Original Article

Comparison of Soft Tissue Thermal Changes Induced by Three Types of Diode Lasers at 810, 940, and 980nm Wavelengths

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ABSTRACT

Background and Aim: Diode laser is a great choice for soft tissue surgery. The diode laser is partially absorbed by hard dental tissues, making it safe for soft tissue surgery. This study aimed to compare the tissue thermal changes induced by three types of diode lasers at 810, 940, and 980nm wavelengths.

Materials and Methods: In this in-vitro experimental study, using a diode laser device (continuous mode with a 400μm fiber tip) at each of the 810, 940, and 980nm wavelengths and powers of 1, 2, and 3W in contact mode, incisions with the length of 2cm were made on pieces of meat over a period of 10 seconds. The primary and secondary temperatures were measured using a thermocouple. Data were analyzed using two-way analysis of variance (ANOVA).

Result: Tissue temperature changes induced by diode laser at 810nm/3W were significantly greater than that of 2W power. These changes were higher with 2W of power compared to 1W ($P<0.05$). Temperature changes induced by diode laser at 940nm/2 and 3W were significantly greater than that of 1W power ($P<0.05$). Temperature changes induced by diode laser at 980nm/3W were significantly greater than that of 2W power. Tissue temperature changes were higher with 2W of power compared to 1W ($P<0.05$).

Conclusion: Diode laser (continuous mode with a 400μm fiber tip) at 3W of power and 980nm wavelength caused the highest rate of thermal changes. The 810nm diode laser with the power of 1W caused the slightest heat changes in the soft tissue.

Keywords: Diode Laser, Temperature, Soft Tissue Injuries

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Introduction:

The surgical blade has been traditionally used in soft tissue surgery for many years. The surgical blade is the first choice in soft tissue surgery due to its accuracy, speed, ease of use, reasonable cost, and minimal damage to the tissues surrounding the surgical site. However, it cannot provide a bleeding-free environment necessary for surgeries of highly vascularized tissues.[1,2]

In contrast, lasers are a new method introduced for oral soft tissue surgery. The main difference between surgical blades and laser is the ability to create homeostasis by the laser.[2,3] Other benefits of laser include high cutting power, disinfection of the surgical environment, better vision, minimal bleeding, reduced edema, infection, postoperative pain, and scarring, as well as faster healing and increased patient acceptance. [1-4]

But this method also has limitations, such as the high cost of equipment, the training of specialist personnel for the clinical applications of different lasers, the need for more than one laser (with different wavelengths) in diverse processes, and thermal damage.[5] Lasers used in soft tissue surgery include erbium-doped yttrium aluminum garnet (Er:YAG), carbon dioxide (CO2), neodymium-doped yttrium aluminum garnet (Nd:YAG), diode, and erbium, chromium-doped yttrium-scandium-gallium-garnet (Er,Cr:YSGG) lasers. [6,7] The diode laser is a great choice for soft tissue surgery. The diode laser is partially absorbed by hard dental tissues, thereby making it safe for soft tissue surgery; it is now widely used in surgical excision of oral pathologic lesions.[5] The biggest advantage of a diode laser is that it is a portable device of small size and low weight.[5,8] The diode laser causes horizontal and vertical thermal damage around the incision site, which results in carbonization, necrosis, and irreversible tissue changes, delaying the wound healing, reducing the tensile strength of the tissue, causing pulp and periodontium tissue injury, causing delay in graft repair, and preventing the correct histopathological diagnosis of the specimens.[1,4,6]

Various studies have compared the tissue thermal changes caused by different lasers, but none of the previous studies has investigated the effect of different wavelengths of diode laser (810, 940, and 980nm) on soft tissue thermal changes. Considering the information gap mentioned above, in this study, it is intended to compare the soft tissue thermal changes induced by three types of diode lasers at 810, 940, and 980nm wavelengths in the Faculty of Dentistry of Islamic Azad University of Medical Sciences, Tehran, Iran.

Materials and Methods:

In this in-vitro experimental study, 2 kg of lean beef was prepared 24 hours before the study. Then, the meat was divided into 4×4×2 cm3 pieces and was kept in the refrigerator at 4°C. One hour before laser irradiation, the meat was removed from the refrigerator to make the temperature similar to the environment. To uniformize the temperature of the meat, the primary temperature of the meat was measured using a thermocouple (D55 Hanyoung Nux, South Korea). The purchased thermocouples were placed one millimeter (mm) from the laser irradiation site at a depth of five mm and perpendicularly at the center of the incisions (Figure 1). [7]

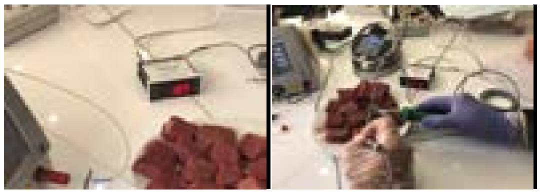

Figure 1. Meat preparation and thermocouple placement to measure the initial temperature

To uniformize the incisions, templates prepared with the dimensions of 2×2 cm2 were used. Then, using a diode laser device (continuous mode with a 400μm fiber tip) at each of the 810, 940, and 980nm wavelengths and powers of 1, 2, and 3W in contact mode, incisions with the length of 2cm were made on the pieces of meat over a period of 10 seconds (cutting speed of 2mm/second; Figure 2) as follows:

The wavelength of 810nm (Pulsar, Iran): the power of 1W (4 times) - 2W (4 times) - 3W (4 times)

The wavelength of 940nm (Biolase Technology, Irvine, CA, USA): the power of 1W (4 times) - 2W (4 times) - 3W (4 times)

The wavelength of 980nm (Wiser Doctor Smile, Lambda SPA, Italy): the power of 1W (4 times) - 2W (4 times) - 3W (4 times).

The secondary temperature shown by the thermocouple after laser irradiation was recorded in datasheets.

Data were analyzed using two-way analysis of variance (ANOVA).

Figure 2. 810, 940, and 980nm lasers used in research

Results:

In this in-vitro experimental study, using a diode laser device (continuous mode with a 400μm fiber tip) at each of the 810, 940, and 980nm wavelengths and the powers of 1,2, and 3W in contact mode, 2cm incisions (1mm/second cutting speed) were made on 36 pieces of meat.

The primary and secondary temperatures indicated by the thermocouples before and after laser irradiation were recorded in datasheets, and the resulting thermal changes were examined. The results are summarized in Tables 1 to 9 and Figure 3.

With the 810nm wavelength and power of 1W, the average tissue temperature increased from 19.7 to 20.45 (0.75°C). This temperature increased from 19.7 to 21.3 (1.6°C) with 2W of power and from 19.7 to 22.45 (2.75°C) with 3W of power. Tissue temperature changes induced by diode laser at 810nm/3W were significantly greater than that of 2W power. Tissue temperature changes were higher with 2W of power compared to 1W (P<0.05; Tables 1 and 4).

Table 1: Tissue temperature changes induced by diode laser at 810nm wavelength and different powers

Wavelength (nm)	Power (W)	Temperature (°C)	Minimum	Maximum	Mean	SD
810	1	before	19.7	19.7	19.7	0.000
		after	20.2	20.7	20.45	0.238
		Temp.diff	0.5	1.00	0.75	0.238
	2	before	19.7	19.7	19.7	0.000
		after	21.0	21.9	21.3	0.424
		Temp.diff	1.3	2.20	1.6	0.424
	3	before	19.7	19.7	19.7	0.000
		after	22.2	22.7	22.45	0.216
		Temp.diff	2.5	3.00	2.75	0.216

SD=Standard Deviation

With the 940nm wavelength and power of 1W, the average tissue temperature increased from 18.4 to 19.2 (0.8°C). This temperature increased from 19.8 to 22.32 (2.52°C) with 2W of power and from 20 to 22.8 (2.8°C) with 3W of power. Tissue temperature changes induced by diode laser at 940nm/2 and 3W were significantly greater than that of 1W power (P<0.05; Tables 2 and 5).

Table 2: Tissue temperature changes induced by diode laser at 940nm wavelength and different powers

Wavelength (nm)	Power (W)	Temperature (°C)	Minimum	Maximum	Mean	SD
940	1	before	18.4	18.4	18.4	0.000
		after	18.9	19.4	19.2	0.216
		Temp.diff	0.50	1.00	0.8	0.216
	2	before	19.8	19.8	19.8	0.000
		after	21.4	23.4	22.32	0.869
		Temp.diff	1.6	3.6	2.525	0.869
	3	before	20	20	20	0.000
		after	22.3	23.3	22.8	0.416
		Temp.diff	2.3	3.3	2.8	0.416

SD=Standard Deviation

With the 980nm wavelength and power of 1W, the average tissue temperature increased from 20.2 to 21.1 (0.9°C). This temperature increased from 18.4 to 20.17 (2.77°C) with 2W of power and from 19.9 to 24.57 (4.67°C) with 3W of power. Tissue temperature changes induced by diode laser at 980nm/3W were significantly greater than that of 2W power. Tissue temperature changes were greater with 2W of power compared to 1W ($P<0.05$; Tables 3 and 6).

Table 3: Tissue temperature changes induced by diode laser at 980nm wavelength and different powers

Wavelength (nm)	Power (W)	Temperature (°C)	Minimum	Maximum	Mean	SD
980	1	before	20.2	20.2	20.2	0.000
		after	20.9	21.3	21.1	0.23
		Temp.diff	0.7	1.1	0.9	0.23
	2	before	18.4	18.4	18.4	0.000
		after	21	21.3	20.17	0.126
		Temp.diff	2.6	2.9	2.77	0.126
	3	before	19.9	19.9	19.9	0.000
		after	24.3	24.8	24.57	0.206
		Temp.diff	4.4	4.9	4.67	0.206

SD=Standard Deviation

Tissue temperature changes induced by diode laser at 810nm/3W were significantly greater than that of 2W power. Tissue temperature changes were higher with 2W of power compared to 1W (Table 4).

Table 4: Tissue temperature changes induced by diode laser at 810nm wavelength and different powers

(I) power		Mean Difference (I-J)	Std. Error	Sig.
1	2	-.85000*	0.21602	0.009
	3	-2.00000*	0.21602	0.000
2	1	.85000*	0.21602	0.009
	3	-1.15000*	0.21602	0.001
3	1	2.00000*	0.21602	0.000
	2	1.15000*	0.21602	0.001

Tissue temperature changes induced by diode laser at 940nm/2 and 3W were significantly greater than that of 1W power (Table 5).

Table 5: Tissue temperature changes induced by diode laser at 940nm wavelength and different powers

(I) power		Mean Difference (I-J)	Std. Error	Sig.
1	2	-1.72500*	0.40329	0.005
	3	-2.00000*	0.40329	0.002
2	1	1.72500*	0.40329	0.005
	3	-0.27500	0.40329	0.780
3	1	2.00000*	0.40329	0.002
	2	0.27500	0.40329	0.780

Tissue temperature changes induced by diode laser at 980nm/3W were significantly greater than that of 2W power. Tissue temperature changes were greater with 2W of power compared to 1W (Table 6).

Table 6: Tissue temperature changes induced by diode laser at 980nm wavelength and different powers

(I) power		Mean Difference (I-J)	Std. Error	Sig.
1	2	-1.87500*	0.13642	0.000
	3	-3.77500*	0.13642	0.000
2	1	1.87500*	0.13642	0.000
	3	-1.90000*	0.13642	0.000
3	1	3.77500*	0.13642	0.000
	2	1.90000*	0.13642	0.000

The tissue thermal changes caused by the diode laser with 1W power at 810, 940, and 980nm wavelengths were not significantly different (Table 7).

Table 7: Tissue temperature changes induced by the diode laser with 1W power at different wavelengths

(I) W.L		Mean Difference (I-J)	Std. Error	Sig.
810	940	-0.05000	0.16159	0.949
	980	-0.15000	0.16159	0.637
940	810	0.05000	0.16159	0.949
	980	-0.10000	0.16159	0.814
980	810	0.15000	0.16159	0.637
	940	0.10000	0.16159	0.814

WL=Wavelength

The tissue thermal changes induced by the diode laser with 2W power at 980nm were significantly greater than those at the 810nm wavelength were. The 940nm wavelength showed no significant difference with 980nm and 810nm wavelengths (Table 8).

Table 8: Tissue temperature changes induced by the diode laser with 2W power at different wavelengths

(I) W.L		Mean Difference (I-J)	Std. Error	Sig.
810	940	-0.92500	0.39826	0.103
	980	-1.17500*	0.39826	0.039
940	810	0.92500	0.39826	0.103
	980	-0.25000	0.39826	0.809
980	810	1.17500*	0.39826	0.039
	940	0.25000	0.39826	0.809

WL=Wavelength

The tissue thermal changes induced by the diode laser with 3W power at 980 nm were significantly greater than those at 810nm and 940nm wavelengths (Table 9).

Table 9: Thermal changes induced by the diode laser with 3W power at different wavelengths

(I) W.L		Mean Difference (I-J)	Std. Error	Sig.
810	940	-0.05000	0.20783	0.969
	980	-1.92500*	0.20783	0.000
940	810	0.05000	0.20783	0.969
	980	-1.87500*	0.20783	0.000
980	810	1.92500*	0.20783	0.000
	940	1.87500*	0.20783	0.000

WL=Wavelength

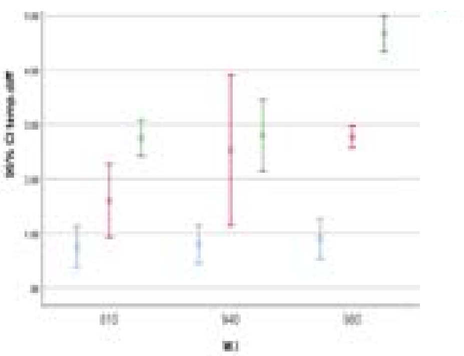

Figure 3. Tissue thermal changes induced by diode laser at 810, 940, and 980nm wavelengths with 1, 2, and 3W of power; WL=Wavelength, CI=Confidence Interval

Discussion:

According to the experiments and the results obtained, the soft tissue thermal changes induced by the diode laser at 810nm wavelength with 3W power were significantly greater than that with the power of 2W. These changes were significantly greater with the power of 2W compared to 1W. With the 940nm wavelength with the powers of 2W and 3W, the changes were significantly greater than that at 1W, and with the 980nm wavelength with the power of 3W, the changes were significantly greater than that at 2W. These changes at 2W were significantly greater than those at 1W were.

In addition, tissue thermal changes induced by the diode laser with 1W power at different wavelengths of 810, 940, and 980nm were not significantly different. With the power of 2W at a 980nm wavelength, these changes were significantly greater than that at the 810nm wavelength. Thermal changes were significantly greater at a 980nm wavelength with the power of 3W than that at 810nm and 940nm wavelengths

In 2012, Beer et al histologically examined the effects of different modes (pulse and micropulse) and powers (2.5, 3.5, and 4.5W) of a 980nm diode laser on soft tissue thermal damage of bovine liver samples.[1] They concluded that the depth and the width of the incision and the extent and the depth of carbonization, necrosis, and irreversible tissue damage were significantly and inversely correlated with the cutting speed ($P<0.0001$) and directly correlated with the power. The extent and the depth of the reversible injury area were inversely correlated with the power ($P<0.01$). The micropulse mode created a smaller area of carbonization and necrosis and a smaller incision width,[1] similar to the results of the present study, in that with the diode laser at a wavelength of 980nm, with increasing the power, tissue thermal changes significantly increased.

In 2010, Cercadillo-Ibarguren et al investigated the thermal and histological effects of diode, Er,Cr:YSGG (830nm with 2, 5, and 10W, pulse mode), and CO_2 lasers on the porcine soft tissue of oral mucosa.[3] They showed that the lowest thermal effects resulted from the Er,Cr:YSGG laser with 1W of power and air-water spray and then with the CO_2 laser with a power of 20W in pulse mode and then with the diode laser with a power of 2W in pulse mode.[3] The results of the cited study are also consistent with our study that, with increasing the power, the temperature of the tissue significantly increases with the 810nm diode laser.In 2004, Fontana et al studied thermal damage caused by a diode laser at a wavelength of 810nm and powers of 600mW, 800mW, 1W, and 1.2W in continuous mode in the mouse oral mucosa (in vitro) and the mandibular alveolar bone (in vivo) using an electronic thermistor.[8] In this case, the temperature raised to 2.8°C; this heat change is considered safe and close to thermal injury.[8] In the mentioned study, with increasing the power and duration of diode laser irradiation, thermal changes in different tissue thicknesses (1, 2, and 3mm) and periodontal pocket increased, which is in line with the findings of the current study.

In a study by Goharkhay et al in 1999, the cutting characteristics and damage of porcine mandibular soft tissue because of the application of an 810nm diode laser (pulse and continuous with 0.5-4.5W of power and 200 and 400µm fiber tips) were histologically evaluated.[9] The results of the said study showed that the depth and the width of the incisions directly and strongly correlated with the power, and no damage was observed in the bone beneath the incisions.[9] In the cited study, the extent of tissue damage correlated with laser parameters (pulse/continuous, time, power, fiber tip, etc.). [9]In all studies on diode lasers, the thermal effects are directly proportional to the increase in power. At high powers, compared to low powers, heat accumulates mainly in the tissue until it spreads to the surrounding structures, which increases the temperature.[4] The reason for the increase in thermal changes with increasing the wavelength is that there is more water and hemoglobin absorption with the 980nm diode laser compared to the 810 and 940nm diode lasers. At higher wavelengths, due to the good absorption of these wavelengths by water and hemoglobin of tissues, a further increase in temperature is observed.[10]

Conclusion:

The results of the present study showed that diode laser (continuous mode with a 400µm fiber tip) with 3W of power at a 980nm wavelength soft tissue. Diode laser with the power of 1W at the wavelength of 810nm caused the slightest heat changes in the soft tissue.

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