Journal of
Lasers
in Medical Sciences

J Lasers Med Sci 2024;15:e29

Original Article

http://journals.sbmu.ac.ir/jlms

doi 10.34172/jlms.2024.29

Temperature Rise and Pain Following the Use of 810 and 980 nm Diode Lasers for Second-Stage Dental Implant Surgery: A Clinical Trial

Bahareh Hosseini Mehvar[1], Arash Azizi[1], Shirin Lavaf[2*], Ardavan Etemadi[3], Ali Hassani[4]

[1]Department of Oral Medicine, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
[2]Department of Prosthodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
[3]Department of Periodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran
[4]Department of Oral and Maxillofacial Surgery, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

***Correspondence to**
Shirin Lavaf,
Email: drshlawaf@yahoo.com

Received: November 26, 2023
Accepted: May 14, 2024
ePublished: July 31, 2024

Abstract

Introduction: Many surgical procedures in a soft tissue are performed using diodes lasers. This study aimed to assess the temperature rise and pain following the use of 810 and 980 nm diode lasers for second-stage dental implant surgery.

Methods: This clinical trial was conducted on 24 osseointegrated dental implants that were randomly divided into two groups of 810 nm and 980 nm diode lasers. The temperature rise in each group was measured right after uncovering by the laser and 15 minutes later by a thermocouple, compared with the baseline temperature of gingival tissue. The level of pain was also measured at 24 hours postoperatively by using a visual analog scale. Data were analyzed by ANOVA, Tukey's test, and *t* test (alpha = 0.05).

Results: Within-group comparisons by ANOVA showed a significant difference in tissue temperature between the three time points in both groups ($P < 0.0001$). Pairwise comparisons by Tukey's test showed that the temperature at baseline ($P < 0.0001$) and 15 seconds after uncovering was significantly lower than that immediately after uncovering in both groups ($P < 0.0001$). The mean tissue temperature and the mean pain score in the 980 nm laser group were significantly higher than the corresponding values in the 810 nm laser group ($P < 0.05$).

Conclusion: According to the results, temperature rise in the use of the 980 nm laser was higher than the 810 nm laser. The use of 810 nm diode laser was associated with lower temperature rise and significantly lower pain score after 24 hours.

Keywords: Temperature; Pain; Lasers; Semiconductor; Dental implants.

Introduction

Acceleration of impression making, pain reduction, and enhancement of patient recovery after the second-stage implant surgery are highly favored by dental clinicians. However, delayed healing after the second-stage implant surgery is a common problem.[1,2] Surgeons and prosthodontists are searching for strategies to minimize the edentulism period of patients and enable fast delivery of prosthetic restorations. However, scalpel surgery is the most commonly adopted approach for second-surgery implant surgery, which necessitates a minimum of 2 weeks for gingival healing.[3-5]

Laser is another suggested modality for second-stage implant surgery. However, laser application is contraindicated in cases with inadequate attached gingiva width around dental implants.[6] Despite the advantages of laser-assisted surgery, heat generation at the implant site is a shortcoming associated with the use of diode lasers, which can lead to treatment failure. Due to the direct contact of an implant with the bone and the type of soft tissue at the implant neck, excessive heat generation due to laser irradiation decreases the blood supply in this region and increases the risk of thermal damage.[7] Worni et al[8] found that a temperature rise in the bone by up to 10 °C for 60 seconds can cause permanent changes in the bone structure. Thus, temperature change should be below 10 °C in order to be considered safe.[8]

Different wavelengths of a diode laser, including 810, 940, 980, and 415 nm wavelengths, are used for the second-stage implant surgery. However, no previous study is available comparing the level of postoperative pain and generated heat by the use of 810 and 980 nm diode lasers for second-stage implant surgery.[9] Thus, this study aimed to assess the temperature rise and the pain score following the use of 810 and 980 nm diode lasers for second-stage dental implant surgery.

Materials and Methods

This study was conducted at the Oral Medicine Department of the School of Dentistry, Islamic Azad University, Tehran between September 2018 and March 2019.

Please cite this article as follows: Hosseini Mehvar B, Azizi A, Lavaf S, Etemadi A, Hassani A. Temperature rise and pain following the use of 810 and 980 nm diode lasers for second-stage dental implant surgery: a clinical trial. *J Lasers Med Sci.* 2024;15:e29. doi:10.34172/jlms.2024.29.

Trial Design

A clinical trial was conducted, and in this trial, one group underwent second-stage implant surgery with an 810 nm diode laser and the other group underwent second-stage implant surgery with a 980 nm diode laser. The results were reported in accordance with the Consolidated Standards of Reporting Trials.

Participants, Eligibility Criteria, and Settings

The inclusion criteria were as follows: (I) patients presenting to Dental Implant Research Center of School of Dentistry, Islamic Azad University, Tehran for second-stage implant surgery, (II) patients with no systemic disease or contraindication for implant surgery, (III) patients having osseointegrated implants with a maximum of 2 mm of gingival thickness covering the implant cover screw, (IV) patients with a minimum of 4 mm of attached gingiva width as measured by a periodontal probe, and (V) patients signing informed consent forms for the surgery and participation in the study.

The exclusion criteria were (I) patients with peri-implantitis or peri-implant mucositis and (II) contraindications for laser-assisted surgery.

The sample consisted of 24 osseointegrated implants (Implantium, South Korea) with green cover screws and no peri-implantitis or peri-implant mucositis.

Interventions

Dental implants were randomly assigned to two groups:

- Group 1: An 810 nm diode laser (Diode Dental Laser Pulsar, Iran) was used with 1.5 W power, with a 400 μm fiber tip, in continuous-wave mode, in contact with the tissue, and with back-and-forth movement on the gingiva until the tissue was incised.
- Group 2: A 980 nm diode laser (Doctor Smile, Lambda, Italy) was used with 1.5 W power, with a 400 μm fiber tip, in continuous-wave mode, in contact with the tissue, and with back-and-forth movement on the gingiva until the tissue was incised.

The selected cases had a minimum of 4 mm of keratinized gingiva width and a maximum of 2 mm of gingiva over the cover screw for the use of laser for second-stage surgery as measured by a Williams probe (Hu-Friedy, USA).[2] Complete osseointegration of dental implants was clinically and radiographically ensured by the attending surgeon. To accurately locate the implant, we obtained a periapical radiograph by the parallel technique. Also, the area was probed, and the implant was detected by the tactile sense. The area was anesthetized by infiltration anesthesia using 2% lidocaine (Persocaine , DaruPakhsh, Iran). The injection was performed in the buccal vestibule at 1 cm distance from the ridge crest and similarly in the maxilla in the palatal region at 1 cm distance from the ridge crest. Before incising and removing the gingival tissue by the laser, a thermocouple (HANYOUNG D55 NUX.SU-105 IPN, Samwon ENG, Korea) with AC100-240 V power, a temperature range of -50 °C to + 150 °C and 0.1 °C accuracy was used to record the temperature. The thermocouple probe was placed 1 mm mesial to the external implant border in the bone crest perpendicularly at the incision site and in contact with the peri-implant soft tissue. The temperature of the soft tissue was recorded at baseline prior to using the laser (T0) and also immediately after uncovering by the use of the laser (T1), and 15 seconds after tissue removal (approximate time of tightening of healing abutments) (T2), with a constant power of 1.5 W in continuous-wave mode with 400 μm fiber tip in contact with the target tissue under saline irrigation (Figure 1). The pain score of patients was also recorded 24 hours after surgery using a visual analog scale in which zero indicated no pain and 10 indicated maximum pain imaginable. The patients were instructed on how to use the visual analog scale on the day of surgery and were requested to express the level of pain experienced.

Outcomes (Primary and Secondary)

The main objective of this study was to assess the temperature rise following the use of 810 and 980 nm diode lasers for second-stage dental implant surgery. Pain at 24 hours after surgery was considered as the secondary outcome.

Sample Size Calculation

The sample size was calculated to be 12 implants in each group according to a study by Fornaini et al,[10] assuming $\alpha = 0.05$, $\beta = 0.2$, mean standard deviation of 2.5°C, and effect size of 0.57 using t-test analysis.

Interim Analyses and Stopping Guidelines

No interim analyses were performed, and no stopping guidelines were established.

Randomization

The patients were randomly assigned to two groups by

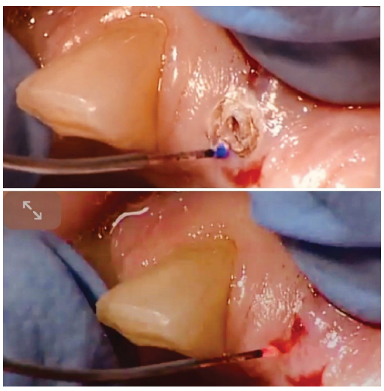

Figure 1. Gingival Tissue Removal and Uncovering of the Dental Implant by the Laser

using a table of random numbers.

Blinding

The patients were not aware of the wavelength of the laser used for their surgical procedure. The statistician who analyzed the data was also blinded to the group allocation of patients.

Statistical Analysis

The normality of data distribution was evaluated by the Kolmogorov-Smirnov test. Since the data were normally distributed, the temperature and pain scores were compared between the two groups by *t* test. ANOVA was applied to compare the temperature at different time points within each group. Pairwise comparisons were performed by Tukey's post hoc test. The level of significance was set at 0.05.

Results

Participant Flow

A total of 24 patients were evaluated in two groups (n = 12). The mean age of patients was 50.4 ± 4.12 years (range: 40-55 years) in the 810 nm laser group and 48.8 ± 3.93 years (range: 40-55 years) in the 980 nm laser group. The student *t* test showed no significant difference between the two groups regarding the mean age (P = 0.839). Also, each group included 6 males and 6 females.

Figure 2 shows the flow diagram of the study.

Harms

No patient was harmed during the study.

Subgroup Analyses

Within-Group Comparison of Temperature at Different Time Points

Table 1 presents the temperature at different time points in the two groups. In the 810 nm laser group, the temperature reached the maximum value immediately after uncovering and then decreased. ANOVA showed a significant difference in temperature between the three time points (P < 0.0001). Pairwise comparisons by Tukey's test showed that the temperatures at baseline (P < 0.0001) and 15 seconds after uncovering (P < 0.000) were significantly lower than that immediately after uncovering. However, the baseline temperature and the temperature at 15 seconds after uncovering were not significantly different (P > 0.05).

In the 980 nm laser group, the temperature reached the maximum value immediately after uncovering and then decreased. ANOVA showed a significant difference in temperature between the three time points (P < 0.0001). Pairwise comparisons by Tukey's test showed that the temperatures at baseline (P < 0.0001) and 15 seconds after uncovering (P < 0.000) were significantly lower than that immediately after uncovering. However, the baseline temperature and the temperature at 15 seconds after uncovering were not significantly different (P > 0.05).

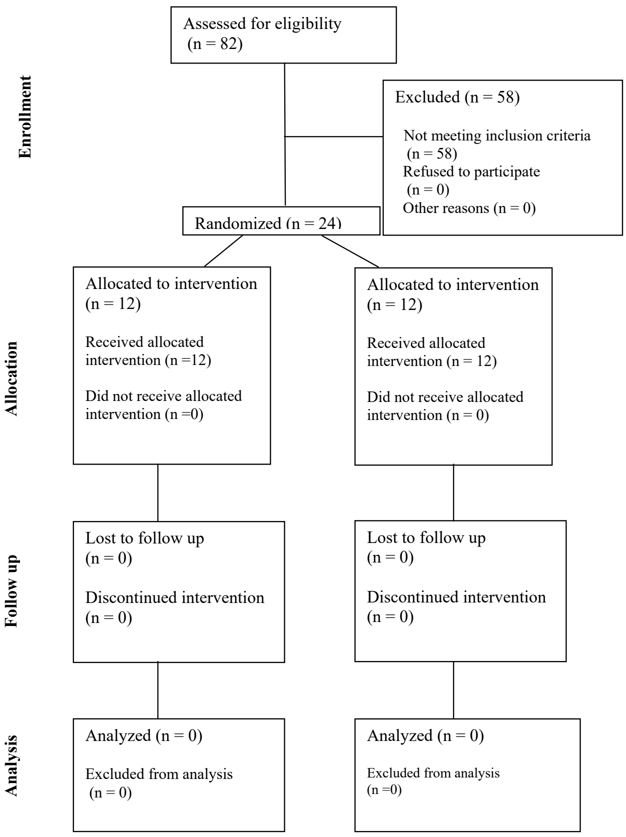

Figure 2. Flow Diagram of the Study

Comparison of 810 and 980 nm Laser Groups at Different Time Points

The student *t* test showed no significant difference in the baseline temperature of the two groups ($P=0.132$). However, immediately after uncovering, the temperature in the 980 nm laser group was significantly higher than that in the 810 nm laser group ($P<0.0001$). Also, the temperature at 15 seconds after uncovering was still significantly higher in the 980 nm laser group than in the 810 nm laser group ($P<0.0001$).

Comparison of the Pain Score Between the Two Groups

Table 2 shows the mean pain score of the patients in the two groups. The student *t* test showed that the mean pain score of the patients in the 980 nm laser group was significantly higher than that in the 810 nm laser group.

Discussion

Dental lasers have photothermal and ablative effects and are extensively used for oral surgical procedures due to enhanced wound healing.[11] This study assessed the temperature rise and pain following the use of 810 and 980 nm diode lasers for second-stage dental implant surgery. According to the results, within-group comparisons by ANOVA showed a significant difference in temperature between the three time points in each of the two groups ($P<0.000$). Pairwise comparisons by Tukey's test showed that the temperatures at baseline ($P<0.000$) and 15 seconds after uncovering were significantly lower than that immediately after uncovering in both groups ($P<0.000$). The mean temperature and the mean pain score in the 980 nm laser group were significantly higher than the corresponding values in the 810 nm laser group ($P<0.05$).

Sadeghi et al[12] compared the effects of a diode laser with 810, 980, and 1470 nm wavelengths on vascular endothelial tissue and showed that low laser wavelengths had high absorption in hemoglobin. Thus, the 980 nm laser had higher heat generation than the 810 nm laser and caused greater damage to the endothelial lining of blood vessels. They showed that in the use of the 1470 nm laser, lower power can be employed to obtain favorable results. They also demonstrated that increased duration of radiation with lower power generated greater heat compared with the application of a laser with higher power for a shorter period of time. Similar to the present study, they reported higher heat generation by the 980 nm laser compared with the 810 nm laser, although their methodology was different from the present study. Geminiani et al[13] evaluated thermal changes during diode laser irradiation of implant surfaces in non-contact mode for the treatment of peri-implantitis. They used 810 and 980 nm diode lasers with 2 W power for 60 seconds. The laser handpiece had 3 mm distance from the implant neck. They reported that the temperature rise exceeded the critical threshold of bone damage only after 980 nm laser irradiation for 10 seconds, which was different from the present findings, probably due to the use of different powers of the laser and different positions of the thermocouple. Matys et al[14] evaluated the temperature rise following the use of the 980 nm Er:YAG laser. They showed that 17 to 18 seconds of time was required for the 980 nm laser to cause a 10° temperature rise. They added that laser parameters and chemical composition and diameter of implants also play a role in this respect. The Er:YAG laser does not require local anesthesia, and since it has lower penetration depth in tissues, it generates less heat and is safer. Fornaini et al[15] compared the temperature rise by 810, 980, 1470, and 1950 nm lasers for oral surgical procedures and reported maximum heat generation by the 980 nm laser with 4 W power causing a 17.3 °C temperature rise, while minimum heat was generated by the 1950 nm laser with 2 W power that caused a 9.7 °C temperature rise. Similarly, the present study showed that 980 nm laser caused a greater temperature rise due to higher absorption in water. Fornaini et al,[3] in an animal study, compared the temperature rise caused by the irradiation of Er:YAG, Nd:YAG, diode, and KTP lasers for second-stage implant surgery in pigs. They reported a smaller temperature rise in the use of the KTP laser with a 532 nm wavelength and the Er:YAG laser with a 2940 nm wavelength in second-stage surgery, while the diode laser with an 810 nm wavelength and the Nd:YAG laser with a 1064 nm wavelength caused a greater temperature rise. These findings can be explained by the shallow penetration depth of Er:YAG and KTP lasers, compared with the diode laser, which has high penetration depth into the tissues. In a study by Shahbazi et al,[16] 980 nm

Table 1. Temperature Rise at Different Time Points in the Two Groups

Laser Group		Time: Prior to Surgery (Baseline)	Immediately After Uncovering	15 s After Uncovering	*P* Value
810 nm	Mean ± SD	33.1 ± 0.82	40.7 ± 0.74	33.1 ± 1.48	< 0.0001
	Minimum	32	40	30	
	Maximum	34.2	42	35.3	
980 nm	Mean ± SD	33.6 ± 0.92	43.8 ± 2.2	35.5 ± 1.1	< 0.0001
	Minimum	32.1	40.2	34.4	
	Maximum	34.8	46.7	38	
P value		0.132	< 0.000	< 0.000	-

Table 2. Mean Pain Score of Patients in the Two Groups

Pain Score	Laser Group: 810 nm Laser	980 nm Laser	*P* Value
Mean	3.1 ± 0.47	4.2 ± 0.66	< 0.0001
Minimum	2.5	3	
Maximum	4	5	

diode laser irradiation in continuous-wave mode with 400 µm fiber tip and 3 W power caused the highest rate of thermal alterations; however, the 810 nm diode laser with 1 W power caused the slightest thermal changes in the soft tissue. Similar to the present study, they reported greater heat generation by the 980 nm laser compared with the 810 nm laser. Matys et al[17] compared 445 and 980 nm diode lasers and found that the use of a diode laser in contact mode increased the temperature by 12.67 °C, as measured by a thermocouple placed 3 mm below the implant collar. In the present study, the thermocouple was placed 1 mm mesial to the external implant border at the ridge crest, and the temperature rise immediately after uncovering was found to be 10.2 °C in the 980 nm laser group. Differences in the results of studies can be due to the different wavelengths and powers of lasers and the location of thermocouples. Matys and Dominiak[18] compared the Er:YAG laser and the surgical scalpel for second-stage surgery regarding the postoperative pain score of patients. They reported a lower postoperative pain score and shorter duration of the surgical procedure in the Er:YAG laser group. Also, it did not require anesthesia. Furthermore, the quality of impression for prosthetic treatment was acceptable in the laser group. Their results were generally in line with the present findings regarding the pain score. However, since the Er:YAG laser has very shallow penetration depth in the tissue, it generates less heat and subsequently less pain. In the use of a diode laser, the wavelength with lower absorption in water generates less heat and pain. EL-Kholey[4] reported that the use of a diode laser for second-stage surgery can be associated with less surgical trauma, better vision during surgery as the result of minimal bleeding, and lower levels of pain and discomfort in patients. Saline irrigation of the surgical site during the procedure and interruption of irradiation every 20-30 seconds can prevent temperature rise in the gingival tissue and bone. They reported that the absence of adequate peri-implant attached gingiva width can be the only limitation against the use of a laser for implant surgery. In the present study, saline irrigation was used during the procedure. However, the laser was used in contact mode and there was no interval between the pulses, which may be responsible for the excessive temperature rise.[4] Augustin et a1[19] compared different laser wavelengths regarding the temperature rise in soft tissue surgery. They reported a maximum temperature rise in the use of the CO2 super-pulse laser with 2 W power and a minimum temperature rise in the use of the Er:YAG laser. The maximum temperature rise was reported for the 5 W diode laser and the minimum temperature rise for the Er:YAG laser. They concluded that the 808 nm diode laser with 3 W power caused a 21 °C temperature rise. Histologically, they reported bone necrosis following the temperature rise to 47 °C for 5 minutes, 50 °C for 1 minute, and 56 °C for less than 1 minute. They also showed less heat generation in the use of the Er:YAG laser due to its lower penetration depth. Their results cannot be compared with the present findings due to different methodologies and laser parameters. Arnabat-Domínguez et al,[20] in their ex vivo study, showed that the Er,Cr:YSGG laser did not cause a temperature rise and tissue damage. This device has a cooling system without which it can cause a temperature rise of approximately 5 °C (maximum of 7.5 °C) which can lead to irreversible bone damage. Thus, it should not be used without water spray. The use of air and water spray during laser irradiation can decrease the temperature rise.

Regarding the pain score, Jiang et al[21] reported that the 980 nm diode laser induces the activation of transient receptor potential proteins (TRPV1, TRPV2). In this process, C and A-delta nociceptors are primarily responsible for pain perception in the peripheral nervous system. Heat results in pain generation by TRPV1 proteins in C fibers while A-delta fibers are stimulated by TRPV2. Pain generation by the diode laser in the present study can be explained as such.[21] Also, following mechanical, thermal, and chemical stimulations, different mediators are generated, and this causes tissue damage, inflammation, and pain and also increases the susceptibility to pain. The pro-nociceptor mediators primarily and directly activate the afferent nerve fibers or indirectly increase signal transmission of nociceptors to the central nervous system. Primary stimulation of afferent nerve fibers by extrinsic mediators is referred to as peripheral desensitization, which is an important parameter in tissue damage and pain. ATP, glutamine, kinins, and cytokines are among the pro-nociceptor mediators released in tissue injury that cause pain at the site of thermal or mechanical damage. This process explains pain generation following heat generation by laser irradiation.[22]

This study compared two commonly used wavelengths of a laser in dental offices. The results showed that despite higher heat generation and pain by the 980 nm diode laser, both wavelengths were safe in terms of not damaging the gingival tissue and the dental implant. Also, the present results, similar to the findings of Romanos et al,[2] indicated that diode lasers should be used with caution due to their higher penetration depth into the tissue and risk of bone damage.

Heat generation by laser irradiation is affected by the maximum absorption and mode of a laser as well as tissue properties and may vary from one site to the other.[2] Selection of pulse or super pulse mode,[23] use of air and water spray,[24] and reduction of energy density of a laser[25] are among the suggested strategies to minimize heat generation. Also, in the process of irradiation of implant surfaces with the diode laser, the lowest power, pulse mode, and minimal irradiation time should be selected. Gingival tissue contains high amounts of water and hemoglobin, and diode lasers are highly absorbed by water and hemoglobin. Accordingly, the 980 nm diode laser has higher absorption in water and, consequently, generates greater heat. It resultantly stimulates the pain receptors and pro-inflammatory cells, which also cause pain. However, by decreasing its power, favorable results may be obtained.[12]

Future split-mouth clinical trials are required to compare diode lasers with other dental lasers with different powers to find the best type and protocol of lasers for second-stage implant surgery.

Conclusion

According to the results, the temperature rise in the use of the 980 nm laser was higher than the 810 nm laser. The use of the 810 nm diode laser was associated with a lower temperature rise and a significantly lower pain score after 24 hours.

Acknowledgements

Our research was financially supported by the university and the laser department. Statistical calculations were done by Dr. Kharrazi fard (statistical consulting).

Authors' Contribution

Conceptualization: Arash Azizi.
Data curation: Bahareh Hosseini Mehvar.
Formal analysis: Bahareh Hosseini Mehvar, Shirin Lavaf.
Funding acquisition: Ardavan Etemadi.
Investigation: Bahareh Hosseini Mehvar, Arash Azizi.
Methodology: Arash Azizi, Ali Hassani.
Project administration: Arash Azizi, Shirin Lavaf.
Resources: Bahareh Hosseini Mehvar, Ardavan Etemadi
Software: Bahareh Hosseini Mehvar
Supervision: Arash Azizi, Ardavan Etemadi, Ali Hassani.
Validation: Arash Azizi, Ardavan Etemadi, Shirin Lavaf
Visualization: Bahareh Hosseini Mehvar, Arash Azizi.
Writing–original draft: Bahareh Hosseini Mehvar.
Writing–review & editing: Shirin Lavaf.

Competing Interests

None declared.

Ethical Approval

The study was approved by the ethics committee of the university (2107) and registered in the Iranian Registry of Clinical Trials (identifier: IRCT20140105016090N7).

Funding

None.

References

1. Misch C. Contemporary Implant Dentistry. 4th ed. Canada: Mosby; 2019.
2. Romanos GE, Gutknecht N, Dieter S, Schwarz F, Crespi R, Sculean A. Laser wavelengths and oral implantology. Lasers Med Sci. 2009;24(6):961-70. doi: 10.1007/s10103-009-0676-1.
3. Fornaini C, Merigo E, Vescovi P, Bonanini M, Antonietti W, Leoci L, et al. Different laser wavelengths comparison in the second-stage implant surgery: an ex vivo study. Lasers Med Sci. 2015;30(6):1631-9. doi: 10.1007/s10103-014-1623-3 .
4. El-Kholey KE. Efficacy and safety of a diode laser in second-stage implant surgery: a comparative study. Int J Oral Maxillofac Surg. 2014;43(5):633-8. doi: 10.1016/j.ijom.2013.10.003.
5. Azar DE. Dental implant uncovering techniques with emphasis on increasing keratinized mucosa. Compend Contin Educ Dent. 2015;36(4):290-7.
6. Esposito M, Grusovin MG, Maghaireh H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: management of soft tissues for dental implants. Cochrane Database Syst Rev. 2007(3):CD006697. doi: 10.1002/14651858.cd006697.
7. Heinemann F, Hasan I, Kunert-Keil C, Götz W, Gedrange T, Spassov A, et al. Experimental and histological investigations of the bone using two different oscillating osteotomy techniques compared with conventional rotary osteotomy. Ann Anat. 2012;194(2):165-70. doi: 10.1016/j.aanat.2011.10.005.
8. Worni A, Marchand L, Sailer I, Cornish D, Hicklin SP. Explantation of an osseointegrated titanium implant using laser-induced thermo-necrosis: a case report. Int J Oral Maxillofac Implants. 2018;33(6):e151-5. doi: 10.11607/jomi.6898.
9. Romanos GE. Treatment of peri-implant lesions using different laser systems. J Oral Laser Appl. 2002;2(2):75-81.
10. El-Kholey KE. Efficacy and safety of a diode laser in second-stage implant surgery: a comparative study. Int J Oral Maxillofac Surg. 2014;43(5):633-638. doi:10.1016/j.ijom.2013.10.003.
11. Augustin G, Davila S, Mihoci K, Udiljak T, Vedrina DS, Antabak A. Thermal osteonecrosis and bone drilling parameters revisited. Arch Orthop Trauma Surg. 2008;128(1):71-7. doi: 10.1007/s00402-007-0427-3.
12. Sadeghi S, Miranbeigi M. The comparison between different wavelengths of diode lasers in modeling of endovenous laser treatment. Laser in Medicine. 2014;11(3-4):2-7. [Persian].
13. Geminiani A, Caton JG, Romanos GE. Temperature change during non-contact diode laser irradiation of implant surfaces. Lasers Med Sci. 2012;27(2):339-42. doi: 10.1007/s10103-010-0876-8.
14. 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(5):499-507. doi: 10.1515/bmt-2015-0135.
15. Fornaini C, Merigo E, Sozzi M, Rocca JP, Poli F, Selleri S, et al. Four different diode lasers comparison on soft tissues surgery: a preliminary ex vivo study. Laser Ther. 2016;25(2):105-14. doi: 10.5978/islsm.16-OR-08.
16. Shahbazi S, Moezzi Ghadim N, Mirzaei A, Azizi A. Comparison of soft tissue thermal changes induced by three types of diode lasers at 810, 940, and 980nm wavelengths. J Res Dent Maxillofac Sci. 2020;5(2):7-13. doi: 10.29252/jrdms.5.2.7.
17. Matys J, Flieger R, Dominiak M. Effect of diode lasers with wavelength of 445 and 980 nm on a temperature rise when uncovering implants for second stage surgery: an ex-vivo study in pigs. Adv Clin Exp Med. 2017;26(4):687-93. doi: 10.17219/acem/68943.
18. Matys J, Dominiak M. Assessment of pain when uncovering implants with Er:YAG laser or scalpel for second stage surgery. Adv Clin Exp Med. 2016;25(6):1179-84. doi: 10.17219/acem/62456.
19. Augustin G, Davila S, Udiljak T, Vedrina DS, Bagatin D. Determination of spatial distribution of increase in bone temperature during drilling by infrared thermography: preliminary report. Arch Orthop Trauma Surg. 2009;129(5):703-9. doi: 10.1007/s00402-008-0630-x.
20. Arnabat-Domínguez J, España-Tost AJ, Berini-Aytés L, Gay-Escoda C. Erbium:YAG laser application in the second phase of implant surgery: a pilot study in 20 patients. Int J Oral Maxillofac Implants. 2003;18(1):104-12.

21. Jiang N, Cooper BY, Nemenov MI. Non-invasive diode laser activation of transient receptor potential proteins in nociceptors. Proc SPIE Int Soc Opt Eng. 2007;6428. doi: 10.1117/12.699204.
22. Amaya F, Izumi Y, Matsuda M, Sasaki M. Tissue injury and related mediators of pain exacerbation. Curr Neuropharmacol. 2013;11(6):592-7. doi: 10.2174/1570159x11311060003.
23. Niemz MH. Laser-Tissue Interactions. Berlin, Heidelberg: Springer-Verlag; 2007. p. 432-8.
24. Sperandio FF, Meneguzzo DT, Ferreira LS, da Ana PA, Azevedo LH, de Sousa SC. Different air-water spray regulations affect the healing of Er,Cr:YSGG laser incisions. Lasers Med Sci. 2011;26(2):257-65. doi: 10.1007/s10103-010-0849-y.
25. Fornaini C, Rocca JP, Merigo E, Meleti M, Manfredi M, Nammour S, et al. Low energy KTP laser in oral soft tissue surgery: a 52 patients clinical study. Med Oral Patol Oral Cir Bucal. 2012;17(2):e287-91. doi: 10.4317/medoral.17428.