Temperature Changes Resulting from a GaAlAs Laser in the Decontamination of a Failing Dental Implant

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A periodontal implant can become infected by oral bacteria and the surrounding bone will dissolve, resulting in a failed implant. In contemporary practices, the only therapy is to scrape the infected site with a scalar- a very primitive method of debridement. The purpose of this experiment was to determine if the technique of lethal photosensitization is practical for the treatment of a failing dental implant. Previous studies have demonstrated that 47ï¿½C is the threshold temperature for healthy bone cells. Exceeding this temperature results in cell death and the eventual loss of implant integration. It was predicted that that the 47ï¿½C temperature threshold would be exceeded after prolonged exposure to laser energy. This was so because charring and odors were observed as a result of the lasing of a dental implant in a previous study. In this experiment, a Ti-plasma sprayed dental implant was inserted into a bone block cut from a pig femur. An artificial periimplant bone defect was cut into the bone to simulate a failing dental implant and to provide access for the laser treatment. A 940nm GaAlAs laser was used at wattages of .2, .5, 1.0, 1.5 and 2.0 in both continuous and pulsed mode. The bone block was placed in a water bath maintained at 37ï¿½C the human body's thermal conductivity. A J/K-type thermocouple was inserted in the bone adjacent to the implant and connected to a digital meter to register temperature changes at the surface of the implant every 15 seconds for 180 seconds. The results indicate that when the laser was used in continuous mode, the threshold temperature of 47ï¿½C was exceeded at wattages of 1.0, 1.5 and 2.0 watts. In pulsed mode, only the wattage to exceed the critical temperature was 2.0 watts. This was true regardless of the time of laser exposure. The hypothesis was rejected. Although some of the wattages did exceed the threshold temperature, the use of lower wattages and the use of a pulsed beam reduced the maximum temperature to below 47ï¿½C. After comparing the data to the data of similar experiments performed with different types of lasers, it can be concluded that a pulsed setting will allow for optimum wattage output and maximum bacterial death without exceeding the critical temperature needed to maintain implant integration.

Introduction and Related Research

Lasers, an acronym for Light Amplification by the Stimulated Emission of Radiation, have an extensive history that is still being developed today. The first conception of the laser was by Newton in 1704, when he stated that laser light was not like ordinary light. He said that it was an organized beam of particles. The earliest operating laser was created by Theodore Maiman on May 16, 1960 at the Hughes Research Laboratory in California. The next revolution was semi-conductor lasers, first designed by Robert Hall and his associates at the General Electric laboratories in Schenectady, New York in 1962. "Diode lasers now involve many different materials and forms, can be quite small and inexpensive, and are by far the most common type of laser. They are used, for example, in supermarket bar-code readers, in optical-fiber communications, and in laser pointers." [1].

Oral bacteria that are responsible for dental caries and periodontal disease (including the breakdown of bone around dental implants) may be photo-sensitive; they may die when exposed to diode laser light. Others have studied the effect of a similar laser on the regeneration of bone around failing dental implants. They used an 830 nm laser and tested in live dogs. The results were clear; the bone regeneration rate was 41% higher with laser treatment. "The lethal photosensitization associated with GBR allowed for better re-osseointegration at the area adjacent to the peri-implant defect regardless of the implant surface." [2]

Of greatest interest, is the experiment completed last year by Adam Oppenheimer. Oral bacteria were cultured and applied to a dental implant's surface. The implant was then exposed to a 940nm laser in continuous mode of varying wattages and times. This experiment confirmed that the bacteria could almost be eliminated from the implant surface by the use of a diode laser.

In a classic study performed by Ericsson et.al, [3] it was determined that at 47ï¿½C, the bone would not integrate an implant properly or not at all. During a dental implant procedure, great care is taken to ensure that the bone temperature during drilling never exceeds 47ï¿½C. This must extend to the treatment of peri-implantitis with a dental laser. If the treatment of a contaminated implant surface with a dental laser causes the surrounding bone temperature to rise above 47ï¿½C, then that implant will likely be lost regardless of the treatment's decontamination success because the bone will lose its integration to the implant.

The most common reason for implant failure is periimplantitis. Periimplant disease refers to the pathological inflammation that occurs in the tissue surrounding an infected implant. These bacterial diseases are associated with symptoms such as increased pocket formation, bleeding, and mobility [4]. Titanium plasma sprayed implants increase implant-bone contact and anchorage force in the alveolar bone [5]. However, this also facilitates a surface to inhibit bacterial growth [6]. Many methods have been suggested to treat periimplantitis implants [7-10]. Mechanical debridement, antiseptics, antibiotics, surgical procedures, and explantation have been suggested therapy based

on the progress of the clinical case [11]. Plastic scalars have been proven as a safe method of debridement [12], while metal scalars and ultrasonic scalars have been shown to induce surface alteration in implants [13]. Bactericidal chemicals such as chlorhexidine gluconate as well as local and systemic antibiotics are useful adjuncts in the treatment of periimplantitis. The use of laser therapy has been discussed [14, 15] and now seems to be very promising [16-17]. Some lasers may not be suitable for the decontamination of implant surfaces because they cause considerable surface damage to the implant and the surrounding tissues [18]. In addition to surface damage caused by the radiation, heat is a major risk to the implant/bone integration. Temperatures in excess of 47-50ï¿½C cause significant damage to bone and tissue [19]. In several studies on the bactericidal effect of high-powered pulse laser radiation have shown to be a very effective method of debridement due to the fact that the laser energy is mostly absorbed by water. In bacteria, this causes cellulysis without damaging the surface of the implant. Many publications have shown the value of lethal photosensitization in decreasing the amount of viable pathogens without damaging the periimplant tissues[20, 21].

Purpose

The purpose of this experiment is to determine if the technique of lethal photosensitization is practical for the treatment of a failing dental implant by measuring the change in temperature to observe if the temperature change as a result of radiation will cause the implant's surface to exceed the 47ï¿½C critical threshold.

Hypothesis

It is predicted that over the 180 seconds of exposure, the 47ï¿½C critical temperature threshold will be exceeded after exposure to laser energy. This is so because significant charring was noted on implant surfaces after prolonged exposure to laser energy in previous studies.

Procedures

1. A block of porcine femur of similar thickness to a human mandible is obtained.
2. Conventionally prepare and place a dental implant into a pig femur and create a bone defect to simulate the exposed implant surface of a diseased (peri-implantitis) implant.
3. Small holes in the bone adjacent to the dental implant are prepared, one immediately adjacent to the created osseous defect and another 180ï¿½ opposite the defect. The thermocouple probe is inserted into each site to record the temperature changes.
4. The bone/implant is placed in a water bath maintained at 37ï¿½C to simulate the environment of the human body.
5. The exposed implant surface was exposed to the laser at wattages of 0.2, 0.5, 1.0, 1.5, and 2.0 in both continuous mode and in pulsed mode (20ms on- 20ms off) and the temperature readings were recorded every 15 seconds for 180 seconds for each thermocouple site.

Results

The data revealed that when exposed to radiation in continuous mode, the critical temperature of 47ï¿½C was exceeded at all wattages above 0.5. When the laser was set in pulsed mode (20ms on/20ms off), the temperature did not exceed the critical threshold with the exception of 2.0 watts. By using the pulsed interval setting, a higher wattage was able to be imparted to the implant surface and over a longer period of time without worry of exceeding the critical temperature. The temperature stopped increasing for pulsed intervals of exposure at approximately 165 seconds at both measured sites for 1.5 and 1.0 watts. In addition, the temperature measured at the 2 thermocouple sites about the implant demonstrated the same increases in temperature when exposed to the same laser energy.

Conclusions

The hypothesis was rejected. Although some of the wattages did exceed the threshold, the use of lower wattages and the use of pulse interval exposure prevented temperatures from exceeding the critical threshold of 47ï¿½C. According to these results, the range of safe application of a 940nm GaAlAr laser to a dental implant surface is between 0.2-0.5 watts in continuous mode and 0.2-1.5 watts in pulsed (20ms/20ms) mode.

In addition, it can be concluded that the temperature elevation experienced by the implant and imparted to the adjacent bone will be uniform as both thermocouple sites recorded similar temperature changes under similar circumstances.

Discussion

Using a pulsed interval versus a continuous interval on the same wattage would allow for maximum bacterial mortality while maintaining a low temperature. After comparing the data to the data of similar experiments performed with different laser systems, it is concluded that a pulsed setting will allow for optimum wattage output without exceeding the critical temperature. Although fairly accurate, the J/K-type thermocouple used has an error estimated at 1ï¿½C. The fiber-optic tip of the laser hand piece may have also had a newer or older tip, slightly changing the strength and accuracy of the beam. A porcine femur was used as it would have similar density, heat absorbing properties, and thickness to that of a human mandible. It also contained soft marrow on the inside just as a human jaw would. The laser was initiated before and after every trial. Future studies could examine the effect of a water mist or stream applied to the site as it is being lased in an effort to use a stronger wattage while minimizing temperature transferred to the implant and the surrounding bone. Although this new technique may improve the amount of bacteria killed in relation to the heating of the implant, the GaAlAs laser used in the this study cannot allow any form of water to obstruct the beam or it will not function properly. In addition, other intervals of pulsed exposure may be varied which may allow for higher wattage to be used, again increasing the bactericidal effects of the laser. The burning look and odor as a

result of the lasing observed in previous studies may have been absent in this study due to the water bath which the implant was submerged or due to the fact that the heat could distribute itself through the bone and moderate the temperature of the implant, and thereby allow enough heat to be released that charring would not occur. This laser has not been tested for this purpose before. It did not harm the surface of the implant as other types of lasers have been shown to do and it also was able to impart a significant amount of energy without exceeding the 47ï¿½C threshold. These results could lead to the introduction of this type of therapy into dental practices for the treatment of failing dental implants. This laser treatment could lead to more effective bacterial mortality with the least disturbance to the implant itself and its environment.

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