The Influence of Low-power Laser on Healing of Bone Defects after Periapical Surgery: A Clinical Study

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Purpose: The stimulating effect of low-power laser (LPL) irradiation on wound healing has been noticed in several in vitro studies. The aim of this study was to investigate the influence of the LPL irradiation in vivo on bone healing of jaw defects created after surgical treatment of chronic periapical lesions.

Materials and Methods: This prospective clinical study encompassed 40 patients with radiographically and clinically diagnosed chronic periapical lesions or radicular cysts that were surgically removed. They were divided into two groups: (1) The study group comprised 20 patients who received daily LPL irradiation of the operative field (bone defect) for 7 postoperative days (energy output 4 J/cm^2, with constant power density of 50 mW, wavelength 637 nm); (2) The control group comprised 20 patients who did not receive postoperative LPL irradiation of postsurgical bone defects. Healing of bone defects was evaluated by densitometry, investigating optical density in precisely defined areas of the panoramic radiographs made immediately after the operation, and 3 and 6 months thereafter. Comparison of identical anatomical details on different radiographs was made by the use of PVC foil, with inscribed vertical and horizontal lines at equal distances.

Results: Differences in values of relative optical density were statistically significant between the examined groups of patients in every period of investigation, as well as between the values registered within each group during the period of investigation. In the study group of patients who were irradiated with the LPL, the process of bone defect healing was noticeably accelerated in all periods of investigation, the mean optical density being 1.56 after 6 months in the study group in comparison to 1.28 in controls, which was statistically significant. Comparing the investigated groups of patients, significantly faster bone regeneration at the periphery of defects (greater optical density) was noticed in the study group than in the control, in all the periods of investigation (2.06 at the beginning, 1.81. after 3 months, and 1.56 after 6 months in the study group, in comparison to 1.74, 1.50 and 1.32, respectively, in the control).

Conclusion: LPL irradiation of periapical bone defects with GaAlAs laser, using daily intraoral irradiation with energy output of 4 J/cm^2, significantly influences healing of periapical bone defects in vivo. Bone regeneration was faster at the periphery of the defects, which agrees with the fact that bone regeneration proceeds from periphery to central areas of the defect.

Keywords: low-power laser, GaAlAs laser, periapical surgery, bone healing, clinical study.

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Wound healing is a complex process that comprises a wide spectrum of cellular reactions and biological responses of the organism, serving to preserve function.[11] Generally speaking, this is a physiological process, but its prolongation or deviation from the normal repair process could be regarded as pathological.[2] Wound healing comprises the following processes: induction of acute inflammation, regeneration of parenchymal cells, migration and proliferation of parenchymal and connective tissue cells, synthesis of protein and extracellular matrix, remodelling of connective tissue and parenchymal components, and, as the last step, collagen formation.[11]

Oral wounds, being in a highly dynamic and non-homogenous environment, are exposed to numerous favorable and unfavorable influences. Apart from that, they heal faster than wounds in other parts of the body, primarily due to the fact that some characteristics of the oral environment – such as the presence of saliva – positively direct and secure the healing process, reducing the frequency of complications.[3]

Bone defects in jaws usually originate after tooth extraction or removal of chronic periapical lesions. Fast and regular healing of these defects, implying their filling with bone tissue, presents the main prerequisite for restitution of function. Bone healing of jaw defects takes place in the following stages:[2] formation of a blood clot filling the defect, organization of the clot and replacement of the clot by granulation tissue, formation of connective tissue, and formation of trabecular bone. General opinion holds that spongy bone completely fills the jaw defect caused by oral surgery (after apicoectomy or surgical extraction of impacted teeth), depending to some extent on the size and location of the defect.

Healing of the bone defect created by cystectomy or tooth root apicoectomy comprises reparation of all periodontal tissues: cementum, periodontal membrane, and bone. Since such complete regeneration seldom occurs, it is generally accepted that healing is successful if complete ossification of the defect occurs, regardless of the forming of periodontal membrane around the apicoectomized root.[4]

An ideal treatment capable of accelerating wound healing and enabling complete bone regeneration does not yet exist. Numerous treatments and bone substitutes have been used to fill in the bone defects, but without significantly influencing the rate of regeneration. However, many studies point out that low-power laser (LPL) irradiation exerts a stimulating effect on the process of wound healing. This stimulating effect has been noticed with the use of LPL regardless of the wavelength, demonstrating faster fibroblast proliferation, bone regeneration, collagen production, and enzymatic activity.[5,8] These findings were obtained mainly from in vitro studies. The aim of this study was to investigate the influence of LPL irradiation in vivo on the bone healing of jaw defects created after surgical treatment of chronic periapical lesions.

MATERIALS AND METHODS

This prospective clinical study encompassed 40 patients with radiographically and clinically diagnosed and surgically removed chronic periapical lesions or radicular cysts on the single-root teeth in the maxilla, regardless of the need for orthograde or retrograde root filling. Surgery was performed under local anesthesia, with a buccal approach and incision in the attached gingiva, in the conventional manner in all patients. Concerning the postoperative course, all the patients gave their consent to enter the study and were divided into two groups, after being completely informed about the procedure:

1. The first (study) group (20 patients) received daily LPL irradiation of the operative field (bone defect) for 7 postoperative days. The patients received low-power GaAlAs laser irradiation (Medicolaser 637, Technoline; Belgrade, Serbia and Montenegro) 10 min after surgery, intraorally from a distance of 1 cm (Fig 1). The energy output was 4 J/cm^2, with constant power density of 50 mW, and a wavelength of 637 nm (visible red light).
2. In the second (control) group (20 patients), postsurgical bone defects were not irradiated by LPL postoperatively; these patients received only the usual instructions concerning postoperative oral hygiene and standard pain control.

The healing of bone defects was evaluated by densitometry, recording optical density with the densitometer DT II 05 (Lunar; London, UK) (Fig 2) and comparing the optical density in the operative area on panoramic radiographs made immediately after surgery, as well as 3 and 6 months later. The fundamental principle of the method is based on the comparison of light intensity before and after it has passed through the precisely defined area of the radiograph. All radiographs of the same patient, recorded in different periods, were made under the same radiographic conditions concerning the patient's position, technical conditions (kV, mAs), and radiograph chemical treatment (type, concentration and temperature of chemicals). Comparison of identical anatomical details on different radiographs was made using PVC foil with inscribed vertical and horizontal lines equally distributed to form areas of 2 mm^2, which was superimposed on the radiograph. To place the foil in same position for different radiographs of the same patient, five characteristic points (anatomical details) determining each radiograph served as markers.

Fig 1 Postoperative LPL irradiation of the periapical area.

Fig 2 Densitometer DT II 05.

Table 1 Mean values of optical density on radiographs of LPL-irradiated and control patients

Patients	Number of measurements	Initially	Optical density after 3 months	After 6 months	Significance (Wilcoxon Z-test)		
		$x \pm SD$	$x \pm SD$	$x \pm SD$	$Z_{(1,2)}$	$Z_{(1,3)}$	$Z_{(2,3)}$
LPL	265	2.08 ± 0.53	1.82 ± 0.54	1.56 ± 0.48	14.1***	14.1***	14.1***
Control	270	1.73 ± 0.50	1.47 ± 0.47	1.28 ± 0.45	14.3***	14.1***	14.0***
		$t_{(1)}$=7.858	$t_{(2)}$=7.315	$t_{(3)}$=5.967			
		p < 0.001	p < 0.001	p < 0.001			

*** p < 0.001

All data were statistically evaluated by the Student's t-test and the Wilcoxon non-parametric z-test.

RESULTS

Differences in values of relative optical density were statistically significant concerning both investigated groups of patients in every period of investigation, as well as between the values registered within each group during the period of investigation (Table 1). Moreover, in the group of patients irradiated with the LPL, the process of bone defect healing was noticeably accelerated in all periods of investigation.

Optical density values in the peripheral zone of 4 mm indicated statistically significant changes in both groups of patients in the tested time periods, concerning both the individual values (excluding patient No 9 in the first group; Tables 2 to 4) and average values (Figs 3 and 4). Lower values of bone density noticed in some bone defects of control patients were most likely the result of fibrous healing.

Comparing the investigated groups of patients, significantly faster bone regeneration at the periphery of defects (greater optical density) was noticed in the study group than in the control, in all the periods of investigation.

DISCUSSION

The possibility of accelerating healing and bone defect regeneration is still an interesting phenomenon from a surgical point of view because of the reduced morbidity

Table 2 Mean values of optical density in the peripheral area (4 mm) on radiographs of LPL-irradiated patients

Patient	Number of measurements	Initially	Optical density after 3 months	After 6 months		Significance (Wilcoxon Z-test)	
		x ± SD	x ± SD	x ± SD	$Z_{(1,2)}$	$Z_{(1,3)}$	$Z_{(2,3)}$
1	9	2.88 ± 0.26	2.73 ± 0.26	2.22 ± 0.20	2.68**	2.67**	2.67**
2	7	1.53 ± 0.13	1.36 ± 0.14	1.02 ± 0.17	2.37*	2.37*	2.37*
3	8	1.39 ± 0.21	0.94 ± 0.13	0.77 ± 0.09	2.52*	2.52*	2.52*
4	13	1.28 ± 0.18	1.15 ± 0.15	0.91 ± 0.14	3.19**	3.19**	3.19**
5	6	2.09 ± 0.26	1.89 ± 0.27	1.71 ± 0.25	2.23*	2.20*	2.20*
6	7	2.12 ± 0.28	1.93 ± 0.29	1.69 ± 0.29	2.37*	2.37*	2.37*
7	7	2.42 ± 0.19	2.00 ± 0.10	1.70 ± 0.08	2.37*	2.37*	2.37*
8	11	1.69 ± 0.11	1.41 ± 0.11	1.23 ± 0.09	2.94**	2.94**	2.94**
9	4	1.51 ± 0.30	1.21 ± 0.08	1.01 ± 0.04	1.83	1.83	1.83
10	7	1.78 ± 0.42	1.66 ± 0.47	1.51 ± 0.33	2.37*	2.37*	2.37*
11	7	2.18 ± 0.24	1.90 ± 0.20	1.63 ± 0.24	2.37*	2.37*	2.37*
12	7	2.46 ± 0.12	2.27 ± 0.08	2.01 ± 0.06	2.37*	2.37*	2.37*
13	7	2.27 ± 0.08	2.06 ± 0.08	1.80 ± 0.10	2.38**	2.38**	2.38**
14	6	1.69 ± 0.12	1.31 ± 0.13	1.08 ± 0.11	2.20*	2.20*	2.20*
15	11	2.41 ± 0.14	2.18 ± 0.12	1.91 ± 0.14	2.94**	2.94**	2.94**
16	6	2.60 ± 0.18	2.30 ± 0.18	2.05 ± 0.17	2.20*	2.20*	2.21*
17	7	2.75 ± 0.19	2.43 ± 0.17	2.14 ± 0.15	2.38*	2.37*	2.37*
18	7	1.72 ± 0.24	1.41 ± 0.25	1.18 ± 0.21	2.38*	2.38*	2.37*
19	6	2.04 ± 0.19	1.80 ± 0.20	1.54 ± 0.20	2.21*	2.21*	2.21*
20	11	2.56 ± 0.18	2.28 ± 0.17	2.05 ± 0.16	2.94**	2.94**	2.95**
Total	154	2.06 ± 0.58	1.81 ± 0.53	1.56 ± 0.48	10.8***	10.6***	10.5***

* p < 0.5 ** p < 0.01 ***p < 0.001

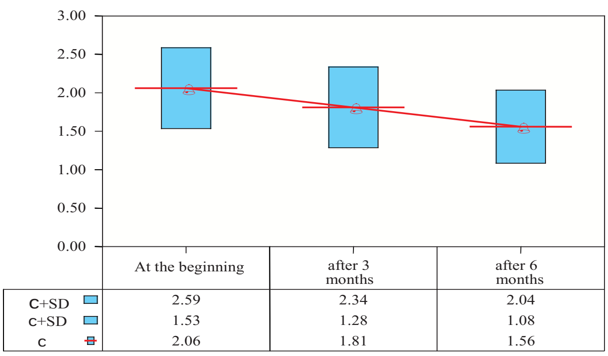

Fig 3 Mean values of optical density in the peripheral area (4 mm) on radiographs of LPL-irradiated patients.

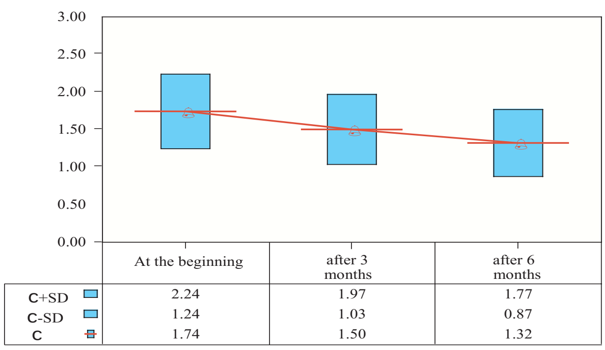

Fig 4 Mean values of optical density in the peripheral area (4 mm) on radiographs of control patients.

Table 3 Mean values of optical density in the peripheral area (4 mm) on radiographs of control patients

Patient	Number of measurements	Initially	Optical density after 6 months	After 3 months	Significance (Wilcoxon Z-test)		
		x ± SD	x ± SD	x ± SD	$Z_{(1,2)}$	$Z_{(1,3)}$	$Z_{(2,3)}$
1	6	1.77 ± 0.25	1.48 ± 0.14	1.32 ± 0.12	2.20*	2.20*	2.20*
2	9	2.07 ± 0.17	1.83 ± 0.18	1.65 ± 0.17	2.68**	2.68**	2.68**
3	9	2.51 ± 0.22	2.20 ± 0.16	2.04 ± 0.16	2.67**	2.67**	2.67**
4	8	1.41 ± 0.12	0.92 ± 0.14	0.78 ± 0.12	2.52*	2.52*	2.53*
5	14	1.37 ± 0.15	1.16 ± 0.13	0.99 ± 0.12	3.30***	3.30***	3.30***
6	8	1.06 ± 0.16	0.94 ± 0.14	0.84 ± 0.18	2.53*	2.52*	2.52*
7	6	1.84 ± 0.33	1.69 ± 0.31	1.37 ± 0.33	2.20*	2.20*	2.20*
8	8	1.08 ± 0.07	0.98 ± 0.05	0.89 ± 0.05	2.53*	2.53*	2.53*
9	6	1.68 ± 0.24	1.41 ± 0.18	1.19 ± 0.15	2.20*	2.21*	2.20*
10	7	1.93 ± 0.63	1.72 ± 0.56	1.54 ± 0.57	2.37*	2.37*	2.38*
11	6	1.85 ± 0.50	1.61 ± 0.52	1.37 ± 0.46	2.20*	2.20*	2.21*
12	7	1.74 ± 0.40	1.52 ± 0.37	1.33 ± 0.32	2.37*	2.37*	2.37*
13	8	1.99 ± 0.08	1.70 ± 0.12	1.46 ± 0.10	2.52*	2.54*	2.52*
14	8	1.82 ± 0.18	1.58 ± 0.19	1.39 ± 0.16	2.54*	2.53*	2.53*
15	8	2.37 ± 0.36	2.14 ± 0.34	1.92 ± 0.34	2.53*	2.52*	2.52*
16	8	1.21 ± 0.05	1.03 ± 0.02	0.78 ± 0.03	2.54*	2.52*	2.52*
17	7	2.10 ± 0.14	1.89 ± 0.14	1.73 ± 0.13	2.38*	2.37*	2.37*
18	7	2.44 ± 0.21	2.17 ± 0.20	1.94 ± 0.21	2.37*	2.37*	2.38*
19	8	1.29 ± 0.13	1.12 ± 0.13	0.96 ± 0.14	2.53*	2.55*	2.54*
20	5	1.46 ± 0.17	2.24 ± 0.17	1.07 ± 0.13	2.02*	2.02*	2.02*
Total	153	1.74 ± 0.50	1.50 ± 0.47	1.32 ± 0.45	10.7***	10.7***	10.7***

* $p < 0.5$ ** $p < 0.01$ ***$p < 0.001$

Table 4 Mean values of optical density in the peripheral area on radiographs of LPL-irradiated and control patients

Patients	Number of measurements	Initially	Optical density after 3 months	After 6 months	Significance (Wilcoxon Z-test)		
		x ± SD	x ± SD	x ± SD	$Z_{(1,2)}$	$Z_{(1,3)}$	$Z_{(2,3)}$
LPL	154	2.06 ± 0.53	1.81 ± 0.53	1.56 ± 0.48	10.8***	10.6***	10.5***
Control	153	1.74 ± 0.50	1.50 ± 0.47	1.32 ± 0.45	10.7***	10.7***	10.7***
		$t_{(1)}$=5.441 $p < 0.001$	$t_{(2)}$=5.421 $p < 0.001$	$t_{(3)}$=4.519 $p < 0.001$			

***$p < 0.001$

and local complications ("dead spaces" during healing of large bone defects). There are numerous data indicating the successful use of LPL irradiation in processes of bone repair.[3,6,7] Moreover, the powerful biostimulating effect reflected in an increased metabolic rate and microcirculation with subsequent increase of cell mitosis of epithelial and fibrous tissue and bone cells is emphasized.[12] A stimulating effect of LPL is noticed after the use of almost all utilized wavelengths.[5,8]

In clinical studies, on the basis of subsiding symptoms of periapical lesions, Nagasawa[9] concluded that LPL irradiation exerts a favorable effect on bone regeneration in the periapical region. Faster healing of soft tissue and bone was noticed with postoperative LPL irradiation in periodontal surgery.[5] LPL irradiation is considered to contribute to faster bone maturation and callus formation by strongly influencing the osteogenic potential of surrounding cancellous bone and activation of osteoblasts.[7]

The fibrous healing indicated by the lower values of bone density noticed in some control bone defects is not an uncommon phenomenon in periapical surgery; according to Andreasen and Rud,[1] it occurs more frequently (approximately in 50%) than was noticed in our study.

CONCLUSION

On the basis of bone optical density evaluation, our study reveals that LPL irradiation of periapical bone defects with GaAlAs laser, using daily intraoral irradiation with energy output of 4 J/cm^2, constant power density of 50 mW, and 637 nm wavelength, significantly promotes healing of these defects. Bone regeneration was faster at the periphery of the defects, which corresponds to the fact that bone regeneration proceeds from the periphery to central areas of the defect. Measurement of relative optical density on panoramic radiographs was done with a densitometer established to have an absolute error of only 0.02,[10] which indicates the accuracy of the densimetric method and the validity of evaluation of the obtained data.

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REFERENCES

1. Andreasen JO, Rud J. Modes of healing histologically after endodontic surgery in 70 cases. Int J Oral Surg 1972;1:148-160.
2. Arambašiç M, Bordeviç M, Jovanoviç V. Opta stologija. Beograd: Svetozar Markoviç, 1983 (in Serb).
3. Kafedžiska V. The influence of saliva on the coagulum in the wound after tooth extraction. PhD Thesis, Faculty of Stomatology, Beograd, 1987 (in Serb).
4. Simpson HE. The healing of extraction wounds. Br Dent J 1969; 126:550-557.
5. Kawamura M. Effect of Nd:YAG and diode laser irradiation on periodontal wound healing. Innov Techn Biol Med 1990;11:113-118.
6. Kokino M, Tozun R, Alatli M, Temelli Y, Berkman M, Altug T. Effect of laser irradiation on tendon healing. Proc Internat Congr Laser Med Surg, Bologna, 1986:405-412.
7. Kokino M, Tozun R, Alatli M, Temelli Y, Berkman M, Altug T. An investigation of the simulating effect of laser in callus in the treatment of fractures. Proc Internat Congr Laser Med Surg, Bologna, 1986:387-393.
8. Nagasawa A. Application of LLLT in dentistry. In: Ohshiro T (ed). Low reactive laser therapy - practical application. John Wiley and Sons, 1991:76.
9. Nagasawa A. Clinical Applications of LLLT in Dental and Oral Surgery in the Urawa Clinic. Int J Low Level Laser Therapy 1991; 3:119.
10. Postić S. Analysis of osteoporotic changes in the mandible and their clinical significance. PhD Thesis, Faculty of Stomatology, Beograd, 1998 (in Serb).
11. Robbins SL. Inflammation and Repair. In: Cotran RS, Kumar V, Robbins SL (eds). Robbin's Pathology Basis of Disease. Philadelphia: WB Saunders, 1994:51-92.
12. Zivković B, Katić V. Enzyme-histochemistry study of soft-laser treatment during wound healing. Zbornik radova VI Kongresa patologa Jugoslavije, Zlatibor, 1994; pp 14-15 (in Serb).

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