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Original Article

Healing of surgical wounds treated with 810nm, 940nm, and 980nm diode lasers in different operation modes

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Abstract

Aim: The aim of the present study was to analyze the comparative effectiveness of the diode lasers having 3 different wave-lengths (810nm, 940nm, 980nm) and also the different application modes on the cellular basis in animal models.Many surgical instruments like scalpel, electrosurgery, and different laser types can be used for surgical incisions. Each of these have their own advantages and disadvantages.

Material and Methods: 10 mm in length and 1 mm in depth dorsal skin incisions were created on 18 male Wistar albino rats via 3 different laser wave-lengths: 810nm (Gigaa, Cheese, China), 940nm(Epic 10, Biolase, USA) and 980nm (SIROlaser Advance, Sirona, Bensheim, Germany). The animals were sacrificed at either post-operative 24 hours, 3 days or 1 week. All incision sites were removed by excisional biopsies and the samples underwent histopathological evaluation.

Results: There were no statistically significant differences in thermal changes, inflammation, and fibrosis in all wave-length groups ($p>0.05$). The chopped mode of irradiation of all wave-lengths showed significant increase in epithelial closure following the operation ($p<0.05$). There were significant increases of the granulation tissue formation on the 3rd post-operative day with 940nm using chopped mode and 810nm in continuous mode ($p<0.05$).

Conclusion: Pulsed mode of lasers accelerates the epithelization regardless of the wave-lengths while 940nm and 810nm lasers in continuous mode speeds up the granulation tissue formation.

Keywords: Diode lasers; wound healing; surgery.

INTRODUCTION

Wound healing is divided into 4 topics as maturation, coagulation, inflammation, and proliferation. The main events occurred during the healing are angiogenesis, epithelization, collagen deposition, and granulation tissue formation in the proliferation phase (1-3).

Numerous surgical instruments have been introduced in dental practice for surgical purpose. These include scalpel, electrosurgery, CO2, Er:YAG, Nd:YAG, and diode lasers. Each of these devices has their own advantages and disadvantages. The steel scalpel, also known as cold knife, has been used extensively for many years because of its minimal damage to the soft tissues (4,5). However, it is quite difficult to provide hemostasis in scalpel surgery due to the bleeding tendency. So operative field cannot be observed clearly especially for cases with hemorrhagic disorders or those on antithrombotic therapy and on highly vascular tissue. Therefore, various advanced technologies have been developed to provide hemostasis. The use of devices that provide both incision and coagulation during the procedure has increased in both medicine and dentistry (6-8).

Electrosurgeryis a surgical process that uses high frequency electrical currents (7). Electrosurgery provides adequate hemostasis by closing the vessels before cutting. On the other hand, wound healing is delayed by extensive thermal damage and also electrosurgery units have the damage of causing muscle fasciculation (5-8).

The use of soft tissue lasers in surgical procedures in dentistry aims to benefit both the dentist and the patient

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(7,9). Practitioners began to investigate different type of laser for surgical applications. Diode lasers are the most common laser type owing to its compact size affordability and probability to be used in in many procedures such as soft tissue surgery, endodontics, periodontics, orthodontics, bleaching, and low level laser therapy (LLLT). It was introduced in mid-90's by Harris and Pick in 1995. Latest reports have suggested that diode laser with wave-lengths between 810 to 970nm in continuous and pulsed mode is a possible equipment for soft tissue procedure in the intraoral region (5,9). Furthermore, diode lasers have a fiber optic tip that provides opportunity to work with or without contact depending on the clinical requirements. Good bleeding control and high hemoglobin absorption are other reasons for this choice. This feature provides clear view of the surgical and bloodless area and also there is often no need for a suture after the incision (4,10,11). The heat generated during laser incision causes carbonization, protein denaturation, drying and evaporation of the application area. As a result of that pain, receptors at the incision area are inhibited. This eliminates the need for anesthesia injection and disinfection of the area. A faster and better healing process provides a good comfort to the patient after the operation so no medication is needed (7,12).

There are different wave-lengths of diode lasers that were produced by various companies in the market and each diode laser has continuous and pulsative application mode. It has a crucial importance to determine the soft tissue damage resulting from standardized incision using different wave-lengths and application modes (8,13). However, There is no study to assess the efficacy of each diode laser and the efficiency of the mode of application as pulsative or continuous. Therefore, this research aims to investigate the comparative effects of the diode lasers of 3 different wave-lengths (810nm, 940nm, 980nm) and also different application mode on the cellular basis in animal models. The first null hypothesis of the study is that there is no effect of the wave-length and the second one is that there is no effect of mode of application on the wound healing in animal models.

MATERIAL and METHODS

Eighteen male Wistar albino rats (body mass of 250-300 g and 5 months old) were used in the research. Ethical clearance was taken from Committee on Animal Research of Bezmialem Vakif University (Protocol number: 2015/243). Rats were anesthetized by 5 mg/kg xylazine HCL and 35 mg/kg ketamine. Following anesthesia, the dorsum (operative field) of each rat was shaved. After marking the incision line on every rat, 3 different laser wave-lengths; 810nm (Gigaa, Cheese, China), 940nm (Epic 10, Biolase, USA) and 980nm (SIROlaser Advance, Sirona, Bensheim, Germany) were used to create an incision (10 mm in length and 1 mm in depth) on animals' dorsal side to the subcutaneous level using the lasers in continuous (3 W/cm^2) or chopped modes (3 W/cm^2 50% Duty cycle). Totally each rat had 6 incisions that were cut at least 1 cm apart.

Rats were sacrificed after 24 hours, 3 days or 1 week. Incision areas of the dorsal side of each rat were removed from region by excision and the specimens underwent histopathological evaluation. Samples were fixed with formalin (10%) and processed normally. These were disintegrated and with hematoxylin-eosin. Light microscope (CX 31; Olympus, Tokyo, Japan.) was used for histopathological evaluation. Sections were evaluated by a pathologist and thermal changes, closure of epithelium granulation tissue, inflammation, and fibrosis were recorded (grading range 0 to 3+).

Statistical analysis

Statistical analysis was performed with Statistical Package for Social Science (SPSS v.22. Chicago.IL, USA) for Windows 10.0 and where appropriate Kruskal Wallis and Mann Whitney U tests were performed for paired comparisons between groups (Statistically significant at the level $p<0.05$).

RESULTS

There were no statistically significant difference in the thermal changes, epithelial closure grade, levels of granulation tissue, inflammation levels, and fibrosis among first day, third day, and seventh days of wave-lengths when pulsed and continuous mode were used (Table 1). For all wave-lengths; there were no statistically significant differences between the pulsed and continuous modes in terms of thermal change levels, epithelial closure grades, granulation tissue levels, inflammation levels, and fibrosis levels on the first day, third day, and seventh days (Table 2).

Figure 1 shows the thermal changes on the tissues after laser irradiations groups. There were gradually decrease day by day in all wave-lengths and application modes; however, there were no statistically differences among the tested days ($p>0.05$).

There were statistically significant difference between the epithelial closure grades on the first day, third day and seventh day when used in pulsed mode and using 810nm laser ($p=0.031$) or 940nm laser ($p=0.015$) or 980nm laser ($p=0.008$) (Table 3). After bilateral comparisons to determine the days of significance; the level of epithelial closure in the seventh day was found significantly higher on the first day in all wave-length groups ($p<0.05$). There was no significant difference between epithelial closure grades on the first day and on the third day in all wave-length groups ($p>0.05$) (Figure 2).

When 810nm laser and the 940nm lasers were used in pulsed mode, there were statistically significant differences among granulation tissue levels on the first day, third day and seventh day ($p<0.05$) (Table 3). After bilateral comparisons to determine the days of significance; the level of granulation tissue texture on the seventh day

was significantly higher on the first day (p<0.05) and on the third day (p<0.05). There was no significant difference between granulation tissue levels on the first and third days (p>0.05) (Figure 3).

When running in continuous mode and using 810nm, 940nm and the 980nm diode laser, there were statistically significant differences among the granulation tissue levels on the first day, third day and seventh day (p<0.05) (Table 3). Level of granulation texture on the first day was found significantly lower on the third and seventh days (p<0.05). Granulation tissue texture on the third day was significantly lower on the seventh day (p<0.05) in 810nm laser group, however was not statistically different in 940nm and 980nm laser groups (p>0.05) (Table 3).

Table 1. Evaluation of individual wavelengths in day and modes in terms of thermal change, epithelial closure grade, granulation tissue, inflammation and fibrosis

Mode	Day	Wave-lengths	Thermal change	Epithelial closure grade	Granulation tissue	Inflammation	Fibrosis
			Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)
Pulsative	1st day	810nm	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	2.33±0.52 (2)	0±0 (0)
		940nm	2.83±0.41 (3)	0±0 (0)	0.67±0.82 (0.5)	2±0.89 (2)	0±0 (0)
		980nm	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	1.5±0.84 (1)	0±0 (0)
		p	**1.000**	**1.000**	**0.836**	**0.181**	**1.000**
	3rd day	810nm	2.33±0.82 (2.5)	0.17±0.41 (0)	1.67±0.82 (1.5)	2.33±0.82 (2.5)	0.17±0.41 (0)
		940nm	2.67±0.52 (3)	0.33±0.52 (0)	2±0.89 (2)	2±0.63 (2)	0.17±0.41 (0)
		980nm	2.67±0.52 (3)	0±0 (0)	2±0.89 (2)	1.5±0.55 (1.5)	0.33±0.52 (0)
		p	**0.683**	**0.322**	**0.728**	**0.139**	**0.738**
	7th day	810nm	1.67±1.03 (2)	1±1.1 (1)	3±0 (3)	2±0.89 (2)	0.5±0.55 (0.5)
		940nm	2.17±0.98 (2.5)	0.83±0.41 (1)	2.67±0.82 (3)	1.67±0.82 (1.5)	0.67±0.82 (0.5)
		980nm	2.33±0.82 (2.5)	0.67±0.52 (1)	2.5±0.55 (2.5)	2±0.63 (2)	0.67±0.82 (0.5)
		p	**0.474**	**0.845**	**0.161**	**0.663**	**0.953**
Continuous	1st day	810nm	2.33±0.82 (2.5)	0±0 (0)	0.67±0.82 (0.5)	1.83±0.98 (1.5)	0.17±0.41 (0)
		940nm	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.67±0.82 (1.5)	0.33±0.82 (0)
		980nm	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.83±0.98 (1.5)	0±0 (0)
		p	**0.299**	**1.000**	**0.954**	**0.954**	**0.586**
	3rd day	810nm	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.75 (2)	2.67±0.52 (3)	0.33±0.52 (0)
		940nm	2.17±0.75 (2)	0.5±0.55 (0.5)	2.33±0.52 (2)	2.17±0.41 (2)	0.33±0.52 (0)
		980nm	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.98 (2.5)	2.33±1.03 (3)	0.5±0.55 (0.5)
		p	**0.328**	**0.351**	**0.948**	**0.349**	**0.802**
	7th day	810nm	1.83±0.98 (1.5)	0.5±0.55 (0.5)	3±0 (3)	2.33±0.82 (2.5)	0.5±0.55 (0.5)
		940nm	2.33±1.03 (3)	0.67±0.52 (1)	2.5±0.84 (3)	2.33±0.82 (2.5)	0.67±0.52 (1)
		980nm	2.67±0.82 (3)	0.5±0.55 (0.5)	2.67±0.52 (3)	2.17±0.98 (2.5)	0.33±0.52 (0)
		p	**0.283**	**0.809**	**0.298**	**0.954**	**0.533**

*Statistically significant at the level p<0.05 (Kruskal Wallis Test)
n=6 pergroup
nm: nanometer
SD: Standard Deviation

Table 2. Evaluation of individual modes in day and wavelength in terms of thermal change, epithelial closure grade, granulation tissue, inflammation and fibrosis

Wave-length	Day	Mode	Thermal change	Epithelial closure grade	Granulation tissue	Inflammation	Fibrosis
			Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)
810nm	1st day	Pulsative	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	2.33±0.52 (2)	0±0 (0)
		Continuous	2.33±0.82 (2.5)	0±0 (0)	0.67±0.82 (0.5)	1.83±0.98 (1.5)	0.17±0.41 (0)
		p	**0.211**	**1.000**	**0.600**	**0.306**	**0.317**
	3rd day	Pulsative	2.33±0.82 (2.5)	0.17±0.41 (0)	1.67±0.82 (1.5)	2.33±0.82 (2.5)	0.17±0.41 (0)
		Continuous	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.75 (2)	2.67±0.52 (3)	0.33±0.52 (0)
		p	**0.465**	**1.000**	**0.268**	**0.465**	**0.523**
	7th day	Pulsative	1.67±1.03 (2)	1±1.1 (1)	3±0 (3)	2±0.89 (2)	0.5±0.55 (0.5)
		Continuous	1.83±0.98 (1.5)	0.5±0.55 (0.5)	3±0 (3)	2.33±0.82 (2.5)	0.5±0.55 (0.5)
		p	**0.867**	**0.423**	**1.000**	**0.495**	**1.000**
940nm	1st day	Pulsative	2.83±0.41 (3)	0±0 (0)	0.67±0.82 (0.5)	2±0.89 (2)	0±0 (0)
		Continuous	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.67±0.82 (1.5)	0.33±0.82 (0)
		p	**1.000**	**1.000**	**0.794**	**0.495**	**0.317**
	3rd day	Pulsative	2.67±0.52 (3)	0.33±0.52 (0)	2±0.89 (2)	2±0.63 (2)	0.17±0.41 (0)
		Continuous	2.17±0.75 (2)	0.5±0.55 (0.5)	2.33±0.52 (2)	2.17±0.41 (2)	0.33±0.52 (0)
		p	**0.212**	**0.575**	**0.484**	**0.598**	**0.523**
	7th day	Pulsative	2.17±0.98 (2.5)	0.83±0.41 (1)	2.67±0.82 (3)	1.67±0.82 (1.5)	0.67±0.82 (0.5)
		Continuous	2.33±1.03 (3)	0.67±0.52 (1)	2.5±0.84 (3)	2.33±0.82 (2.5)	0.67±0.52 (1)
		p	**0.715**	**0.523**	**0.598**	**0.176**	**0.859**
980nm	1st day	Pulsative	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	1.5±0.84 (1)	0±0 (0)
		Continuous	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.83±0.98 (1.5)	0±0 (0)
		p	**1.000**	**1.000**	**0.799**	**0.527**	**1.000**
	3rd day	Pulsative	2.67±0.52 (3)	0±0 (0)	2±0.89 (2)	1.5±0.55 (1.5)	0.33±0.52 (0)
		Continuous	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.98 (2.5)	2.33±1.03 (3)	0.5±0.55 (0.5)
		p	**1.000**	**0.317**	**0.733**	**0.125**	**0.575**
	7th day	Pulsative	2.33±0.82 (2.5)	0.67±0.52 (1)	2.5±0.55 (2.5)	2±0.63 (2)	0.67±0.82 (0.5)
		Continuous	2.67±0.82 (3)	0.5±0.55 (0.5)	2.67±0.52 (3)	2.17±0.98 (2.5)	0.33±0.52 (0)
		p	**0.338**	**0.575**	**0.575**	**0.670**	**0.465**

*Statistically significant at the level p<0.05 (Mann Whitney U Test)
n=6 pergroup
nm: nanometer
SD: Standard Deviation

Table 3. Evaluation of thermal changes, epithelial closure grade, granulation tissue, inflammation and fibrosis of laser days separately in wavelength and modes

Mode	Day	Wave-lengths	Thermal change	Epithelial closure grade	Granulation tissue	Inflammation	Fibrosis
			Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)
Pulsative	810nm	1st day	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	2.33±0.52 (2)	0±0 (0)
		3rd day	2.33±0.82 (2.5)	0.17±0.41 (0)	1.67±0.82 (1.5)	2.33±0.82 (2.5)	0.17±0.41 (0)
		7th day	1.67±1.03 (2)	1±1.1 (1)	3±0 (3)	2±0.89 (2)	0.5±0.55 (0.5)
		p	**0.066**	**0.031***	**0.004***	**0.714**	**0.119**
	940nm	1st day	2.83±0.41 (3)	0±0 (0)	0.67±0.82 (0.5)	2±0.89 (2)	0±0 (0)
		3rd day	2.67±0.52 (3)	0.33±0.52 (0)	2±0.89 (2)	2±0.63 (2)	0.17±0.41 (0)
		7th day	2.17±0.98 (2.5)	0.83±0.41 (1)	2.67±0.82 (3)	1.67±0.82 (1.5)	0.67±0.82 (0.5)
		p	**0.351**	**0.015***	**0.010***	**0.663**	**0.110**
	980nm	1st day	2.83±0.41 (3)	0±0 (0)	1±1.1 (1)	1.5±0.84 (1)	0±0 (0)
		3rd day	2.67±0.52 (3)	0±0 (0)	2±0.89 (2)	1.5±0.55 (1.5)	0.33±0.52 (0)
		7th day	2.33±0.82 (2.5)	0.67±0.52 (1)	2.5±0.55 (2.5)	2±0.63 (2)	0.67±0.82 (0.5)
		p	**0.423**	**0.008***	**0.049***	**0.298**	**0.150**
Continuous	810nm	1st day	2.33±0.82 (2.5)	0±0 (0)	0.67±0.82 (0.5)	1.83±0.98 (1.5)	0.17±0.41 (0)
		3rd day	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.75 (2)	2.67±0.52 (3)	0.33±0.52 (0)
		7th day	1.83±0.98 (1.5)	0.5±0.55 (0.5)	3±0 (3)	2.33±0.82 (2.5)	0.5±0.55 (0.5)
		p	**0.267**	**0.119**	**0.002***	**0.267**	**0.492**
	940nm	1st day	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.67±0.82 (1.5)	0.33±0.82 (0)
		3rd day	2.17±0.75 (2)	0.5±0.55 (0.5)	2.33±0.52 (2)	2.17±0.41 (2)	0.33±0.52 (0)
		7th day	2.33±1.03 (3)	0.67±0.52 (1)	2.5±0.84 (3)	2.33±0.82 (2.5)	0.67±0.52 (1)
		p	**0.270**	**0.057**	**0.017***	**0.261**	**0.348**
	980nm	1st day	2.83±0.41 (3)	0±0 (0)	0.83±0.98 (0.5)	1.83±0.98 (1.5)	0±0 (0)
		3rd day	2.67±0.52 (3)	0.17±0.41 (0)	2.17±0.98 (2.5)	2.33±1.03 (3)	0.5±0.55 (0.5)
		7th day	2.67±0.82 (3)	0.5±0.55 (0.5)	2.67±0.52 (3)	2.17±0.98 (2.5)	0.33±0.52 (0)
		p	**0.803**	**0.119**	**0.017***	**0.643**	**0.160**

*Statistically significant at the level p<0.05 (Kruskal Wallis Test)
nm: nanometer
SD: Standard Deviation

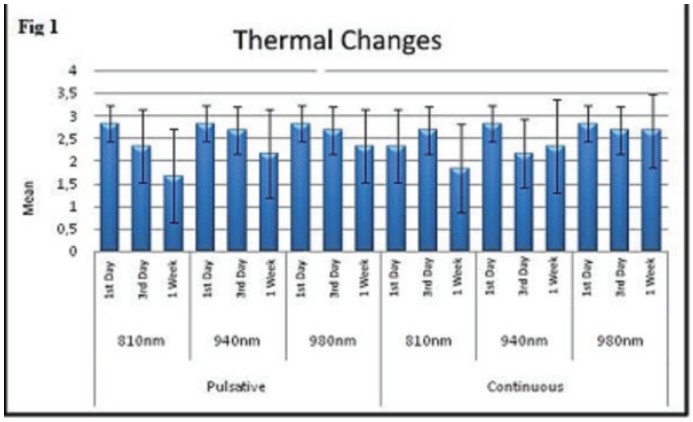

Figure 1. The mean degrees of thermal changes

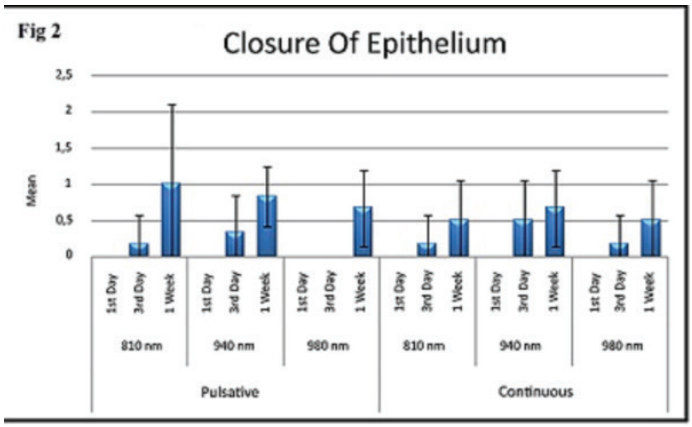

Figure 2. The mean degrees of closure of epithelium

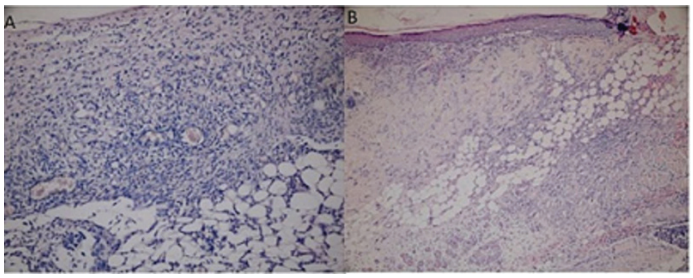

Figure 3. Granulation tissue on the 3rd day after surgery. A. 940 nm with chopped mode (x200). B. 810 nm in continuous mode (x100)

DISCUSSION

In dentistry, the used wave-lengths of the diode lasers are 655, 810, 940, 1064nm respectively (14). They are used for different clinical applications such as cutting/destructing tissues and coagulating bleeding. 810, 940 and 980nm wave-lengths are ideal for soft tissue applications due to the well absorption characteristics by melanin and hemoglobin with a penetration depth between 0.5 to 3 mm. Not only the wave-length but the power, pulse duration, fiber diameter, and frequency may also affect the cutting efficiency of lasers on the soft tissues. Thermal damage of the tissue may be influenced by the following factors: transmission, output power, wave-length, affinity with the target tissue, and type of the optic fiber (14). Yammie et al. (14) investigated diode lasers with three different wave-lengths 810, 940, 980nm similar to our study. They have created 10 incisions measuring 10 mm in length and 2 mm in depth on fourteen male rabbits' ventral surface of their tongues. The laser parameters were 2 W with continuous mode, delivered using a 400 nm optical fiber. They've detected similar thermal changes in different wave-length groups. They've reported that there was no statistically significant difference for the cutting depth and the incision's width. They've observed that 940nm group showed a wider marked thermal change zone but there was no statistically significant difference between the groups. The highest necrotic zone reported at 980 nm group but there was no statistically significant difference, either. They also reported no significant difference for inflammatory zones among the groups (14). Similar to Yammie et al's study, our results showed no statistically significant difference of the different wave-lengths for the inflammatory zones; we also found no statistically significant difference between chopped and continuous modes.

Jin et al. (15) investigated guinea pig mucosa wound healing on the 15 mm length incisions created by a scalpel, diode laser and Er,Cr:YSGG laser. The laser used in this research is 810nm diode laser with pulse length of 0.5 ms continuous wave, 2 W of power, and aiming beam of 635nm. They used continuous mode and with non-contact technique. The inflammatory response at diode laser group had the lowest values at post surgery of the first day but at postsurgical 3 and 5 day groups the inflammation at the diode laser group was the highest (15). They also investigated TNF-α and TNF-β1 expression in the groups and concluded that diode laser was a well device for oral mucosal incisions but the tissue damage created by diode laser was higher than the scalpel or Er,Cr:YSGG laser. Kaur et al. (16) investigated two different techniques as scalpel and diode laser (810nm) for uncovering the implants, found no statistical significant difference between healing index scores. Saperia et al.'s research which was the first research to investigate the effect of laser on wound healing. They made whole layered wounds in pigs, and created three different group as irradiation with helium-neon laser, tungsten-light, and no-light each other. They suggested that laser irradiation increased collagen synthesis (17).

Suzuki et al (18) investigated the wound healing efficiency of the 660nm diode laser with different energy intensities in a rat incision wound model. Samples were divided into groups to receive 660nm diode laser irradiation at an energy intensity of 0 (control), 1, 5 or 10 J/cm2 twenty four hours after the operation. Tissue sections were stained with hematoxylin-eosin and to determine the number of macrophages around the wound. They found that the 660nm diode laser with an energy intensity of 1 and 5 J/cm2 increased wound healing in the rat incision,

while increasing laser irradiation could not provide this increase. Mun et al. (19) conducted an animal research to clarify the effect of diode laser on wound healing based on microscopic findings. The diode laser at wavelengths of 655, 785 and 850nm was applied to rat skin for 9 days, 20 minutes per day for rat skin. They concluded that the 850nm group resulted in the greatest amount of collagen formation, that the diode laser had positive effects on fibroblast and collagen formation and provided better wound healing. In our study, there was no statistically significant difference in the fibrosis between first, third, and seventh days for three wave-length when pulsed and continuous mode was used. This result may come from that the method difference. Saperia et al. (17), Suzuki et al. (18) and Mun et al. (19) did not create the wounds with laser, they just apply laser after the wound created to assess the healing properties. There are many studies assessing the healing effects of different kind of lasers on wounds/scars, but the studies assessing healing of wounds created by lasers are limited.

Bryant et al. (20) compared the incisional wound healing created by scalped and CO2 laser on canine oral mucosa and monitored at 3, 7, 14 days after the incision, they found a significant delay in the laser group and they linked the situation to excess thermal damage of the continuous wave laser beam. They also reported that short pulsed-free electron laser caused by the delay from the scalpel group on wound healing shortens. They concluded that the importance of laser pulse duration was much more important on the wound healing than the wave-length. Our study's results are compatible with Bryant et al's(20) findings, chopped mode laser applications, and showed faster epithelization than the continuous mode independent from the wave-length.

Havel et al. (21) compared 940nm and 1470nm wave-length laser diode system in vitro and in vivo. In vitro setup was in the pig and turkey tissue model and 20 patients with nasal obstruction due to hyperplasia of inferior nasal turbines for in vivo evaluation were included in the study. They reported that the healing process following diode laser application revealed to be improved using 1470nm diode laser compared to 940nm. In our study, 940nm and 810nm continuous mode applications show faster granulation tissue formation. Both Havel et al. (21) and our study's results may show that the higher wave-length laser applications may accelerate the healing process.

In conclusion, within the limitation of this study, the chopped mode of lasers accelerates the epithelization regardless of wave-lengths while 940nm and 810nm laser in continuous mode speeds up granulation and tissue formation.

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