different points: “point A” (laser spot) , “point B” (3mm apically to the laser spot) and “point C” (2mm horizontally to the laser spot) (fig 1). The aim of the evaluation was to determine the parameters of irradiation over which the critical threshold for bone necrosis of 47°C was exceeded.

Finally, to make a subjective analysis of the rough implant surfaces after laser irradiations, an optical stereomicroscope (Zeiss 475052-9901®, Germany) at 32× and 50× magnifications was carried out.

Results

- Temperature measurements

The recorded values of temperature increase for the 0.6 W power output are reported in Table 1. A moderate increase of temperature was recorded in "point A" (range 5.5°C- 15.0°C) meanwhile a slight increase was recorded in "point B" (range 0.1°C- 6.2°C) and "point C" (range 0.1°C- 5.7°C) (fig 2). The graphic temperature increase-time (Fig 3), elaborated by the thermal-camera, presents in the first part a little step induced by a very fast temperature increase over superficial titanium plasma layer (50μm). This is probably due to the thermal properties of this thin layer. The second part the graphic presents a gradual temperature increase as a consequence of the thermal properties of the inside part of the implant leading the dynamic temperature evolution.

The recorded values of temperature increase for the 6.0 W power output are reported in Tab 2. In "point A" an impressive ΔT increase was immediately recorded (ranged over 70°C).

In "point B" was recorded a slight ΔT after 2 sec. irradiation (range 2.3 °C - 6.0°C), a moderate ΔT after 4 sec. irradiation (16.4°C) and a consistent ΔT after 8-10 seconds irradiation (range 36.6°C- 46.2°C). In "point C" ΔT values were very similar to those collected in "point B".

The graphic temperature increase-time at 6W (fig 4) showed, in "point A", an immediate rise in temperature and, in "point B" and "point C", a continuous gradual increase.

In general:

- Optical Stereomicroscope

Optical stereomicroscopy examination (32x) did not show any surface alteration or damage after whichever laser irradiation independently from irradiation time and power output (**Fig 5**).

Discussions

The treatment of peri-implantitis consists of the elimination of bacteria without damaging the implant surface and the surrounding hard and soft tissues. Different protocols have been proposed to face periimplantitis, but although none of them is able to gain the complete elimination of bacteria [21-28].

As reported by Esposito et al in 2012 in a Cochrane systematic review [29], there is no reliable evidence suggesting which could be the most effective interventions for treating peri-implantitis and, as this can be a chronic disease, re-treatment may be necessary.

The efficacy of lasers has been demonstrated by several studies, that showed that, at controlled parameters, irradiations are safe for the surrounding tissues [30-32]. Exposure time is a very important parameter to consider during implant irradiation, because increasing of temperature is primarily linked to power output and exposure time especially at the beginning of laser application. In the present study, an InfraRed thermo-camera was used to record real-time temperature variations during the application of a laser beam on implant surface.

The highest ΔT (15 °C) was recorded at point "A" after 30s, meanwhile at point "B" ΔT was 6,2 °C and 5,7°C in point C. At point "A", when laser was used at 6 Watt, the increase of temperature was so fast (in very less of a second) that all the thermal-camera sensors were saturated (maximum detectable ΔT>70°C). At point "B" and "C" (power output of 6 W) a ΔT lower than 20°C was recorded when exposure time was ≤ 5 sec.

In agreement with some studies [8,16] we found that laser exposure time and power output are important parameters determining thermical effects on implant surfaces. In accordance with Kreisler M al [15,19], diode laser tested could be safety use with power output 0.6 W for a long exposure time.

Optical stereomicroscopy (32x) detected no titanium implant surface alterations (such as crater-like surfaces or melting) even when laser diode 980nm was used with high power values (6W) and for long exposure time (120s), according to the literature [14,16]. Romanos et al in 2000 [14], in a SEM study on titanium discs, concluded that the diode laser 980nm in CW does not damage titanium surfaces, which should be of value when uncovering submerged implants and treating peri-implantitis, while Nd:YAG laser caused loss of porosity, coating microfractures, and a relatively smooth surface.

GaAlAs laser 980nm can be used safety with power output value 0.6W for an exposure time of 30s, since highest ΔT recorded (15C°, point "A") was lower than critical threshold (20°C). When output value 6W was used for a maximum of 5 seconds critical threshold was reached in point "C" (20°C) and slightly overcame (22.5°C) in point "B". On account of this laser can be used safety with power output value 6 W for an exposure time of maximum 4 sec in CW and in dry condition of irradiation since highest ΔT recorded was lower (16.4C°; point "B") than critical threshold. However, it is toconsider that, in clinical practice, there are a lot of variables (blood, saliva) that could modify the results and probably highest ΔT recorded may be lower than "in vitro" values. The observation of no titanium implant surface alterations by optical stereomicroscopic analysis (32x) and the well documented antimicrobial activity confirms that diode laser 980nm can be used in the management of peri-implant infections.

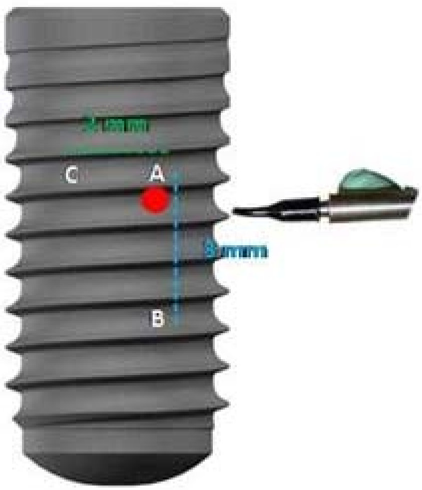

Fig 1: the three point A, B, and C evaluated in the study

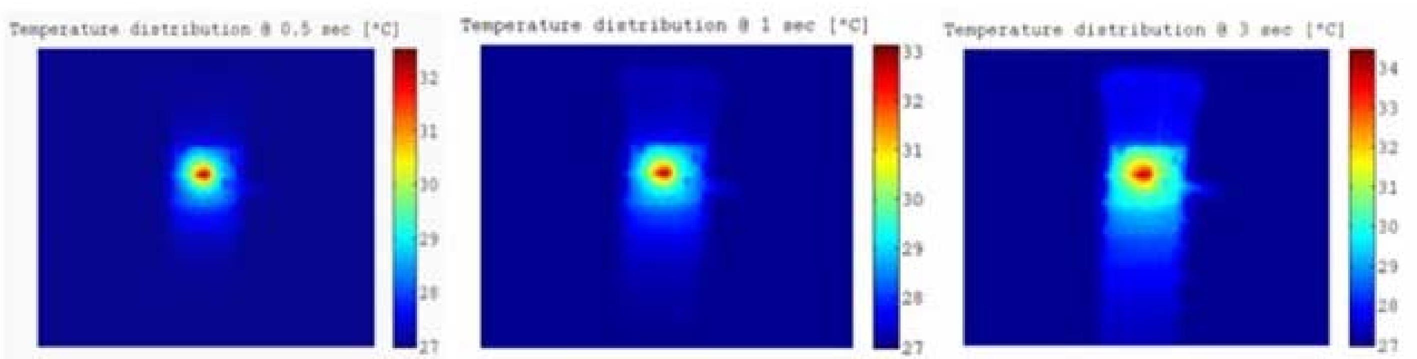

Fig 2: temperature distribution on implant surface exposed to laser GaAlAs 980nm: power 0.6W after 0.5s, 1s, 3s

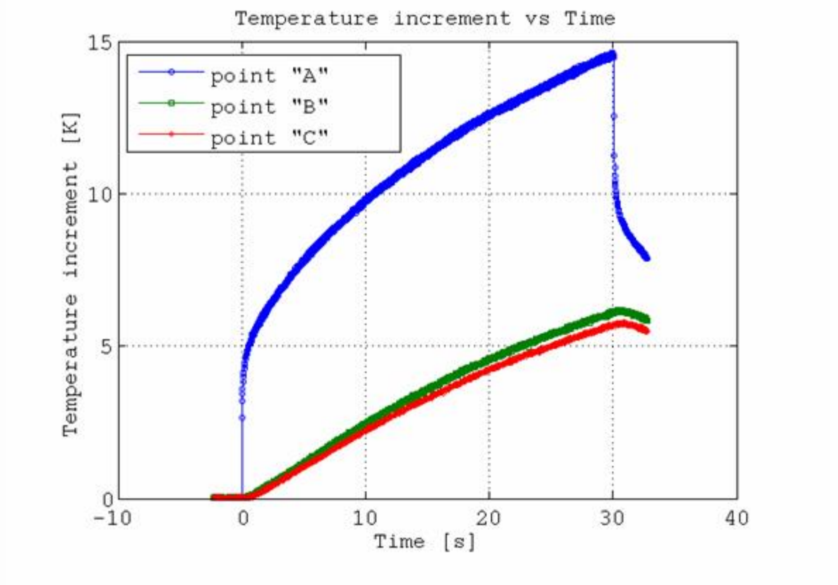

Fig 3: temperature increase on surface treated with Laser GaAlAs 980nm: power output 0.6W, exposure time 30s

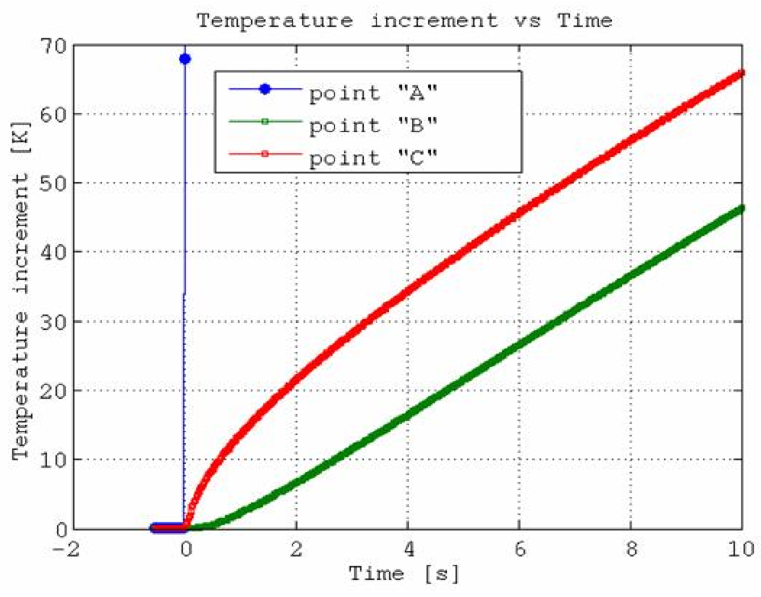

Fig 4 Temperature increase on surface treated with Laser GaAlAs 980nm: power output 6W, exposure time 10s

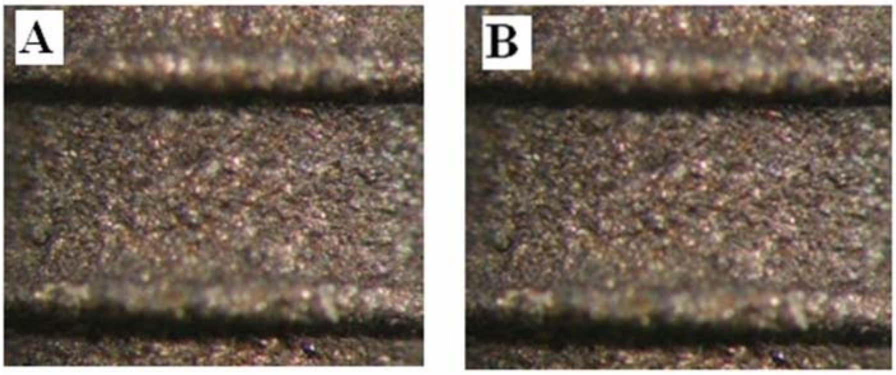

Fig 5: Optical stereomicroscopy examination (32x) of implant body surface at the beginning of the experiment (A) and after treatment (B) with diode laser 980nm (power 6W / 10 sec). No alterations or damages were revealed

TIME	TEMPERATURE INCREASE ΔT		
	POINT “A”	POINT “B”	POINT “C”
1 sec.	5.5 °C	0.1 °C	0.1 °C
3 sec.	7.0 °C	0.6°C	0.5°C
5 sec.	7.8 °C	1.2°C	1.0°C
15 sec.	11.4 °C	3.6 C	3.3 C
30 sec.	15.0 °C	6.2 C	5.7 C

Table 1: temperature increase (ΔT) on implant surface respect to environmental temperature (27 °C). Laser irradiation with power output of 0.6 W at different locations

TIME	TEMPERATURE INCREASE ΔT		
	POINT “A”	POINT “B”	POINT “C”
1 sec.	> 70 °C	2.3 °C	2.2 °C
2 sec.	> 70 °C	6.0°C	5.8°C
4 sec.	> 70 °C	16.4°C	16.1°C
8 sec.	> 70 °C	36.6 °C	36.5° C
10 sec.	> 70 °C	46.2 °C	46.1 °C

Table 2: temperature increase (ΔT) on implant surface respect to environmental temperature (27 °C). Laser irradiation with power output of 6 W at different locations for exposure time of 10 sec

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