PHOTOBIOMODULATION OF ACUTE PAIN SYNDROME AFTER COMPLEX TOOTH EXTRACTION

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Abstract

The study evaluated various types of low-intensity photobiomodulatory therapy (PBMT) in reducing acute pain after complex tooth extraction. Complex extraction of maxillary molars and premolars (no more than two teeth, on one side) was performed in 119 patients (aged 18-44 years). In Group 1 (n = 28), PBMT was not performed. In Group 2 (n = 32), pulsed infrared laser radiation in combination with a magnetic mirror tip was used. In Group 3 (n = 30), dental tips with a pulsed infrared laser emitting head were used in the area of the socket formed after tooth extraction. In Group 4 (n = 29), a laser head with a continuous red spectrum was used. The exposure time of the tips and heads in all groups was 3 minutes in the projection of the extracted tooth. All patients underwent PBMT at 1, 24, and 48 hours after surgery. At these same times, acute pain was assessed using a visual analog scale (VAS) and a numerical rating scale (NRS) in millimeters. Acute pain was lowest already on the first postoperative day in the pulsed infrared laser group with a mirror magnetic head. Among the PBMT groups, the continuous red laser demonstrated the worst pain results. In the group without PBMT, pain requiring medical management persisted for up to 48-72 hours after tooth extraction.

Key words: photobiomodulating therapy, tooth extraction, pain syndrome, visual analogue scale, digital rating scale.

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For citations: Yudin D.K., Kastyro I.V., Romanko Yu.S., Ali R.B., Popadyuk V.I., Zaborova V.A., Dragunova S.G., Gusev K.S. Photobiomodulation of acute pain syndrome after complex tooth extraction, *Biomedical Photonics*, 2026, vol. 15, no. 1, pp. 11–18. doi: 10.24931/2413–9432–2026–15-1-11-18

ФОТОБИОМОДУЛЯЦИЯ ОСТРОГО БОЛЕВОГО СИНДРОМА ПОСЛЕ СЛОЖНОГО УДАЛЕНИЯ ЗУБА

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Резюме

В исследовании были оценены различные виды воздействия низкоинтенсивной фотобиомодулирующей терапии (ФБМТ) на снижение острого болевого синдрома после сложного удаления зуба. Сложное удаление моляров и премоляров верхней челюсти (не более двух зубов и с одной стороны) было проведено у 119 пациентов (возраст 18-44 года). В 1-й группе (n = 28) не проводили ФБМТ. Во 2-й группе (n = 32) применяли импульсное инфракрасное лазерное излучение в сочетании с магнитной зеркальной насадкой. В 3-й группе (n = 30) применяли стоматологические насадки с импульсной инфракрасной лазерной излучающей головкой в области, сформированной после удаления зуба лунки. В 4-й группе (n = 29) использоваи лазерную головку с непрерывным красным спектром. Время экспозиции насадок и головок во всех группах составляло 3 мин в проекции удаленного зуба. Всем пациентам ФБМТ проводили через 1, 24 и 48 ч после хирургического вмешательства и в эти же сроки оценивали острый болевой синдром при помощи визуально-аналоговой шкалы (ВАШ) и цифровой рейтинговой шкалы (ЦРШ) в мм. Острый болевой синдром был самым низким уже в первые постоперационные сутки в группе импульсного инфракрасного лазерного излучения с зеркальной магнитной головкой. Среди групп с ФБМТ худший результат по уровню боли был показан при применении непрерывного красного лазера. В группе без ФБМТ боль, требующая медикаментозной коррекции, сохранялась до 48-72 ч после удаления зуба.

Ключевые слова: фотобиомодулирующая терапия, удаление зуба, болевой синдром, визуально-аналоговая шкала, цифровая рейтинговая шкала.

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Для цитирования: Юдин Д.К., Кастыро И.В., Романко Ю.С., Али Р.Б., Попадюк В.И., Заборова В.А., Драгунова С.Г., Гусев К.С. Фотобиомодуляция острого болевого синдрома после сложного удаления зуба // Biomedical Photonics. – 2026. –Т. 15, № 1. – С. 11–18. doi: 10.24931/2413–9432–2026–15-1-11-18

Introduction

Tooth extraction is a surgical dental procedure that can lead to a number of complications [1]. The histological healing process of sockets after tooth extraction is a four-stage sequential process, including a blood clot phase, an inflammation phase, a proliferation phase, and a modeling and remodeling phase [2, 3]. Following tooth extraction, a blood clot begins to form within the first minutes, performing a protective function and serving as a matrix for further thrombus formation and subsequent healing. During the inflammation phase, immune-inflammatory reactions are triggered, accompanied by the formation of granulation tissue, which is critical for wound cleansing of necrotic tissue and creating conditions for healing [1, 4, 5]. Early in this stage, acute postoperative pain syndrome develops [6, 7]. During the recovery phase, active proliferation of bone cells, particularly osteoblasts, and the formation of a trabecular bone structure are observed, which is completed within 4 to 8 weeks after tooth extraction [8]. During the modeling and remodeling stage, bone tissue maturation and remodeling continue, ensuring the mechanical strength and stability of the alveolar ridge. These stages are key to successful healing and tissue restoration after dental interventions, and understanding these processes facilitates the development of effective treatment and rehabilitation methods [9].

The search for new methods to accelerate wound healing after tooth extraction and improve bone restoration is driven by the need for subsequent dental implantation [10, 11]. The use of low-intensity photobiomodulatory therapy (PBMT) allows for the development of new methods for patient rehabilitation during dental surgery [12]. The use of low-intensity PBMT in dental practice helps to reduce inflammatory reactions, has an antibacterial effect, prevents the development of pain, and promotes accelerated tissue healing in the area of damage due to its immune-correcting effect [13].

The aim of the study was to evaluate various options for the effect of low-intensity PBMT on reducing the intensity of acute pain after complex tooth extraction.

Materials and Methods

All patients were divided into 4 groups. Group 1 included 28 patients (7 women and 21 men) aged 18 to 46 years. These patients underwent complex maxillary molar extractions without the use of PBMT. Group 2 included 32 patients (10 women and 22 men) aged 20 to 47 years. PBMT was performed in Group 2 using a LO-904-25 cutaneous laser emitting head with a wavelength of 904 nm and a ZM-50 magnetic mirror attachment with a wavelength of 0.89 µm and a magnetic field strength of 50 mT. The pulsed radiation power in this group was 10 W, and the radiation frequency was 80 Hz. Group 3 included 30 patients (10 women and 20 men) aged 19 to 43 years. In this group, dental tips from the S-1 set were used for PBMT together with the LO-904-25 laser emitting head with a wavelength of 904 nm. The tips were placed in the oral cavity in the area of the socket formed after tooth extraction. The pulsed radiation power in this group was 7 W, and the radiation frequency was 80 Hz. Group 4 consisted of 17 men and 12 women (29 patients) with complex tooth extraction. For PBMT with continuous radiation, a laser head with a wavelength of 0.63 µm (laser head KLO 635-15) was used, emitting a continuous red spectrum, which has an anti-inflammatory (vascular) effect and stimulates cellular proliferation. The radiation power was 10 mW, the radiation frequency was 635 nm. The exposure time of the tips and heads in all groups was 3 minutes in the projection of the extracted tooth. All patients underwent the procedure 1, 24, 48, and 72 hours after surgery using the LAZMIK-01 device (Russia). All patients were prescribed ketorolac 10 mg orally, 1 tablet 3 times daily, for pain relief and amoxicillin + clavulanic acid, 875 mg + 125 mg, 1 tablet 2 times daily for 6 days, to prevent purulent complications. Complex extraction of maxillary premolars and molars was performed in all patients using mucosal infiltration anesthesia and intraosseous administration of articaine hydrochloride and epinephrine in a 1:200,000 ratio. The study included patients who had no more than two teeth removed from one side of the maxilla.

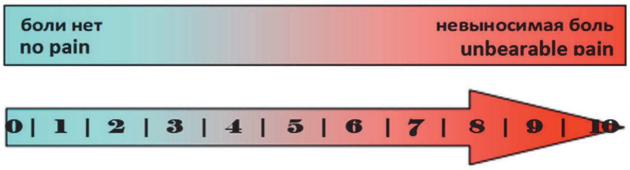

Рис. 1. Визуально-аналоговая шкала (a) и цифровая рейтинговая шкала (b) оценки интенсивности острого болевого синдрома.
Fig. 1. Visual analogue scale (a) and digital rating scale (b) for assessing the intensity of acute pain syndrome.

Pain Assessment

Acute pain was assessed at 1, 3, 24, 48, and 72 hours after complex tooth extraction using a visual analog scale (VAS) (Fig. 1a) and a numerial rating scale (NRS) (Fig. 1b), each 100 mm long. Patients indicated their pain level on the scale using a vertical line at the point on the scale that they believed corresponded to the intensity of their pain. The scales were presented to patients alternately: first the VAS and then the NRS [14]. For each patient, the mean values for both scales were calculated at each pain assessment interval.

Statistical Analysis

Data were processed using Microsoft Excel, MATLAB, STATISTICA 12.6, and JASP 0.14.0.0 software. The Wilcoxon signed-rank test was used to compare data within groups at different times after drug administration. The Kruskal-Wallis, Mann-Whitney, or Student's tests were used to compare data between groups. For each comparison, a significance level was determined based on statistical analysis (from p < 0.0001 to 0.05).

According to the Wilcoxon signed-rank test, acute pain, assessed by the mean VAS and NRS scores, was significantly lower in Group 1 at 1 hour postoperatively than at 3 hours (p < 0.0004). Pain levels decreased at 24 hours compared to 3 hours postoperatively (p < 0.007) and remained unchanged at 48 hours. On the 3rd day, the pain intensity significantly decreased compared to the previous day (p<0.048) (Fig. 2a, Table 1). In the 2nd group (pulsed laser therapy with a magnetic mirror attachment), the pain syndrome was significantly higher after 3 hours than after 1 hour after tooth extraction (p<0.046). The next day in the 2nd group, the intensity of acute pain significantly decreased compared to the previous point of its assessment (p<0.042), and on the 2nd day it decreased significantly again (p<0.0001). After another 24 hours (72 hours after the operation), the acute pain syndrome significantly decreased compared to the previous day (p<0.05) (Fig. 2b, Table 1). In the 3rd group (the group with pulsed laser therapy), 3 hours after the operation, the pain, as in the other groups, increased (p<0.029), and after 3 hours it significantly decreased (p<0.034) and continued to decrease significantly on the

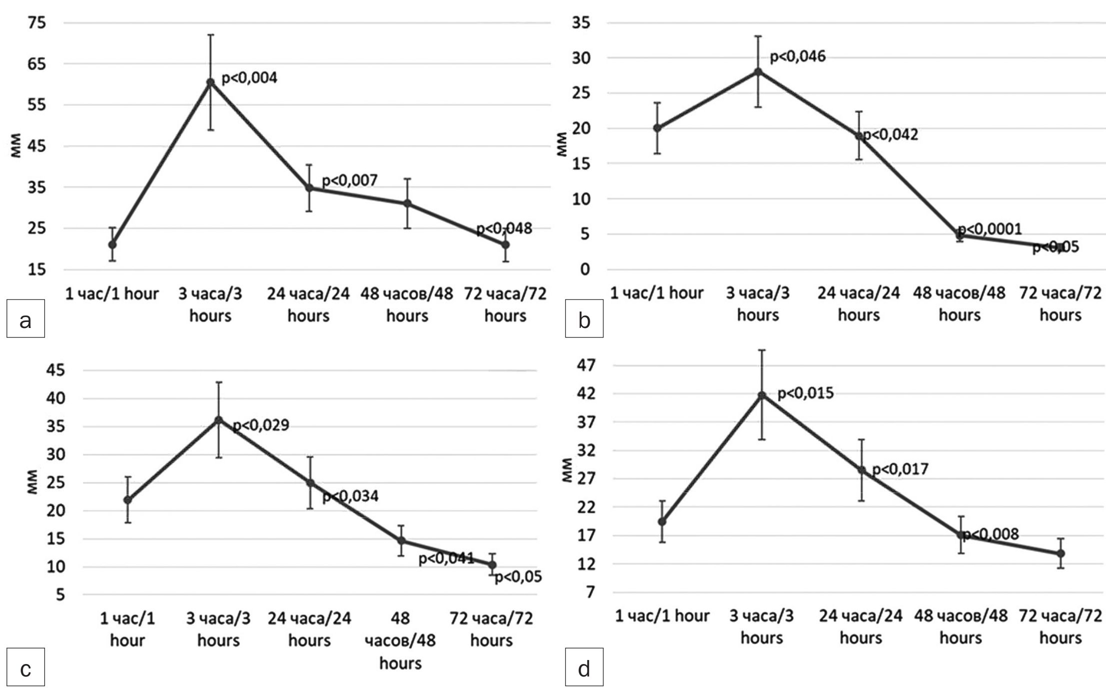

Рис. 2. Внутригрупповая динамика острого послеоперационного болевого синдрома по средним значениям ВАШ и ЦРШ у пациентов со сложным удалением зуба с применением ФБМТ: a – первая группа (группа сравнения); b – вторая группа (группа импульсного лазера+зеркальная магнитная насадка); c – третья группа (группа импульсного лазерного излучения); d – четвертая группа (группа непрерывного лазерного излучения).
Fig. 2. Intragroup dynamics of acute postoperative pain syndrome according to average VAS and NRS values in patients with complex tooth extraction using PBMT: a – first group (comparison group);b – second group (pulsed laser group + mirror magnetic attachment);c – third group (pulsed laser radiation group); d – fourth group (continuous laser radiation group).

2nd (p<0.041) and 3rd (p<0.05) postoperative days (Fig. 2c, Table 1). Thus, after 3 hours, acute pain significantly increased compared to the 1st postoperative hour (p<0.015), and at the 24th (p<0.017) and 48th (p<0.008) hours it decreased and remained the same at the 72nd postoperative hour of its control (Fig. 2d, Table 1). One hour after complex tooth extraction, no reliable differences were found in all groups of patients. The level of pain syndrome according to the average values of VAS and NRS corresponded to very mild pain.

According to the Mann-Whitney test, the intensity of acute pain in Group 1 3 hours after surgery was significantly higher than in Groups 2, 3, and 4 (p<0.018, p<0.032, and p<0.048, respectively). During this period, patients in Group 2 experienced the least pain compared to the pulsed laser and continuous laser groups (p<0.045 and p<0.048, respectively).

Twenty-four hours after tooth extraction, the severity of acute pain was significantly lower in Groups 2 (p<0.012), 3 (p<0.036), and 4 (p<0.043) compared to Group 1. Also, as at 3 hours after surgery, in patients of group 2 at the indicated time point, pain intensity was lower than in group 3 (p < 0.045) and group 4 (p < 0.048) (Fig. 3, Table 1).

Таблица 1
Показатели острой боли по средним значениям ВАШ и ЦРШ после сложного удаления зуба и применения фотобиомодулирующей терапии в раннем послеоперационном периоде

Table 1
Acute pain indices based on average VAS and NRS values after complex tooth extraction and the use of photobiomodulatory therapy in the early postoperative period

мм mm	1 час 1 hour	3 часа 3 hours	24 часа 24 hours	48 часов 48 hours	72 часа 72 hours
1-я группа (сравнения) 1st group (comparisons)	21,05±4,05	60,5±11,64	34,82±5,7	31,03±5,97	20,98±4,03
2-я группа (импульсный лазер+зеркальный магнит) 2nd group (pulse laser + mirror magnet)	20,04±3,6	28,09±5,04	18,96±3,4	4,79±0,86	3,07±0,55
3-я группа (импульсный лазер) 3rd group (pulse laser)	21,91±4,06	36,2±6,72	24,98±4,63	14,66±2,72	10,37±1,92
4-я группа (непрерывный лазер) 4th group (continuous laser)	19,48±3,68	41,75±7,89	28,55±5,39	17,08±3,22	13,84±2,62

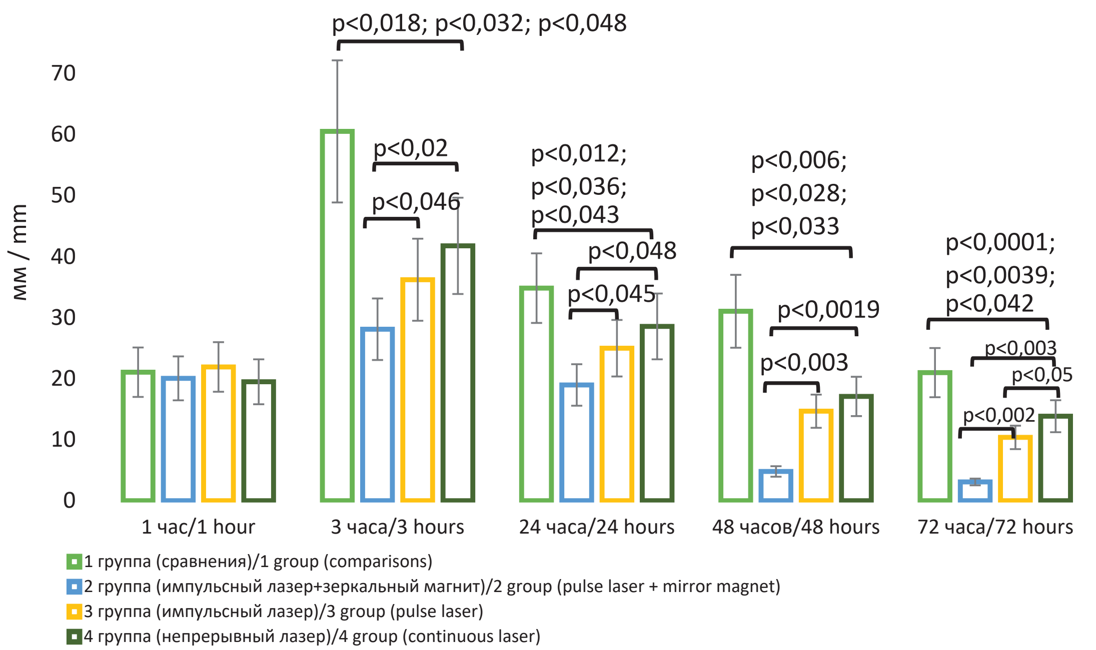

Рис. 3. Динамика острого послеоперационного болевого синдрома по средним значениям ВАШ и ЦРШ у пациентов со сложным удалением зуба с применением ФБМТ.
Fig. 3. Dynamics of acute postoperative pain syndrome according to average values of VAS and NRS in patients with complex tooth extraction using PBMT.

According to the Student's t-test, after 48 hours, pain severity was also higher in Group 1 than in the other PBMT groups (Groups 2, 3, and 4 – $p<0.006$, $p<0.028$, and $p<0.033$, respectively). In group 2, patients experienced practically no pain compared to group 3 ($p < 0.003$) and group 4 ($p < 0.0019$). On the third day (72 hours) after tooth extraction, patients in group 1 experienced significantly higher pain than in the groups with PBMT (groups 2, 3 and 4 - $p < 0.0001$, $p < 0.0039$ and $p < 0.042$, respectively). In group 4, the pain syndrome was significantly higher than in groups 2 ($p < 0.003$) and 3 ($p < 0.05$). Patients in group 2 experienced less intense pain than patients in group 3 ($p < 0.002$) (Fig. 3, Table 1).

Discussion

Healing of dental sockets after tooth extraction is a complex process involving the reconstruction of damaged soft and hard tissues. This process involves the proliferation and differentiation of osteoblasts, as well as the synthesis and mineralization of the extracellular matrix, leading to bone formation and remodeling. New bone formation is regulated by various cytokines, including transforming growth factor β (TGFB), vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), and bone morphogenetic protein (BMP) [15]. Controlling inflammation and reducing acute pain are particularly important in the early post-extraction period [5, 16-18]. In the study, pain levels were significantly lower in the PBMT groups at all assessment stages compared to patients without PBMT, indirectly indicating the positive anti-inflammatory effects of PBMT combined with nonsteroidal anti-inflammatory drugs (NSAIDs).

An analysis of the use of diode lasers generating radiation in the infrared region of the electromagnetic spectrum demonstrated their bactericidal effect in dental implantation, which can significantly reduce the risk of infectious complications [19]. Low-intensity lasers have been shown to have biostimulating and anti-inflammatory effects, making them useful in wound healing and bone tissue restoration [20, 21]. In the present study, in addition to NSAIDs, antibacterial therapy was also used, but no purulent complications were identified in any of the groups. Nevertheless, the observed pain level clearly indicates the advantage of using PBMT in the early period following complex tooth extraction.

Low-intensity laser irradiation has been shown to promote biostimulation and enhance tissue regenerative potential when applied in doses ranging from 1.5 to 3 J/cm^2. It has been shown that the regenerative properties of the oral epithelium increase, the activity of human gingival fibroblasts changes, and the activity of cells interacting with the implant is modulated, which improves tissue regeneration and reduces the duration of the rehabilitation period in patients [22, 23]. A study by M. Khadra *et al.* demonstrates interesting results regarding the effect of laser therapy on cellular proliferation and the synthesis of important biomolecules. An increase in cell proliferation 96 hours after laser irradiation indicates that laser therapy can activate tissue regeneration and restoration processes. Osteocalcin synthesis, a marker of osteoblastic activity, and TGF-beta (1), a key factor in tissue regeneration and healing, were significantly increased in samples exposed to 3 J/cm^2 laser radiation. This suggests that this therapy may improve implant osseointegration and accelerate bone healing. These results highlight the potential of low-level laser therapy as an effective tool in dentistry and orthopedics. Although, as with any new methods, it is important to continue conducting additional research to confirm and clarify these effects [24]. In the present study, the use of pulsed laser therapy in combination with a mirror magnetic tip resulted in lower pain levels compared to other types of PBMT, which requires clarification of the mechanisms of physiological and pathological changes in tissues depending on the physical characteristics of low-level laser therapy in further clinical and experimental studies.

It has also been established that the use of low-intensity PBMT has a positive effect on the stability of implants 3 weeks after dental implantation [25]. F. Chellini *et al.* evaluated the effect of laser radiation of 808±10 nm average power (2 W, 400 J/cm^2; CW or pulsed mode, 20 kHz, 7 µs, 0.44 W, 88 J/cm^2) on cell viability, their proliferation, adhesion, and also characterized the osteogenic differentiation potential in comparison with the action of chlorhexidine. The authors showed that PBMT has osteoinductive potential, when compared with the cytotoxic effect of chlorhexidine [26]. These data confirm our results, which showed a decrease in the level of acute pain. This indirectly suggests that the type of photobiomodulation applied in the present study helps to reduce inflammation. Reducing inflammatory responses and, consequently, pain levels, leads to improved bone regeneration [27-31].

PBMT improves socket healing during experimental destructive treatment with alendronate in rats. However, pulsed infrared radiation also has a positive effect on the cytoarchitecture of alveolar bone tissue in rats [32]. The present study demonstrated that the higher the PBMT frequency used, the less pain patients reported after complex tooth extraction. These data are consistent with studies evaluating the effectiveness of photobiomodulation after septoplasty. Several studies have shown that in this type of rhinosurgical intervention, which also involves the bony structures of the nasal septum, the use of PBMT leads to a reduction in acute pain in the early postoperative period [33-35]. In previous studies, we have found that low-intensity PBMT not only has a positive local effect, but also reduces the severity of stress reactions, which was demonstrated in studies of the hippocampus in rats after modeling septoplasty and surgical interventions on the maxilla. Thus, after the use of PBMT in the hippocampus of rats, the level of metabolism of the dopaminergic, noradrenergic and serotonergic systems changes [36]. Moreover, recent studies have shown that during the same experimental surgical interventions, PBMT reduces the level of expression of the stress protein p53, which is responsible for apoptosis, in neurons of the pyramidal layer of the hippocampus [37].

The combined use of PDT and PBMT also promotes more effective tissue restoration after chemoradiotherapy or radiation therapy [38]. Studies of the effectiveness of PBMT demonstrate that increased lipid peroxide and depletion of the antioxidant system are the primary mechanisms of the stress response to various physiological factors. In this process, cell membranes become targets for stress factors, pharmacological agents, and physical agents. PBMT can regulate the formation of free radicals and exert membranotropic effects during PDT of tumors [39, 40].

Conclusion

Although the obtained results indicate the superiority of PBMT over drug therapy alone and the advantage of a pulsed low-intensity infrared laser with a mirror magnetic attachment over a continuous red laser in the management of acute pain after complex tooth extraction, it is necessary to radiographically confirm the effectiveness of these methods in preserving the bone socket and alveolar ridge of the maxilla after complex tooth extraction in clinical practice.

The use of low-intensity PBMT in patients in the early postoperative period following complex tooth extraction results in postoperative pain intensity reductions of 28.2–53.6%, compared to patients without it.

The use of a pulsed low-intensity laser head in combination with a magnetic mirror attachment reduces acute pain in the early postoperative period following complex tooth extraction, compared to the use of a single-pulse emitter and continuous magnetic radiation.

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