Effect of Low-Level Laser Therapy on Bone Repair: Histological Study in Rats

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Background and Objectives: Bone remodeling is characterized as a cyclic and lengthy process. It is currently accepted that not only this dynamics is triggered by a biological process, but also biochemical, electrical, and mechanical stimuli are key factors for the maintenance of bone tissue. The hypothesis that low-level laser therapy (LLLT) may favor bone repair has been suggested. The purpose of this study was to evaluate the bone repair in defects created in rat lower jaws after stimulation with infrared LLLT directly on the injured tissue.

Study Design/Materials and Methods: Bone defects were prepared on the mandibles of 30 Holtzman rats allocated into two groups (n = 15), which were divided in three evaluation periods (15, 45, and 60 days), with five animals each. Control group—no treatment of the defect; laser group—single laser irradiation with a GaAlAs semiconductor diode laser device (λ = 780 nm; P = 35 mW; t = 40 s; θ = 1.0 mm; D = 178 J/cm²; E = 1.4 J) directly on the defect area. The rats were sacrificed at the pre-established periods and the mandibles were removed and processed for staining with hematoxylin and eosin, Masson’s Trichrome and picrosirius techniques.

Results: The histological results showed bone formation in both groups. However, the laser group exhibited an advanced tissue response compared to the control group, abbreviated the initial inflammatory reaction and promoting rapid new bone matrix formation at 15 and 45 days (P < 0.05). On the other hand, there were no significant differences between the groups at 60 days.

Conclusion: The use of infrared LLLT directly to the injured tissue showed a biostimulating effect on bone remodeling by stimulating the modulation of the initial inflammatory response and anticipating the resolution to normal conditions at the earlier periods. However, there were no differences between the groups at 60 days.

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Key words: animals; bone remodeling; LLLT

INTRODUCTION

The need for repairing bone defects has attracted the interest of researchers of several health fields [1]. Currently, bone increment stimulus has been achieved with the application of chemical stimuli, biomaterials, bone morphogenetic proteins (BMPs) as well as the use of physical stimuli, such as ultrasound, electromagnetic fields and more recently low-level laser therapy (LLLT) [2].

Among the chemical stimuli, BMPs are in the forefront of bone repair studies. These proteins are osteoinductive growth factors with potential to act on mesenchymal cells, stimulating a wide array of cell events such as, proliferation, chemotaxis, differentiation, and production of extracellular matrix proteins [3–7].

While the results of physical stimuli associated to bone tissue repair are not yet clearly understood, some knowledge are accepted. Among these, the alterations of ion channel properties and the increase of osteoblast metabolic activity tend to abbreviate the bone repair process [7,8].

One of the hindrances in the bone repair process is the absence of microcirculation at the site of injury, mainly in patients with bone pathologies. The presence of vasculature is a key condition to the occurrence of osteogenesis, which determines the initial events of bone repair [9,10].

Several studies [11–16] have demonstrated that LLLT can biomodulate and accelerate the repair process, stimulating cell proliferation, and vasculization in injured tissues. However, the most important issue is how much energy is necessary to reach a suitable clinical application to yield significant new tissue formation with higher quality of organization within a shorter time. Moreover, the laser light can be delivered either directly on the injured tissue, transcutaneously or postsurgically [17].

LLLT has been indicated for different clinical treatments, encompassing a wide array of applications that range from pain control to tissue healing in general.
[9,14,16,18,19]. Already frequently used in several health fields, low power lasers have begun to impact on dentistry as well. However, whether LLLT can be useful as a treatment modality in hard tissue healing, and how it may beneficial and effective is yet to be determined. It is necessary to investigate comprehensively the effects of LLLT on tissue at a cellular level as the mechanisms of action of clinical laser therapy on bone are not fully elucidated [20].

The purpose of this study was to investigate in bone defects created in rat mandibles the hypothesis that the stimulation with infrared LLLT at a single dose directly to the surgically injured tissue accelerates new bone formation.

MATERIALS AND METHODS

The research proposal was reviewed by the Ethics in Animal Research Committee of the School of Dentistry of Araçarara, São Paulo State University, Brazil (Process number 02/2004) and the study design was approved.

Thirty male, adult Holtzman rats weighing 300 g on average were used in this study. The animals received an intramuscular injection of xylazine chloride (Rompun®; Bayer do Brazil, São Paulo, SP, Brazil; 0.04 ml/100 g body weight) to attain muscular relaxation and were anesthetized intramuscularly with ketamine chloride (Ketalar®; Parke-Davis, Aché Laboratório, São Paulo, SP, Brazil; 0.08 ml/100 g body weight).

After shaving and asepsis of the mandible base with 2% chlorhexidine, a 1-cm long incision was made, skin and periosteal flaps were elevated, the underlying bone tissue was exposed and a groove-shaped defect (4 mm long; 10 mm long) was prepared using a 0.58 cylindrical stainless steel bur at low speed under constant sterile saline coolant. Thereafter, the animals were randomly assigned to two groups (n = 15), according to the treatment of the bone defect. G1 (control) — the periosteum was repositioned over the defect and sutured internally, and the incision was closed with polyglactin sutures (Ethicon, Johnson & Johnson, São José dos Campos, SP, Brazil); G2 (laser) — the bone defect area was stimulated with low-level laser and then the periosteal and skin flaps were repositioned and sutured, as described in G1. The low-level laser source used in this group was a gallium aluminum arsenide semiconductor diode laser device (Laser Beam Multi Laser DR 500 device; Laser Beam Indústria e Tecnologia Ltda., Niterói, RJ, Brazil; λ = 780 nm; P = 50 mW; θ = 1.0 mm; t = 49 s). The laser beam was delivered with an optical fiber on continuous emission mode in direct contact with the bone defect area in a single application. The useful output power had a 80% loss. Therefore, the useful power at the fiber tip was 35 mW as measured with a radiometer (Coherent Fieldmaster, Coherent, Palo Alto, CA), resulting in a fluency of 178 J/cm² and total energy of 1.4 J.

After surgery, the animals received doses of parecoxib analgesic (Tylenol®; Janssen-Cilag, São José dos Campos, SP, Brazil; 1.5 mg/100 g body weight) in order to minimize the surgical trauma. Throughout the experimental period, the animals were housed in individual cages and maintained under a feeding regimen with ration and water ad libitum, and good temperature, illumination and hygiene conditions. Within the first three postoperative days, the animals were fed a soft-consistency cornmeal-based diet [21,22].

Five animals per group were sacrificed by anesthetic overdose at each of the predetermined evaluation periods at 15, 45, and 90 postoperative days. The mandibles were removed and photographed with the aid of a stereoscopic lens at 20× magnification (Citofal; Carl Zeiss Jena, Germany). The pieces were fixed in buffered Lillie's formalin [23] during 86 hours, decalcified in Morse solution [24] during 30 days and thereafter submitted to routine laboratorial processing. The specimens were embedded in paraffin and longitudinal 6 μm thick sections were cut in a buccolingual plane and stained with hematoxylin and eosin for histomorphological analysis, and Masson's trichrome and picrosirius staining for identification of the areas of new bone formation and the degree of collagen maturation, respectively.

The histomorphological analysis was performed under light microscopy and polarized light microscopy. Each specimen was independently examined by two trained examiners blinded to the treatment of each group. In case of disagreement, the specimen was re-evaluated and a consensus was reached between the examiners. The slide was evaluated prior to the identification of each group. The following histomorphological events were evaluated: (A) degree of inflammation; (B) formation and quality of bone tissue; (C) degree of collagen maturation (anisotropy), according to the birefringence obtained under polarized light microscopy. These events were scored and adapted from literature, as displayed on Table 1: A (95); R (3,96); and C [27].

Statistical Analysis

The morphological score data were analyzed statistically by the Kruskal Wallis test to compare the groups with respect to the evaluated histomorphological events (degree of inflammation, formation and quality of bone tissue, collagen maturation degree). BioEstat 3.0 statistical software package [28] was used and the significance level was set at α = 5%.

RESULTS

Macroscopic Results

Control group. The mesoscopic photomicrographs at 20× magnification showed the formation of a fibrotic tissue over the surgical wound (Fig. 1A) at 15 days. At 45 days (Fig. 1B), a fibrotic capsule was observed delimiting the defect area, with characteristics of a filling tissue. At 60 days, the specimens exhibited complete repair, but presented a discontinuity between the repaired lesion and the adjacent bone tissue (Fig. 1C).

Low-level laser group. On the other hand, the laser group (Fig. 2A) presented a bulged filling soft tissue
restricted to the lesion and contiguous to the surgical wound at 15 days. At 45 days (Fig. 2B), unlike the control group, the laser-treated group exhibited partial bone formation with vascularization. At the end of the 60-day period, the specimens were completely filled with bone tissue and numerous capillary vessels, and the surgical wound was in intimate contact with the adjacent bone (Fig. 2C).

**Histologic Results**

The histological results graded according to the criteria defined by the scores are displayed on Table 2.

**Control group.** At 15 days, it was observed the presence of a disorganized connective tissue with a thin fibrin network containing blood cells, fibroblasts, macrophages, and degenerating cells (Fig. 2A). No specimen showed any evidence of collagen fiber maturation. The fibers were randomly arranged and showed no birefringence. At 45 days, the wounds of the control specimens were partially filled by newly formed bone tissue composed of numerous osteoblasts differentiating into osteocytes and forming several layers. All five specimens presented moderate inflammation with large medullary spaces (Fig. 3B). The picrosirius staining technique revealed low anisotropy of collagen fibers. At 60 days (Fig. 3C), there was new bone formation with concentric lamellar organization of collagen fibers that constitute the secondary bone. All specimens showed absence of inflammation and surgical wounds totally filled with bone tissue and its respective union bone line. The picrosirius staining clearly labeled the interface between the surgical wound and the newly formed bone. Analysis under polarized light microscopy showed an intense anisotropy of collagen fibers (Fig. 5A).

**Low-level laser group.** On the other hand, the laser-irradiated group exhibited complete filling of the defects with a dense connective tissue contacting the wound lateral walls. There was a large number of differentiating fibroblasts and osteoblasts producing intrinsic collagen fibers within a large number of osteocytes (Fig. 4A). There was initial birefringence of collagen fibers characterizing an osteon, and a dense connective tissue composed of a large number of blood capillaries and osteoprogenitor cells. Analysis under polarized light microscopy showed low anisotropy of collagen fibers at 45 days, no inflammation was observed. All specimens presented new bone formation and had the defect almost completely filled with bone tissue with characteristics of secondary bone, and presence of lamellae in isolated areas of the surgical wound (Fig. 4B). A large number of blood capillaries were clearly observed in this period. The picrosirius staining showed bone tissue with concentric lamellae, demonstrating bone maturity. This maturity was evident due to the concentric arrangement of the collagen fibers, forming lamellae. There was

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**Table 1. Scores Attributed to the Different Histomorphological Events**

<table>
<thead>
<tr>
<th>Score</th>
<th>(A) Characterization—inflammation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absence of inflammatory cells</td>
</tr>
<tr>
<td>2</td>
<td>Moderate presence of inflammatory cells</td>
</tr>
<tr>
<td>3</td>
<td>Intense presence of inflammatory cells</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>(B) Characterization—formation and quality of bone tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tissue new formation (filling of the defect with connective tissue containing blood capillaries, fibroblasts, macrophages, and newly formed collagen fibers)</td>
</tr>
<tr>
<td>2</td>
<td>Dense connective tissue suggesting bone tissue differentiation with presence of a large number of cells and organizing fibers</td>
</tr>
<tr>
<td>3</td>
<td>New bone formation in which the connective tissue is differentiating to form a bone matrix or osteon</td>
</tr>
<tr>
<td>4</td>
<td>Presence of bone tissue</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Score</th>
<th>(C) Characterization—collagen maturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No evidence of bone union, filling of the surgical wound with connective tissue—isotropy (absence of birefringence)</td>
</tr>
<tr>
<td>2</td>
<td>Osteon (formation of connective tissue in bone with osteoprogenitor and osteogenic cells)—low anisotropy</td>
</tr>
<tr>
<td>3</td>
<td>Isolate immature bone spicules—moderate anisotropy</td>
</tr>
<tr>
<td>4</td>
<td>Compact bone formation—intense anisotropy (total polarization)</td>
</tr>
</tbody>
</table>

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**Fig. 1.** (Control group) A: 15 days—fibrotic tissue (F) on the bone defect (B); B: 45 days—presence of fibrotic capsule (F) delimiting the wound; C: 60 days—bone defect filled with bone tissue (B). Presence of blood capillaries (arrows). Original magnification ±20×.
also a union bone line between the recipient wound and the bone repair tissue with moderate anisotropy.

At the end of the experimental period, the bone tissue was completely incorporated to the recipient wound and was separated from its walls by a thin union bone line (Fig. 4C). In addition to the large number of osteocytes, the newly formed bone also presented large-sized Havers channels and numerous blood capillaries.

All specimens showed absence of inflammation, presence of compact bone with newly formed bone tissue and characteristics of greater organization and mineralization than the recipient wound bone. Analysis under polarized light microscopy showed intense anisotropy of collagen fibers (Fig. 5B).

Figures 6–8 display the medians of the scores of the evaluated histological events comparing the control and low-level laser groups along the evaluation periods.

**DISCUSSION**

The lower jaw bone was chosen for the present experimental model because of the good reproducibility of the masticatory forces acting on the wound area compared to the tibial bone [21,22]. Bone tissue repair is closely related to the amount of incident force on the traumatized region, which generates bone deflexion. This phenomenon is known as piezoelectricity [2,7]. Another important factor is that the lower jaw bone has an underlying residual compact lamina and bone trabeculae internally [29]. The decision for creating groove-shaped bone defects instead of circular defects, as published elsewhere [28,30], was based on the anatomic characteristics of this region. The body of the mandible of rats has an elongated shape, while the ramus of the mandible, chosen for defect preparation in other studies, has a flat shape, which facilitates the preparation of circular defects. Clinically, this type of tissue healing may simulate a bone graft area or even a fractured region to be repaired.

Internal sutures are essential to prevent contamination of the surgical wound filled by blood clot. Resorbable sutures were thus placed to avoid the need of a second surgical intervention. However, the use of resorbable sutures may induce an increase in initial inflammatory

**TABLE 9. Distribution of the Animals According to the Scores Attributed to the Histomorphological Events as a Function of Treatments (Control or Laser Irradiation)**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Total animals</th>
<th>Inflammation</th>
<th></th>
<th>Formation and quality of bone tissue</th>
<th></th>
<th>Collagen maturation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3</td>
<td>1 2 3 4</td>
<td>Scores</td>
<td>1 2 3 4</td>
<td>Scores</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Control</td>
<td>15days</td>
<td>5 0 2 3</td>
<td>5 0 0 0</td>
<td>0 0 0 0</td>
<td>5 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>45days</td>
<td>5 0 5 0</td>
<td>1 3 1 0</td>
<td>0 3 2 0</td>
<td>0 3 2 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60days</td>
<td>5 4 1 0</td>
<td>0 0 1 4</td>
<td>0 0 2 3</td>
<td>0 0 2 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser</td>
<td>15days</td>
<td>5 4 1 0</td>
<td>1 4 0 0</td>
<td>0 5 0 0</td>
<td>0 5 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>45days</td>
<td>5 4 1 0</td>
<td>0 0 5 0</td>
<td>0 0 5 0</td>
<td>0 0 5 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60days</td>
<td>5 5 0 0</td>
<td>0 0 0 5</td>
<td>0 0 0 5</td>
<td>0 0 0 5</td>
<td></td>
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</tr>
</tbody>
</table>
response with phagocytes' activity to promote suture degradation [31,32]. Therefore, in the present study, analytical scores were attributed to mitigate the subjectivity of the results.

Bone was drilled to create defects at low speed and under copious saline irrigation in order to minimize the occurrence of cell necrosis due to heat generated by the contact of the stainless steel bur with the bone tissue. Heat generation during preparation of bone defects has been a concern since the 1950s, as emphasized by Ray and Holloway [11].

Evaluation periods of 15, 45, and 60 days are consistent with those of bone regeneration studies published elsewhere [21,31–33]. These periods correspond to the initial, medium and late repair response, as the surgical defects were completely filled by bone tissue at the final phase of the experiment.

The increase in ATP production and cell mitotic activity produced by LLLT has been confirmed by Karu et al. [34]. These outcomes suggest that LLLT optimizes the tissue
repair processes by stimulating the healing capacity of the connective tissue as well as new vessel formation from pre-existing vessels. Both factors contribute to tissue repair, especially in case of surgical wound healing. Therefore, laser therapy has been used in association with filling biomaterials [35] and/or in defects filled with blood clot alone [36].

Nevertheless, it has been clearly demonstrated that the effects of laser therapy are dose-dependent, that is, wavelength, power, frequency, fluency or dose and energy parameters are of paramount importance for reaching good results [19,37-39]. The laser parameter settings used in this study were chosen due to the good results obtained in a previous study on bone regeneration after implantation of biomaterials bioactivated by low-intensity laser [29]. On the other hand, the choice for a single laser application in direct contact with the wound area, unlike other studies that proposed multiple transcutaneous laser applications, intended to demonstrate the tissue repair potential of LLLT even after a single laser irradiation. A recent study [17] compared single versus multiple applications of GaAlAs laser on tissue repair and found that multiple laser treatments yielded better results than a single treatment with similar parameter settings. Our intention with a single laser application was to outline an immediate transsurgical protocol in contact with the surgically injured tissue, which may provide better effectiveness on clinical application, as the energy will be totally delivered to the wound area.

Comparison of a LLL-treated experimental group to a non-irradiated control group, as performed in the present study, has been described by different authors [8,13,35,40,41], while other studies have compared LLL-treated groups to placebo groups, in which laser irradiation was simulated or non-laser lights were used [17,42].

The picrosirius staining technique for analysis under polarized light microscopy is used to detect the maturation of type I collagen fibers. The color and intensity of collagen birefringence vary depending on the diameter of the fibers and thickness of the formed tissue. This method has the advantage of revealing the three-dimensional arrangement of collagen fibers, which are the major component of the bone tissue [13]. Anisotropy is defined as the degree of

Fig. 6. Inflammation score median between control and laser groups at different periods. Asterisks indicate statistically significant difference between groups at the same period. *P = 0.0169 and **P = 0.0149.

Fig. 7. Bone formation score median between control and laser groups at different periods. Asterisks indicate statistically significant difference between groups at the same period. *P = 0.0149 and **P = 0.0168.
orientation of the trabecular bone within the bone wound. High anisotropy indicates a strong orientation of the trabecular bone within the bone defect, whereas low anisotropy indicates a more disordered orientation of the trabecular bone [27]. The criteria for analysis of the histomorphological events after treatment with laser stimuli are varied. In most cases, the authors describe the histological and morphometric aspects observed, usually based on subjective analytical criteria [4–6,13,30,35, 43,44]. Nevertheless, Dahlin et al. [25] and Hedner and Linde [3] proposed less subjective criteria for analysis of histomorphological results. In the present investigation, the criteria used by these authors were adapted to our study design, in such a way that three histomorphological events were established for analysis. A 3-point scoring system and a 4-point scoring system with well-defined scores were used to quantify each one of these histomorphological events.

The results of the control group are in accordance to those published in other studies. At 15 days, it was observed the presence of a disorganized connective tissue with a thin fibrin network composed of blood cells, fibroblasts, macrophages, and degenerating cells [18,26,35,45]. The inflammatory response in this initial period is a natural body reaction. After trauma and local blood vessel injury, a fibrin-rich blood clot is formed. Four days later, granulation tissue is formed with new capillaries, macrophages, fibroblasts, and local growth factor secretion [46,47]. Although this inflammation is beneficial in the early repair process, it should be controlled to avoid discomfort during the healing process. At 45 days, there was formation of a fibrotic capsule within the osteone tissue with a large number of osteocytes. This condition demonstrates the formation of embryonic bone [29,48]. This phenomenon has been previously described [26,45] and occurs due to the interposition of other tissues in the surgical wound. To overcome this problem, it has been indicated the use of membranes and/or filling biomaterials that act as biological spacers. After 60 days, the surgically prepared control defects were completely filled by newly formed bone. The bone tissue exhibited concentric lamellae with evident collagen fiber birefringence detected by picrosirius staining. In addition, the presence of a strongly HE-stained union bone line was also observed in this period. This line represents the interface between the remaining and new formed bone [29,48].

On the other hand, the laser-treated group presented minimal inflammatory reaction with presence of organizing connective tissue, numerous blood capillaries and fibroblasts at 15 days. Similar results have been previously reported [13,14,18,35,37,40,42,49,50–53]. A possible reason for the shortening of the time for the regeneration process has been proposed by Kuru et al. [34], who demonstrated an increment in ATP level by stimulation of mitochondrial membranes in cell culture. The increase of intracellular energy results in an increment of protein synthesis, greater production of organic matrix and intense cellular mitosis [39]. Another possible explanation is the effect of microcirculation activation, which elevates the levels of oxygenation and tissue nutrition, thus improving considerably the metabolism and tissue regeneration [11]. Acceleration of the tissue repair process has also been observed by Ozawa et al. [53], who reported an increase in cell proliferation and differentiation after laser irradiation. This indicates that the osteoblasts synthesize greater amounts of phosphatase alkaline in the early phases of repair, thus originating the mineralization nodules. Similar response was obtained in the present in vivo study, in which statistically significant differences were observed in the mineralization process at the initial periods of tissue repair.

The comparison of the results of the present study to those of other investigations on 11.11.11 is hindered by the great diversity in methodological designs [37]. However, it is known that the wavelength, the total delivered energy, the emission frequency and the dose are directly related to an effective cell response to laser therapy [12,19,30].

At the 45-day period, the laser-irradiated bone defects were almost completely filled by newly formed bone tissue. The presence of concentric lamellae demonstrates an ongoing process of collagen fiber organization, leading the bone to present supporting characteristics in order to withstand the masticatory forces [48]. The analysis by polarized light microscopy showed a bone tissue with moderate anisotropy, which confirms the presence of secondary or lamellar bone. The picrosirius staining technique identified the structural changes of the newly formed bone matrix. The intensity of the staining and the collagen fiber birefringence varied according to the diameter and the tissue thickness. This analysis revealed a three-dimensional collagen fiber organization.

At the final period, the laser-irradiated wounds were totally filled with lamellar bone tissue amid the blood capillaries. Lozano et al. [10] pointed out the importance of a rapid wound site re-vascularization. For this reason, the
re-positioning of the periosteum is extremely important because the periosteal capillaries originate new capillaries by sprouting. These capillaries present undifferentiated cells juxtaposed to their endothelium, called pericytes, which are capable of differentiating into osteogenic cells that promote wound healing [11,29,30].

Regarding the scores attributed to inflammation, the statistical analysis confirmed the histological results. The laser-irradiated group at 15 and 45 days differed significantly from the control group at the same periods, which demonstrates the biostimulating action of LLLT [16,22,35,42,49,52]. Regarding bone formation score data, there was significant difference among the groups at 15 and 45 days. In these periods, LLLT biostimulation exhibited better results than the control condition (no biostimulation) [13,16,18,22,35,49,54].

The analysis of collagen fiber maturation and anisotropy showed statistically significant difference only at 15 days. There was no significant difference in collagen fiber maturation at 45 and 60 days. These outcomes may be explained by the fact that the histomorphological analysis revealed the process of formation (fibrillogenesis), maturation and organization of collagen fibers, leading to bone tissue formation. In this way, the statistical analysis corroborates the new bone formation at these periods [29,30].

CONCLUSIONS

Based on the results of this study and under the tested conditions, it may be concluded that the application of GaALAs infrared diode laser (830 nm, 35 mW power, 1.4 J energy and 178 J/cm² fluency) at a single dose directly to surgically created bone defects in rats abbreviated the bone healing process by stimulating the modulation of the initial inflammatory response with earlier resolution to the normal conditions. A single laser application to the injured tissue was effective in accelerating bone repair compared to the non-lased surgical wounds.

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