Thermodynamic Effects of 3 Different Diode Lasers on an Implant-Bone Interface: An Ex-Vivo Study With Review of the Literature

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The aim of this study is to assess the increase of temperature following laser irradiation with 810 nm, 980 nm, and 1064 nm diode laser wavelengths, of an implant under conditions that more closely replicate those of the human body. A 4 × 14 mm machined surface implant was placed in a porcine rib to replicate the conductivity of heat given by the bone. A peri-implant vertical defect was made that was 2 mm wide and 2 mm deep to simulate bone resorption. Two thermocouples were positioned crestally and apically on the implant surface. The tip of the laser was kept 3 mm away from the surface and continuously moved in an up-and-down and side-to-side fashion, inside the defect for 60 seconds. Initial temperatures and the time needed to reach an increase of 10°C were recorded. The experiment was repeated at room temperature and in a 37°C water bath with the following settings: 0.6 W, 0.8 W, 1 W continuous and repeated in pulsed. A critical increase of temperature of more than 10°C is reached with all lasers at 0.8 W and 1 W in continuous mode at room temperature. Only the 1064 nm diode laser reached the critical increase at 0.8 W in pulsed mode. No critical increase of temperature was registered with other settings and when the bone block was placed in a 37°C water bath. The results of this study suggest that use of these diode lasers does not cause a harmful increase in temperature when used under conditions similar to those of the human body.

Key Words: lasers, dental implants, peri-implantitis, thermodynamics

INTRODUCTION

Fifty years of documented implant practice and research in dentistry have contributed to a wide spread of implantology with an enormous number of implants placed by dental practitioners worldwide.[1,2] The spread of implant dentistry has brought with it an obvious parallel spread of all the complications related to it, within which peri-implantitis is raising most of the debates in the scientific community.[3] Nothing is clearly defined and commonly accepted, regarding its etiologic and diagnostic features and its management.[4]

To date there are different proposed treatments for peri-implantitis, from the resective to the regenerative ones, involving or not involving use of different grafts, membranes, and implantoplasty (mechanical smoothening of the implant surface).[5–7] What is common among all proposed treatments for peri-implantitis is the necessity of an optimal decontamination of the affected surface that can be done using chemical, antimicrobial, and antibiotic agents, or laser. This latter has shown promising results in in vitro, animal, and human studies, used as is or with the adjunct of photosensitizer dyes (photodynamic therapy).[8–13] Within all lasers available on the market, the diode laser seems to be the most versatile for its multiple applications, ease of use, relative safety, and low cost.[14]

However, there is still not common agreement regarding safety of the laser device when used on implants. Recent in vitro studies have shown that use of certain types of laser, especially diode, can cause overheating of the implant surface, thus possibly affecting vitality of the surrounding bone when used in a clinical scenario.[15,16]

The aim of this study is to assess the variation of temperature on the implant surface during irradiation with 3 diode lasers, the 810 nm, 980 nm, and the 1064 nm, used with different settings, under conditions that closely replicate those of the human body.

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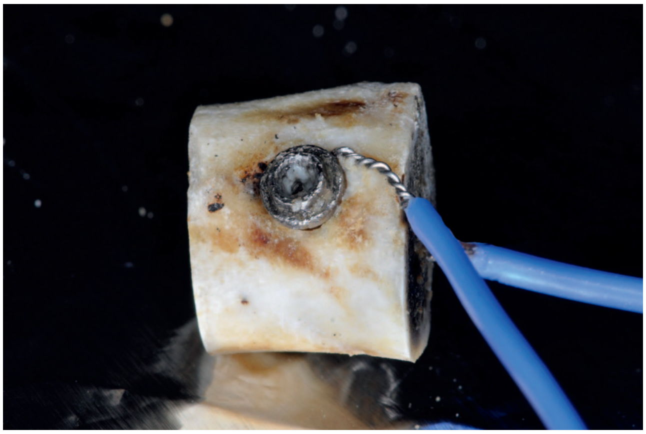

FIGURE 1. Bone block with implant inserted and the crestal and apical thermocouple positioned.

MATERIAL AND METHODS

A 4 mm × 11 mm (Mk III, Nobelpharma, Yorba Linda, Calif) machined implant was placed into a swine rib that was cut into a block of about 1 cm × 1 cm. An angular bony defect was created prior to implant placement with the dimensions of 2 mm width and 2 mm depth, adjacent to the implant site using a pilot drill to replicate the anatomical situation of the crestal bone resorption caused by peri-implantitis.

A lateral perforation, at the level of the implant apex, was drilled on the side of the bone block for access of the thermocouple. Two calibrated type K thermocouples (Model 710, B&K Precision Corp, Yorba Linda, Calif) were then positioned crestally (at the contact interface between the bone and the implant shoulder, at the opposite side of the irradiation), and apically, on the implant surface (Figure 1).

Three different diode lasers were used in this study: the 810 nm (2.4 G Odyssey, Ivoclar Vivadent, Amherst, NY), the 980 nm (SIROLaser, Sirona Dental Inc, Charlotte, NC), and an experimental 1064 nm (Navigator, Ivoclar Vivadent, Amherst, NY).

The study protocol was designed to closely replicate what was used in the studies from Geminiani[15,17] and from Leja[16] in which 1 implant was irradiated once per each different setting.

The implant was irradiated for 60 seconds, keeping the fiber optic tip of the laser 3 mm away from the implant surface. We used an up- and-down and side-to-side motion to apply the laser to the surface exposed in the angular defect.

The irradiation was repeated, setting the power at 0.6 W, 0.8 W, and 1 W, first in continuous and then in pulsed mode. The implant was allowed to cool down to the initial temperature in-between 2 consecutive cycles of irradiation. The experiment was done at room temperature (22°C ± 2°C) and then repeated in a 37°C water bath with the most coronal part of the sample slightly emerging from the water to replicate as close as possible the actual clinical environment for a total of 36 different irradiation modalities.

Initial and final temperatures were recorded as well as the time needed to reach a critical threshold of 10°C increase. The change in temperature was monitored until it cooled down to the initial values. Temperatures were registered at every 10-second time point to allow for a graphical representation of the heat generated over the time of irradiation. Output values were expressed as differential temperature ($\Delta T = \text{final temperature} - \text{initial temperature}$) and expressed in °C.

TABLE 1

Maximum temperature increase after 60 seconds of irradiation with the different lasers and settings*†

	ΔT Coronal	ΔT Apical
810 nm room temperature		
0.6 W continuous	8.3	8
0.6 W pulsed	5.1	4.9
0.8 W continuous	*9.3*	**12.1**
0.8 W pulsed	4.4	2.9
1 W continuous	**10.8**	7.9
1 W pulsed	7.7	5.7
980 nm room temperature		
0.6 W continuous	*9.6*	*8.7*
0.6 W pulsed	4.7	5.2
0.8 W continuous	**11.4**	**11.7**
0.8 W pulsed	3.5	7
1 W continuous	**19.4**	**13.7**
1 W pulsed	*9.8*	*8.9*
1064 nm room temperature		
0.6 W continuous	7.5	2.2
0.6 W pulsed	7.7	1.2
0.8 W continuous	**21.3**	2.3
0.8 W pulsed	**10.9**	1.9
1 W continuous	**23.6**	5.2
1 W pulsed	7.7	5.7
810 nm water bath		
0.6 W continuous	1.1	0.8
0.6 W pulsed	1.7	0.9
0.8 W continuous	2.5	1.1
0.8 W pulsed	1.9	1.1
1 W continuous	1.9	1.5
1 W pulsed	1.6	0.8
980 nm water bath		
0.6 W continuous	1.9	0.9
0.6 W pulsed	1.3	0.8
0.8 W continuous	0.9	0.2
0.8 W pulsed	1.8	0.9
1 W continuous	5.3	4.4
1 W pulsed	2.4	1.2
1064 nm water bath		
0.6 W continuous	3.7	0.3
0.6 W pulsed	2.1	0.3
0.8 W continuous	5.8	1.1
0.8 W pulsed	3.5	0.6
1 W continuous	4.3	1.6
1 W pulsed	3.2	1.1

*Cells in bold reports values that passed the critical temperature (10°C).

†Cells in italics are less than 1.5°C under the critical temperature.

RESULTS

Results of the heating test are summarized in the tables (Tables 1 and 2).

Table 1 shows the maximum temperature reached by the thermocouple under each condition. The ΔT values over the 10°C threshold are in bold; values that are in italics are those that are less than 1.5°C below the threshold.

Analyzing the results, it seems that a critical increase of temperature of more than 10°C is reached at room temperature

Table 2

Time to reach the peak (expressed in seconds)

	Crestal	Apical
810 nm room temperature		
0.6 W continuous	NR	NR
0.6 W pulsed	NR	NR
0.8 W continuous	NR	42.3
0.8 W pulsed	NR	NR
1 W continuous	51.91	NR
1 W pulsed	NR	NR
980 nm room temperature		
0.6 W continuous	NR	NR
0.6 W pulsed	NR	NR
0.8 W continuous	42.46	47.99
0.8 W pulsed	NR	NR
1 W continuous	18.75	32.75
1 W pulsed	NR	NR
1064 nm room temperature		
0.6 W continuous	NR	NR
0.6 W pulsed	NR	NR
0.8 W continuous	5.99	NR
0.8 W pulsed	31.81	NR
1 W continuous	7.43	NR
1 W pulsed	NR	NR

only with the 810 nm laser at 0.8 W and 1 W in continuous mode, with the 980 nm laser at 0.8 W and 1W in continuous mode, and with the 1064 nm laser at 0.8 W in both continuous and pulsed mode and 1W only in continuous mode. The 980 nm laser reached an increase of 9.8°C at 1 W in pulsed mode and an increase of 9.6°C at 0.6 W in continuous mode both on the cervical area. These values are very close to the critical threshold. The critical temperature was never reached when the lasers were used in pulsed mode except with the 1064 nm laser when used at 0.8 W.

When the bone block was placed in a 37°C water bath, a critical increase of temperature was never registered with any setting.

The highest increase of temperature registered was 23.6°C, registered at the cervical point when the 1064 nm laser was used at 1 W in continuous mode at room temperature.

The hottest peaks of temperature always were registered, as expected, at the cervical point, which was the closest to the laser application, whereas, at the apical thermocouple, the values were in a safety range most times.

In summary, the ΔT values ranged between 4.4°C and 10.8°C for the crestal thermocouple and 2.9°C and 12.1°C for the apical thermocouple with the 810 nm diode laser at room temperature, between 1.1°C and 2.5°C for the crestal thermocouple and 0.8°C and 1.5°C for the apical thermocouple in the 37°C water bath.

When the 980 nm diode laser was used, the ΔT values ranged between 3.5°C and 19.4°C for the crestal thermocouple

Table 3

Literature review*

Author	Laser	Model	Power	Continuous/Pulsed
Matys et al[18]	Diode 980 nm Er:YAG	6 implants (different ∅ and Ti grade) placed in pig ribs	0.5, 1, 2, 3, 4 W	Continuous Pulsed
Kushima et al[20]	Diode 808 nm	Ti (SLA and machined) and zirconia disks	1 W	Pulsed
Monzavi et al[19]	Er:YAG	3 implants in sheep mandible blocks	100 mJ	Pulsed with air or water/air or nothing
Yamamoto & Tanabe[21]	Er:YAG CO_2	5 implants in resin blocks	50, 150 mJ not mentioned	Air/water and air not mentioned
Leja et al[16]	Diodes 810–980 nm Er:YAG CO_2	1 implant in bovine rib	1, 2 W 100, 250 mJ 2, 4 W	Continuous and pulsed Pulsed with air or with water/air Continuous and pulsed
Lambrecht et al[22]	CO_2	2 (different ∅) implants placed in Plexiglas cube	4, 5, 6, 7, 8, 9, 10 W	Continuous with superpulsed continuous pulsed
Geminiani et al[15]	Diodes 810–980 nm	1 implant in vinyl polysiloxane	2 W	Continuous and pulsed
Geminiani et al[17]	Er:YAG CO_2	1 implant in vinyl polysiloxane	100 mJ, 250 mJ 2, 4 W	Pulsed with air or with water/air continuous and pulsed

*nm indicates nanometers; mm, millimeters; W, watts; mJ, milliJoule; ∅, diameter; Ti, titanium; SLA, sand blasted and acid etched surface.

and 5.2°C and 13.7°C for the apical thermocouple at room temperature, and between 0.9°C and 5.3°C for the crestal thermocouple and 0.2°C and 4.4°C for the apical thermocouple in the 37°C water bath.

The ΔT values ranged between 7.5°C and 23.6°C for the crestal thermocouple and 1.2°C and 5.7°C for the apical thermocouple with the 1064 nm diode laser used at room temperature, and between 2.1°C and 5.8°C for the crestal thermocouple and 0.6°C and 1.6°C for the apical thermocouple in the 37°C water bath with the same laser.

The crestal thermocouple reached the critical threshold in 51.91 seconds when the 810 nm diode laser was used at 1 W continuous at room temperature, and the apical one reached the threshold in 42.3 seconds with same laser used at 0.8 W continuous under the same conditions.

When the 980 nm laser was used at room temperature, the crestal thermocouple reached the critical temperature in 42.46 seconds when used at 0.8 W continuous and in 18.75 seconds when used at 1 W continuous, whereas the apical thermocouples reached the threshold, respectively, in 47.99 and 32.75 seconds.

The crestal thermocouple passed the critical temperature very rapidly when the 1064 nm diode laser was used at 0.8 W and 1 W in continuous, reaching the threshold in 5.99 and 7.43 seconds, respectively. When the 1064 nm diode laser was used at 0.8 W pulsed, an increase of 10°C was obtained after 31.81 seconds of irradiation.

Discussion

In this study we tested the heating potential of 3 diode lasers, one of which is an experimental prototype not on the market used at different power and wave settings on an implant/bone interface.

Generally, the maximum temperature increases were recorded at the crestal thermocouple with the power set at 0.8 W and 1 W and in continuous wave. The time to critical threshold, when reached, was faster when the laser was used in continuous wave. The 1064 nm diode laser was the fastest with the highest temperatures reached, whereas the 810 nm, when a critical 10°C increase was achieved, was the slowest.

Carrying the experiment using the model here described was essential to investigate the heat transfer and dispersion on an implant when it is surrounded by osseous tissue. This model, to our knowledge, was used in only 3 other studies investigating laser heat transfer: Matys et al[18] used pig ribs, Leja et al[16] used a bovine rib, and Monzavi et al[19] used a sheep mandible. All other studies used polysiloxane, resin, Plexiglas, or titanium disks.[15,17,20–22]

An important improvement that we added to our study

Table 3

Extended

Exposure Time (seconds)	Protocol of Irradiation	Areas Measured	Media	Results
10, 20, 30	Noncontact at 1 mm distance	Single, nonspecified height of implant	Wet in 37°C water but no water bath used (irradiation out of water)	No critical increases
20	In contact	Opposite side of the disk from the irradiated area	Room temperature	Always a critical increase
60	Crestal noncontact at 4 mm distance	Apical	37°C water bath	Critical increase never reached
15	Nonspecified	Whole implant (thermograph)	Room temperature	Critical increase reached only with Er:YAG with no cooling and with CO_2
60	Crestal noncontact at 3 mm distance (moving)	Crestal and apical	Room temperature	Critical increase always reached (except for diodes when used 1 W pulsed)
10, 20, 30, 60	Crestal noncontact at 1 mm distance (steady)	4 mm and 8 mm height at each side of the cube (8 points total)	Room temperature	Critical increase under certain conditions. Proportional to power. Highest values with continuous + super-pulse, lowest with pulsed.
60	Crestal noncontact at 3 mm distance (steady)	Crestal and apical	Room temperature	Critical increase was always reached
60	Crestal noncontact at 3 mm distance (steady)	Crestal and apical	Room temperature	Critical with CO_2 2 W continuous and 4 W pulsed, and with Er:YAG when irrigation was not used and slightly when used ay 250 mJ on coronal

model is the 37°C water bath to replicate the human body temperature. Only in another study in the literature was the irradiation performed while the sample was kept in this device; however, in that study, another type of laser, the Er:YAG, was used.[19] In a different study by Matys et al,[18] the sample was kept in water at 37°C but irradiated out of the water. From our experience we have observed that, when out of the water bath, the drop of temperature starts immediately, thus causing an inconstant environmental temperature during the time of irradiation.

The 10°C critical threshold of temperature increase was decided, according to Eriksson et al,[23–25] based on studies that showed that an increase of more than 10°C over the body temperature could be harmful for the bone vitality.

The power settings that we chose for our experiment were 0.6 W, 0.8 W, and 1 W. Other studies use even higher wattages; however, it is not recommended to use the diode laser at power settings higher than 1 W. Pilot studies conducted in our laboratory showed that these higher wattages can cause harmful histologic changes in the tissues.[26,27]

The fiber optic tip was held 3 mm away from the irradiated surfaces and moved continuously over the target area. The distance was decided according to our clinical laser decontamination protocol, and the continuous movement was performed to reflect the actual clinical application. The studies present in the literature are very heterogeneous regarding the tip distance, varying from 1 mm to 4 mm and, in some cases, the tip is kept in contact with the surface. Studies performed by our group have shown that the fiber optic tip of a diode laser, kept in contact with an implant surface, will modify the surface characteristics.[28] Continuous movement will help dissipating some of the heat transfer from the laser and, to our knowledge, has been performed only in one other study present in the literature.[16]

The studies available are generally extremely variable in terms of study model, power settings, time of application, use of the pulsed wave, mode of irradiation, and type of laser employed. The results of all these studies are also variable, ranging from different degrees of harmful increase of temperature recorded to no critical increases under any condition (Table 3).

Of the 8 studies we found, 4 applied a diode laser. The study by Matys et al[18] does not report any critical increase of temperature with the 980 nm diode laser applied on the implants placed in pig ribs and wet in 37°C water; however, although the power was set to 4 W, irradiation lasted for no more than 30 seconds.

Kushima et al[20] reported negative results using a 808 nm diode laser set at 1 W; however, irradiation was performed at room temperature and, most importantly, with the laser tip in contact with the surface.

In the study performed by Geminiani et al[15] with a 810 nm and a 980 nm laser used at 2 W power at room temperature for 60 seconds in continuous and in pulsed, the critical threshold was always reached. The same group, in another study using the same diode laser on an implant placed in a bovine rib, also obtained the same negative results when the lasers were set at 2 W, but results were similar to ours when the lasers were set at 1 W.[16] However, no 37°C water bath was used. Using the same protocol as in these latter-mentioned studies, we were able to disprove their conclusions, which implied that the use of diode laser is potentially harmful for the tissues. Future studies, using a wider number of samples, repeating the irradiation for each condition more than once, will further confirm our results. However, the values obtained in the pilot studies that we conducted before the experiment are consistent with those resulting from the measurements here reported.

The model used in our study, which involves an implant placed in a pig rib with an apical and a cervical thermocouple, a 37°C water bath and a 60-second noncontact irradiation in movement, is unique within those used for this kind of investigation. The model that most closely resembles ours is the one used by Monzavi et al,[19] with the implant placed in a sheep mandible, a 37°C water bath, a 60-second noncontact irradiation, but only an apical thermocouple.

In conclusion, use of diode lasers with any wavelength is safe for the use on dental implant surfaces, provided that they are used with certain cautionary measures, namely a 3 mm distance from the surface, a continuous movement of the fiber optic tip over the surface, a power of maximum 1 W and, preferably, a pulsed wave mode.

References

1. Adell R, Lekholm U, Rockler B, Branemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg*. 1981;10:387–416.
2. Branemark PI, Adell R, Breine U, Hansson BO, Lindstrom J, Ohlsson A. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg*. 1969;3:81–100.
3. Klinge B, Meyle J, Working G. Peri-implant tissue destruction. The Third EAO Consensus Conference 2012. *Clin Oral Implants Res*. 2012;23 Suppl 6:108–110.
4. Valente NA, Andreana S. Peri-implant disease: what we know and what we need to know. *J Periodontal Implant Sci*. 2016;46:136–151.
5. Mombelli A, Feloutzis A, Bragger U, Lang NP. Treatment of peri-implantitis by local delivery of tetracycline. Clinical, microbiological and radiological results. *Clin Oral Implants Res*. 2001;12:287–294.
6. Romeo E, Lops D, Chiapasco M, Ghisolfi M, Vogel G. Therapy of peri-implantitis with resective surgery. A 3-year clinical trial on rough screw-shaped oral implants. Part II: radiographic outcome. *Clin Oral Implants Res*. 2007;18:179–187.
7. Roos-Jansaker 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. 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.
9. Tosun E, Tasar F, Strauss R, Kivanc 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.
10. Shibli JA, Martins MC, Ribeiro FS, Garcia VG, Nociti FH, Jr., Marcantonio E, Jr. Lethal photosensitization and guided bone regeneration in treatment of peri-implantitis: an experimental study in dogs. *Clin Oral Implants Res*. 2006;17:273–281.
11. 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.
12. Schar D, Ramseier CA, Eick S, Arweiler NB, Sculean A, Salvi GE. Anti-infective therapy of peri-implantitis with adjunctive local drug delivery or photodynamic therapy: six-month outcomes of a prospective randomized clinical trial. *Clin Oral Implants Res*. 2013;24:104–110.
13. Papadopoulos CA, Vouros I, Menexes G, Konstantinidis A. The

utilization of a diode laser in the surgical treatment of peri-implantitis. A randomized clinical trial. *Clin Oral Invest*. 2015;19:1851–1860.

14. Lomke MA. Clinical applications of dental lasers. *Gen Dent*. 2009;57:47–59.

15. Geminiani A, Caton JG, Romanos GE. Temperature change during non-contact diode laser irradiation of implant surfaces. *Lasers Med Sci*. 2012;27:339–342.

16. Leja C, Geminiani A, Caton J, Romanos GE. Thermodynamic effects of laser irradiation of implants placed in bone: an in vitro study. *Lasers Med Sci*. 2013;28:1435–1440.

17. Geminiani A, Caton JG, Romanos GE. Temperature increase during CO(2) and Er:YAG irradiation on implant surfaces. *Implant Dent*. 2011;20:379–382.

18. Matys J, Botzenhart U, Gedrange T, Dominiak M. Thermodynamic effects after diode and Er:YAG laser irradiation of grade IV and V titanium implants placed in bone - an ex vivo study. Preliminary report. *Biomed Tech (Berl)*. 2016;61:499–507.

19. Monzavi A, Shahabi S, Fekrazad R, Behruzi R, Chiniforush N. Implant surface temperature changes during Er:YAG laser irradiation with different cooling systems. *J Dent (Tehran)*. 2014;11:210–215.

20. Kushima SS, Nagasawa M, Shibli JA, Brugnera A, Jr., Rodrigues JA, Cassoni A. Evaluation of temperature and roughness alteration of diode laser irradiation of zirconia and titanium for peri-implantitis treatment. *Photomed Laser Surg*. 2016;34:194–199.

21. Yamamoto A, Tanabe T. Treatment of peri-implantitis around TiUnite-surface implants using Er:YAG laser microexplosions. *Int J Periodontics Restorative Dent*. 2013;33:21–30.

22. Lambrecht JT, Nyffeler T, Linder M. Thermal conduction of titanium implants under CO2 laser irradiation in vitro. *Ann Maxillofac Surg*. 2012;2:12–16.

23. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. *J Prosthet Dent*. 1983;50:101–107.

24. Eriksson RA, Albrektsson T. The effect of heat on bone regeneration: an experimental study in the rabbit using the bone-growth chamber. *J Oral Maxillofac Surg*. 1984;42:705–711.

25. Eriksson RA, Albrektsson T, Magnusson B. Assessment of bone viability after heat trauma. A histological, histochemical and vital microscopic study in the rabbit. *Scand J Plast Reconstr Surg*. 1984;18:261–268.

26. Sagor J, Lavere E, Dobmeier AD, Andreana S. Diode laser: effects of heat transfer to implant and bone. *J Dent Res*. 2013;92(A):#2562.

27. Beneduce C, Angelova D, Angelov N, Andreana S. Thermal propagation of 810nm diode laser in porcine dermal tissues. *J Dent Res*. 2008;87(A):#950.

28. Andreana S, Nihlawi O, Beneduce C. Temperature propagation on implant cover-screw after diode laser irradiation. *J Dent Res*. 2010;89(B):#2536.