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Original Research

Low-Level Laser and Light Therapy After Total Knee Arthroplasty Improves Postoperative Pain and Functional Outcomes: A Three-Arm Randomized Clinical Trial

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ABSTRACT

Background: We examined the effect of low-level laser therapy (LLLT) and Bioptron light therapy on pain and function following primary total knee arthroplasty.
Methods: A single-center, single-surgeon, prospective randomized clinical trial was performed with 3 groups of 15 patients: LLLT (804 nm), light (Bioptron; Bioptron AG, Wollerau, Switzerland), and controls. Range of motion (ROM), visual analog scale pain, opiate consumption (oxycodone in milligrams), knee swelling, and the Knee Society Score (KSS) were assessed before the surgery and on postoperative day 2, postoperative day 3, month 3, and month 12 after the operation.
Results: The preoperative scores were similar between groups. A higher ROM was observed with the LLLT group at all follow-ups except at the 12-month follow-up (3-month ROM: 116.8° vs 104.0° vs 92.3°; $P < .001$). The knee swelling at 3 months was similar between the LLLT and light groups (2.1 cm), which was lower than that in controls (2.1 cm, $P < .001$). Furthermore, visual analog scale pain decreased more in the LLLT group than in other groups (8.5 vs 7.2 vs 6.0 points) at 3 months ($P = .04$) but was similar at 12 months ($P > .05$). Also, the LLLT group consumed fewer opiate painkillers during the first month (48.3 vs 60.3 mg of oxycodone, $P = .02$). In the LLLT group, the KSS at 3 and 12 months and the KSS function score at 3 months exceeded minimally clinically important differences ($P < .05$).
Conclusions: In the early stages of recovery after total knee arthroplasty, LLLT and Bioptron light therapy could be helpful to control immediate and acute knee pain and swelling, reduce the need for opioids, improve ROM and functional scores, and improve recovery.
Level of Evidence: Therapeutic level I.

Introduction

Knee degenerative processes may eventually worsen, develop osteoarthritis (OA), and lead to patient limitations. Patients with advanced knee OA may benefit from total knee arthroplasty (TKA) to restore function and improve quality of life [1]. The management of acute postoperative pain and the early recovery following a TKA are major concerns for orthopedic surgeons. A multimodal analgesic approach is generally used, including nonsteroidal anti-inflammatory drugs (NSAIDs), opioids, periarticular injections, and peripheral nerve blocks [2,3]. Nevertheless, adverse effects of extended use, such as gastrointestinal bleeding and ulcers [4] and renal failure, are harmful to patients, especially the elderly [5]. Prolonged use of NSAIDs prevents local inflammation, which plays a key role in healing, destroys osteoblasts through apoptosis induction, and interferes with a successful healing response [6]. Moreover, an increase in the consumption of opioids leads to a rise in postoperative hospitalization length and complications during recovery [7].

Low-level laser therapy (LLLT) facilitates musculoskeletal rehabilitation with a focused beam of low-power light of wavelength

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between 600 and 1000 nm [8]. Several systematic reviews have established that LLLT as an adjunct to rehabilitation exercise can be beneficial for treating knee OA [9,10] and other musculoskeletal conditions [11]. According to evidence, LLLT provides anti-inflammatory properties that work at the cellular level by influencing the mitochondrial membrane, increasing ATP production and oxygenation of tissues, as well as regulating reactive oxygen species, cytokine levels, and inflammatory mediators [12–14]. Experimental studies have indicated that LLLT and NSAIDs have similar effects on reducing inflammatory cells, while LLLT has even greater efficacy in reducing proinflammatory cytokines (IL-1β, IL-6, and TNF-α), Prostaglandin E2, and myeloperoxidase [15,16]. However, controversy exists among studies, and some other comprehensive reviews found that LLLT is not beneficial for patients with OA [17,18].

Regarding using LLLT to improve postoperative outcomes, many studies in the field of endodontics and oral maxillofacial surgery revealed beneficial effects in terms of implant stability, bone loss, swelling, and postoperative pain [19–21]. Furthermore, some studies have investigated the impact of laser therapy on outcomes of TKA [22–26] and total hip arthroplasty (THA) [27], and others are in progress [28]. According to the study by Huang et al. on older patients with TKA, LLLT reduced postoperative pain severity and morphine usage within 72 hours after the surgery [22]. The study by Langella et al. on THA patients also showed that pain levels and inflammatory factors (TNF-α and IL-8, but not IL-6) decreased significantly in the laser group compared to those in the control group [27]. All in all, LLLT, compared to pharmacological agents, may have better risk benefits and appears to be effective in pain, swelling, and inflammation control and safe in patients with metallic implants with or without cement [23].

Polarized polychromatic noncoherent light (Bioptron light; Bioptron AG, Wollerau, Switzerland) is another new modality that physiotherapists use to ameliorate musculoskeletal conditions such as carpal tunnel syndrome [29] and lateral epicondylitis [30]. As with LLLT, Bioptron light is also a low-power beam, but it is a polychromatic and incoherent 1. It contains visible light at a wavelength of 480-700 nm and infrared at 700-3400 nm, but LLLT includes both types of light at 1 wavelength [31]. As far as no ultraviolet light exists in both LLLT and Bioptron light, there is no concern of tanning or skin burn, and they are safe for pregnant women [31]. However, the use of lasers is rarely associated with complications, including burns, infections, eye injuries, pigmentation abnormalities, and erythema [32]. Researchers claim that Bioptron light has bio-stimulating effects that help cellular processes accelerate and improve blood supply, but additional research is needed to determine exactly how it works [33]. To our knowledge, Bioptron light has not been studied as a supplement to an exercise program during recovery after a TKA surgery.

There is limited evidence that LLLT and light therapy can effectively manage musculoskeletal conditions such as knee OA [9,10], particularly after a joint replacement surgery [22–26]. Therefore, the present study compares the efficacy of LLLT and light therapy as physical modalities in the rehabilitation protocol of patients undergoing TKA with a control group. The study hypothesis is that LLLT reduces postoperative pain and opiate painkiller consumption, improves function, and does not cause complications in early rehabilitation protocols for knee OA patients who underwent TKA.

Material and methods

Study design and ethics statement

A single-center, single-surgeon, 3 parallel-armed, nonblinded prospective randomized clinical trial (RCT) compared LLLT, light therapy, and controls on postoperative pain and functional outcomes after a primary TKA. The institutional review board of our university of medical sciences reviewed the study's protocol and approved the study design, and there is no ethical concern. All patients signed informed consent statements and participated voluntarily. The study was registered in the Iranian registry of clinical trials (IRCT, registry code: IRCT20160809029286N4). This RCT followed the guidance in the Consolidated Standards of Reporting Trials (CONSORT) 2010 [34].

Study sample size and participants

The sample size was calculated based on the study by Eid and Aly (2015) [35] that used LLLT to treat hemarthrosis in hemophilic patients. We considered a β value of 20% and α of 5% for sample size calculation. We used the knee range of motion (ROM) at 6 weeks after the treatment (group 1: 106 ± 5.7 vs group 2: 100.1 ± 5.0) as a reference value for sample size calculation. Therefore, the calculation resulted in 15 patients in each group for a total of 45 patients.

In the present study, 45 consecutive patients (45 knees) were enrolled between February 2017 and February 2018 in Imam Khomeini hospital, Tehran, Iran. The summarized enrollment flow diagram and procedures are shown in the CONSORT flowchart (Fig. 1).

Inclusion and exclusion criteria

Inclusion criteria

- All patients who underwent a primary unilateral TKA for primary knee OA at our institution during the period (February 2017 to February 2018).
- American Society of Anesthesiologists score of I-III.

Exclusion criteria

- TKA in patients with rheumatoid arthritis or secondary OA such as posttraumatic arthritis.
- Light sensitivity
- Hemophilia
- Opium- or narcotic-dependent patients
- Unicompartmental or bilateral knee replacement
- Revision TKA patients or previous knee surgery (eg, arthroscopy, ligament reconstruction, fracture fixation, and osteotomy)
- Patients who developed deep vein thrombosis or infections in the postoperative period.
- Patients who were unwilling to participate in the study or had difficulty in communication due to cognitive dysfunction or mental retardation.

Interventions and study protocol

This study had 2 interventions (Bioptron light or LLLT) and 1 control group. Light (Bioptron light; Bioptron AG, Wollerau, Switzerland) was applied in 1 intervention group and LLLT (LASERPEN; RJ-LASER, Reimers & Janssen, Berlin, Germany) to another group with standardized pharmacological and surgical protocols (Fig. 2). Both groups received light therapy or LLLT on the posterior region of the knee (points H and D). Acupuncture points were chosen due to surgical wound hygiene and possible wound complications caused by acupuncture in the anterior region and also due to the difficulty of exposing the patients immediately following the surgery. The LLLT had the following properties: 804 nm, Ga-Al-As semiconductor diodes, a power density of 500 mW, a

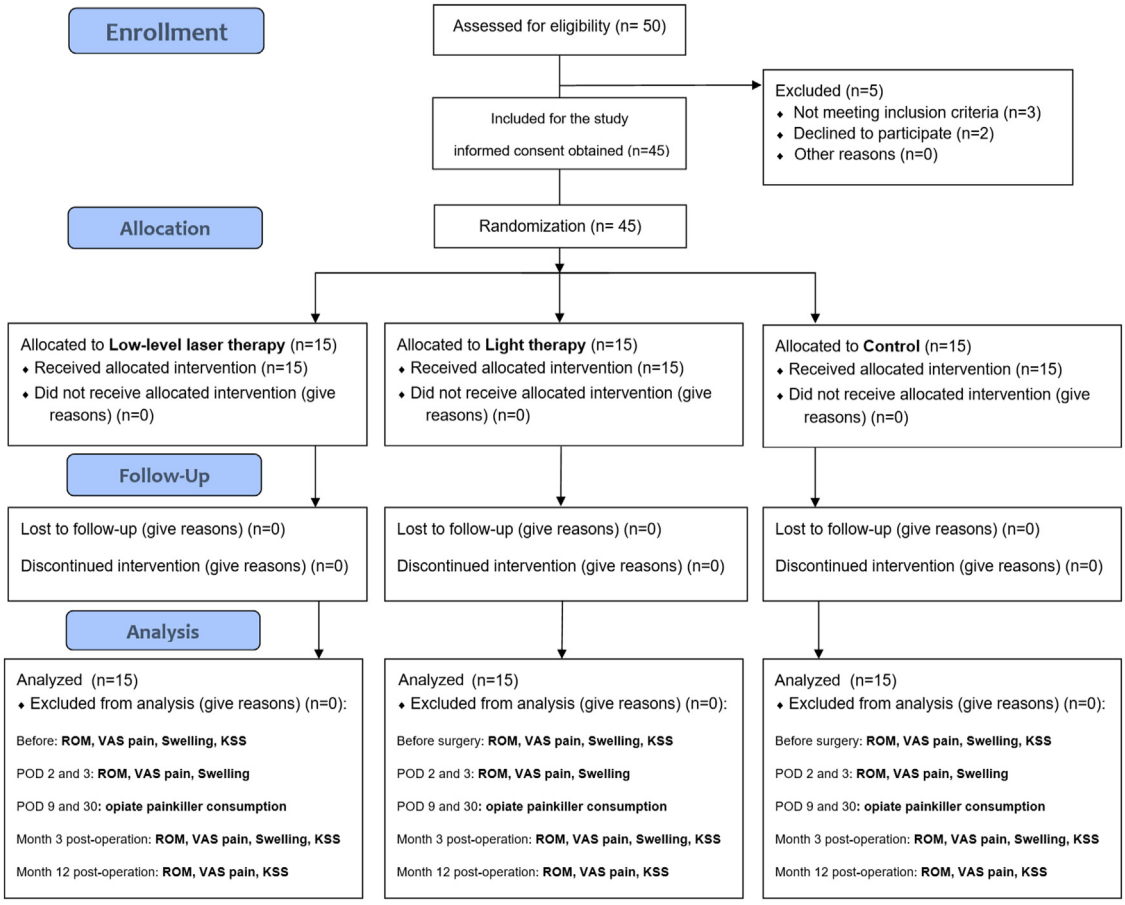

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) flow diagram of patients' enrollment and assessments.

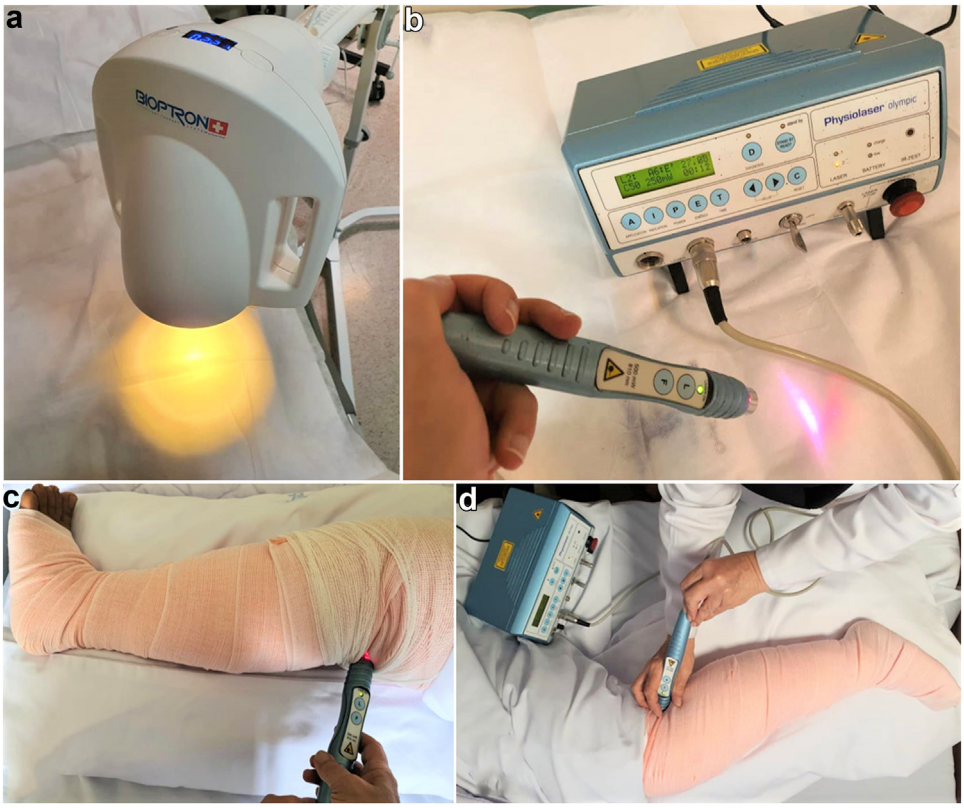

Figure 2. (a) Bioptron light instrument. (b) Low-level laser (LASERPEN; RJ-LASER) instrument. (c and d) Applying laser on the posterior region of the knee.

Table 1
Comparison of demographic data between 3 groups.

Groups	Age (y)	Sex (female, %)	Side (right)	Weight (Kg)	Height (cm)	BMI (Kg.cm^{-2})
Control	64.9 ± 6.5	12 (80.0)	9 (60.0%)	76.0 ± 11.1	163.5 ± 10.5	27.9 ± 2.8
Laser	62.4 ± 8.0	9 (60.0)	10 (66.7%)	78.1 ± 11.0	163.4 ± 8.4	28.7 ± 3.8
Light	65.7 ± 6.8	8 (53.3)	9 (60.0%)	73.4 ± 7.7	161.7 ± 9.0	27.8 ± 4.1
P value	.4	.3	.9	.4	.8	.7

BMI, body mass index.

dosage of 10J per session in 2 points (5J/Point), for 10 seconds. The intervention was applied during the first 3 days after the operation, 1 session of laser therapy each day. Patients were lying supine during the laser and light therapy and used protective goggles. Patients received LLLT during their first 2 days of hospitalization after the surgery, were discharged on day 2, and returned to the hospital on their third postoperative day (POD) for the final session. These procedures are combined with an exercise program [36] and 5 minutes of ice gel on the operated knee for all postoperative TKA patients. The second group received 10-minute treatment with Bioptron light (480-3400 nm; 95% polarization; 40 mW/cm^2; and 2.4 J/cm^2) for the same 3 days at 10-cm distance from the device and the same quadriceps isometric exercise program with ice. The third group only received an exercise program with ice as in all groups. The cost of 3 sessions of LLLT or light therapy is approximately 60$ in our country and is performed by experienced physiotherapists.

All patients were diagnosed with severe knee OA and underwent a standard conventional primary TKA by the anterior midline incision approach, using a tourniquet (250 mmHg) and without suction drainage. All patients underwent a TKA by the senior author, who is an adult joint reconstruction fellowship trained surgeon (SMJM). The NexGen LPS-Flex cemented (Zimmer Biomet Inc., Warsaw, IN) posterior stabilizer TKA. Standardized spinal anesthesia was applied for all patients using Bupivacaine (AstraZeneca, London, UK). Patients were mobilized by a walker within 6-8 hours of the surgery and began ROM and isometric rehabilitation exercises. Patients remained in the hospital for 3 days after the surgery. We did not use any joint immobilizer for the patients postoperatively.

Following the surgery, we administered aspirin (325 mg/two times a day) to all the patients as a venous thromboembolism chemoprophylaxis. The pain management protocol consists of celecoxib (400 mg), pregabalin (75 mg), acetaminophen (1 g), and omeprazole (40 mg) before the surgery. In the end, a cocktail was administered intraarticular containing normal saline (90 mL), ketorolac (60 mg), Bupivacaine (AstraZeneca, London, UK) (4 mL 0.5%), lidocaine (5 mL 2.0%), and 1.5 mg of tranexamic acid. A standard protocol at our center is to prescribe the following medications daily for a month after the surgery: celecoxib (400 mg), omeprazole (20 mg), pregabalin (75 mg), acetaminophen (2 g), and oxycodone 5 mg as needed (maximum 15 mg per day).

Randomization and blinding

Based on the type of conservative treatment after a TKA, 45 patients were randomized into 3 groups: LLLT, light, and control (15 patients per group). Block randomization was performed with a block size of 3. We used opaque and sealed envelopes and random numbers generated by the excel RAND function and divided all the patients into 3 interventions, each consisting of 5 blocks with a size of 3. Patients selected their envelope after the surgery randomly. Despite the difficulties in blinding patients and the surgery team, the researcher performing the assessments and analyzing the data was blind to the interventions in each group. Therefore, the present study was not blinded.

Outcome measures

The study's primary outcome measure was knee flexion ROM (degree) and knee pain level at a 3-month follow-up. The knee ROM was measured by a 360° digital goniometer (Ghamatpooyan Co., Iran) using the method described by Norkin and White [37]. In orthopedic surgery, goniometry is widely used to measure ROM and has an intraclass correlation coefficient of 0.99 [38]. Another primary outcome measure was the articular pain at 3 months assessed using the visual analog scale (VAS). Patients' consumption of opioid painkillers was also measured as a representative of articular pain. Opiate painkiller use (oxycodone) was documented on POD 9 (first postoperative visit) and at the end of the first month after the surgery. Swelling in the knee was measured using a tape

Table 2
Comparison of outcomes of ROM, swelling, and VAS pain score between the 3 groups.

Variables	Before surgery	After surgery				*P* value (repeated measure ANOVA)
		Second day postop.	Third day postop.	3 mo Postop.	1 y Postop.	
ROM						
Control	98.3 ± 5.2	41.7 ± 4.5	70.1 ± 10.6	92.3 ± 5.0	113.7 ± 7.9	Group effect: <.001[a]
Laser	97.5 ± 4.1	60.3 ± 12.9	90.9 ± 3.3	116.8 ± 6.3	119.7 ± 5.8	Time effect: <.001[a]
Light	100.9 ± 4.4	49.8 ± 5.5	87.8 ± 3.6	104.0 ± 6.6	116.0 ± 6.6	Interaction: <.001[a]
P value (ANOVA)	.12	<.001[a]	<.001[a]	<.001[a]	.064	
VAS pain						
Control	9.5 ± 0.9	7.5 ± 0.9	5.9 ± 0.9	3.5 ± 0.9	0.5 ± 0.6	Group effect: <.001[a]
Laser	9.1 ± 0.8	6.0 ± 1.3	3.9 ± 1.2	0.7 ± 0.4	0.6 ± 0.9	Time effect: <.001[a]
Light	9.4 ± 0.9	6.5 ± 0.9	4.7 ± 1.2	2.1 ± 0.5	0.9 ± 0.7	Interaction: <.001[a]
P value (ANOVA)	.56	.002[a]	.04[a]	.04[a]	.31	
Swelling						
Control	49.6 ± 1.2	53.9 ± 1.2	53.3 ± 1.7	52.4 ± 1.4	-	Group effect: <.001[a]
Laser	48.8 ± 2.5	52.5 ± 2.4	51.7 ± 2.5	50.9 ± 2.3	-	Time effect: <.001[a]
Light	48.8 ± 1.4	52.5 ± 1.6	51.7 ± 1.7	50.9 ± 1.9	-	Interaction: .008[a]
P value (ANOVA)	.35	.04[a]	.04[a]	.04[a]	-	

ANOVA, analysis of variance.
[a] Indicates significant *P* value.

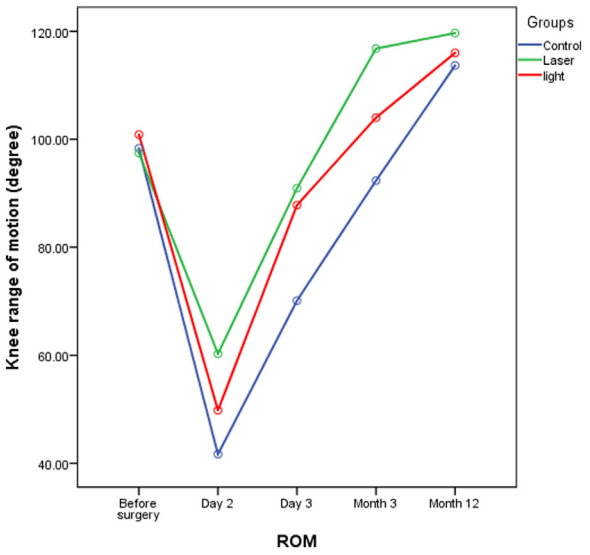

Figure 3. The comparison of the ROM between the 3 groups, which was significantly higher in the laser group after 3 months (laser > light > control).

measure (cm) while the patient was lying supine and in full extension. Approximately 1 cm proximal to the patella was measured as knee circumference [39]. In this case, 2 measurements were made, and the mean value was analyzed. Knee function was measured by the Knee Society Score (KSS), consisting of knee score and function score [40]. Assessments and examinations were performed by an experienced orthopedic resident who was blinded to the groups (A.M., postgraduate year 3). Laser and light interventions were performed by an experienced physical therapist (H.B., Doctor of Physical Therapy).

All patients were followed up for 12 months, and outcomes were measured before the surgery and after the intervention on the POD 2, POD 3, month 3, and month 12. Then, we compared the between-group differences of these measures to the minimally clinically important differences (MCIDs) previously reported for patient-reported outcome measures, 2 points for VAS [41], 5.3 for KSS knee score, and 6.1 for KSS function score [40]. Considering there is no prior literature reporting the MCID of the ROM following TKAs, we only make statistical conclusions regarding the ROM.

Statistical analysis

All data were collected in IBM SPSS v.22.0 software (Armonk, NY). To assess normality, the Shapiro-Wilk test was used. The continuous variables were compared using the students' *t*-test and analysis of variance based on their normality. The nominal variables were also compared using the chi-square test. Repeated-measures analysis of variance was used to compare the group's scores before and after the surgery. A *P* value <.05 was considered significant (two-sided).

Results

The distribution of patients in age, sex, surgery side, weight, height, and body mass index was similar in the 3 groups (Table 1). A wound complication occurred in 1 patient in the light group who was treated conservatively. Thromboembolic events were not found in either of our study groups. No major side effects were reported during or after the treatment period.

Knee ROM was significantly better on all follow-ups, except 12-month follow-up, in the LLLT group than that in the light group and control group ($P < .001$) (Table 2) (Fig. 3). The binary comparison

Table 3
Comparison of outcomes of ROM, swelling, and VAS pain score between binary groups.

Variables	Before surgery	After surgery			
		Second day postop.	Third day postop.	3 mo Postop.	1 y Postop.
ROM					
Laser	97.5 ± 4.1	60.3 ± 12.9	90.9 ± 3.3	116.8 ± 6.3	119.7 ± 5.8
Light	100.9 ± 4.4	49.8 ± 5.5	87.8 ± 3.6	104.0 ± 6.6	116.0 ± 6.6
P value	.12	.005[a]	.42	<.001[a]	.32
Control	98.3 ± 5.2	41.7 ± 4.5	70.1 ± 10.6	92.3 ± 5.0	113.7 ± 7.9
Laser	97.5 ± 4.1	60.3 ± 12.9	90.9 ± 3.3	116.8 ± 6.3	119.7 ± 5.8
P value	.86	<.001[a]	<.001[a]	<.001[a]	.053
Control	98.3 ± 5.2	41.7 ± 4.5	70.1 ± 10.6	92.3 ± 5.0	113.7 ± 7.9
Light	100.9 ± 4.4	49.8 ± 5.5	87.8 ± 3.6	104.0 ± 6.6	116.0 ± 6.6
P value	.30	.03[a]	<.001[a]	<.001[a]	.62
Pain					
Laser	9.1 ± 0.8	6.0 ± 1.3	3.9 ± 1.2	0.7 ± 0.4	0.6 ± 0.9
Light	9.4 ± 0.9	6.5 ± 1.0	4.7 ± 1.2	2.1 ± 0.5	0.5 ± 0.6
P value	.69	.36	.14	<.001[a]	.97
Control	9.5 ± 0.9	7.5 ± 1.0	5.9 ± 1.0	3.5 ± 1.0	0.9 ± 0.7
Laser	9.1 ± 0.8	6.0 ± 1.3	3.9 ± 1.2	0.7 ± 0.4	0.6 ± 0.9
P value	.56	.001[a]	<.001[a]	<.001[a]	.46
Control	9.5 ± 0.9	7.5 ± 0.90	5.9 ± 0.90	3.5 ± 0.90	0.9 ± 0.7
Light	9.4 ± 0.9	6.5 ± 0.90	4.7 ± 1.2	2.1 ± 0.5	0.5 ± 0.6
P value	.98	.04[a]	.02[a]	<.001[a]	.33
Swelling					
Laser	48.8 ± 2.5	52.5 ± 2.44	51.7 ± 2.5	50.9 ± 2.3	-
Light	48.8 ± 1.4	52.5 ± 1.55	51.7 ± 1.7	50.9 ± 1.9	-
P value	.99	1.00	.99	1.0	-
Control	49.6 ± 1.2	53.9 ± 1.18	53.3 ± 1.7	52.4 ± 1.4	-
Laser	48.8 ± 2.5	52.5 ± 2.44	51.7 ± 2.5	50.9 ± 2.3	-
P value	.39	.10	.08	.08	-
Control	49.6 ± 1.2	53.9 ± 1.2	53.3 ± 1.7	52.4 ± 1.4	-
Light	48.8 ± 1.4	52.5 ± 1.6	51.7 ± 1.7	50.9 ± 1.9	-
P value	.45	.10	.07	.08	-

[a] Significant *P* value.

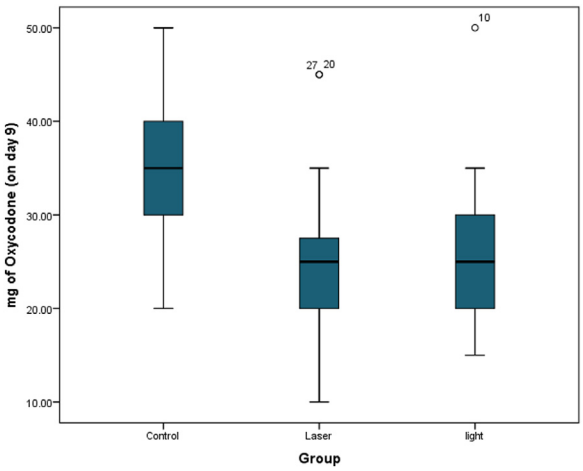

Figure 4. The comparison of the VAS pain score between the 3 groups, which was significantly lower in the laser group after 3 months (laser < light < control).

revealed a significant difference between groups in terms of ROM at 3 months: laser > light > control ($P < .001$) (Table 3).

Pain decreased by 8.5 points (using the VAS score) in the LLLT group, 7.2 points in the light group, and 6.0 points in the control group at 3 months of follow-up, statistically significant (Table 2). As seen in Table 2 and Figure 4, the laser group had the lowest pain score compared to each group, which was significant on POD 3 and month 3 after the surgery (laser > light > control). The binary comparison revealed a significant difference between the groups in terms of VAS pain score at 3 months: laser < light < control ($P < .001$) (Table 3). The VAS pain score difference between the 2 groups for the laser and control groups met the VAS MCID (2 units) but not with that of the light group.

Knee circumference increase (swelling) was 2.1 cm in the LLLT and light groups and 2.8 cm in the control group at 3 months after the intervention. The control group significantly has higher knee swelling than other groups ($P < .001$) (Table 2), but as seen in the Table 3, there are no significant differences in the swelling between the laser and light groups at the 3 months of follow-up ($P > .05$) (control > laser ≈ light).

Opiate painkiller consumption, measured by the milligram of oxycodone consumed on POD 9 and POD 30, significantly differed between groups (Fig. 5a and b). LLLT, light, and control groups consumed 25.0, 26.0, and 34.0 mg of oxycodone on POD 9 and 48.3, 53.3, and 60.3 mg on POD 30 ($P = .02$). Bonferroni's post-hoc analysis revealed that only patients in the LLLT group used fewer opioids in both time points than controls ($P < .05$). Also, the post-hoc analysis did not detect a difference between the light and other groups.

KSS knee scores were increased by 54 scores in the LLLT group, 37.9 in the light group, and 30.2 in the control group at the 3-month follow-up, and it showed significantly greater improvement in the LLLT group (laser > light > control) ($P < .001$) (Fig. 6a) (Table 4, Table 5). For the laser, light, and control groups, the KSS knee score difference between the groups met the MCID (5.3 units). At the last follow-up at 12 months, the laser group was still superior to other groups (Table 5).

The KSS function score increased by 40.3 in the LLLT group, 34.3 in the light group, and 20.3 in the control group at 3 months after the surgery visit, which was statistically higher in the LLLT group ($P < .001$) (Table 4) than that in each group (laser > light > control) as seen in the Figure 6b and Table 5. For the laser and control groups and light and control groups, the KSS function score difference between the 2 groups met the MCID (6.1 units). At the most recent follow-up, no difference was detected regarding the KSS function score, and the 3 groups showed comparable scores ($P = .07$).

Discussion

The main finding of this study was that the LLLT—as an adjunct modality in the rehabilitation of patients undergoing a primary TKA—could effectively improve ROM and function and reduce pain in the short-term follow-up (3 months) compared to light therapy or controls. These improvements were clinically significant as they met MCID for patient-reported outcome measures. No adverse effects related to LLLT or light were observed in intervention groups, indicating these modalities' safety. In the case of swelling, both light and LLLT groups were significantly more effective than controls but comparable with themselves. Another important finding is that LLLT patients used a significantly lower amount of opiate painkillers (oxycodone) than controls during the first 30 days after the surgery. At the end of the 12-month follow-up, most pain and functional scores are similar, indicating these modalities are efficient in the short-term and early recovery.

Reviewing the literature revealed some articles investigating the impact of laser therapy on total joint arthroplasty (TJA) outcomes [22–28]. According to a recent RCT by Huang et al. on old-aged participants with TKA, the low-level laser acupuncture group had significantly less pain 10 to 72 hours after the surgery. Also, they showed that the intervention group used a lower amount of

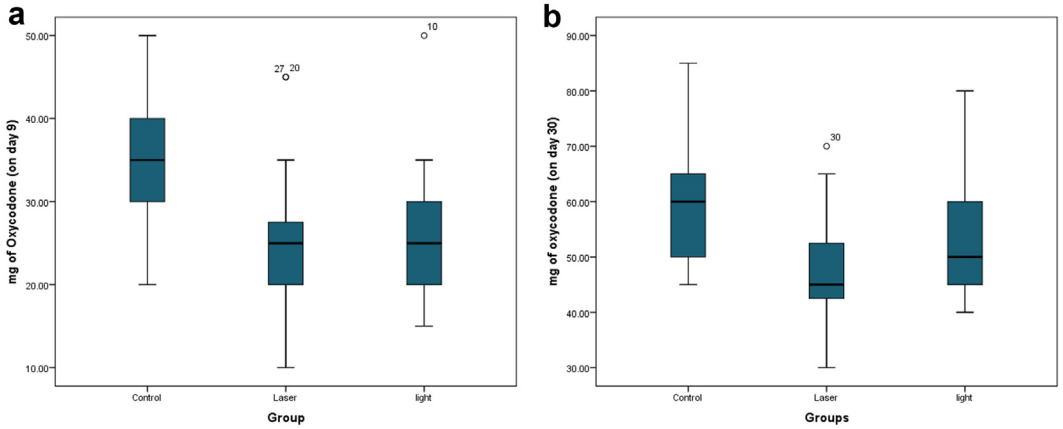

Figure 5. Mean consumption of opiate painkiller (oxycodone 5-mg tablets) on (a) postoperative day 9 and (b) postoperative day 30, which were significantly lower in the laser group.

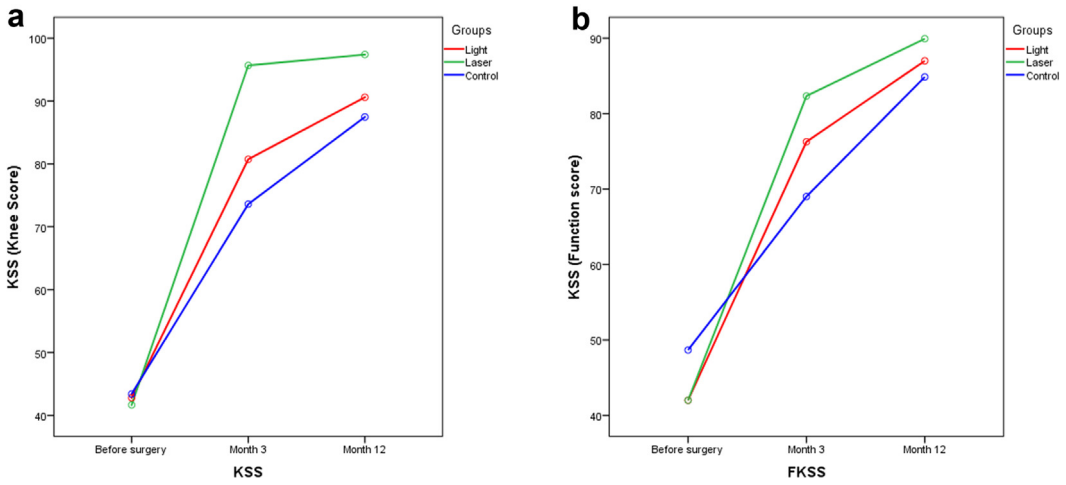

Figure 6. The comparison of the KSS (a) knee score and (b) function score between the 3 groups, which were significantly higher in the laser group after 3 months (laser > light > control).

morphine and had a significantly lower rate of related complications than the controls [22]. However, they did not evaluate patients' function and only followed them up for 72 hours. Their results are in line with our study regarding pain and opioid consumption. The same author in an earlier study [24] reported ROM and Western Ontario and McMaster Universities Arthritis Index stiffness scores as the representative measures of function. They claimed that LLLT could facilitate recovery and improve ROM during the first 3 days after the surgery but not significantly influence the knee stiffness score.

Moreover, in a scientific abstract by Fusakul et al., they reported significantly superior outcomes in TKA patients regarding ROM at POD 2, pain at POD 4 and 2 weeks after the operation, and KSS at 6-week follow-up [23]. Their study concludes that postoperative LLLT reduced pain early and improved knee flexion and extension ROM without causing side effects [23]. Also, this survey confirms the present study's results that pain, ROM, and function (KSS) were superior in the LLLT group at the very early stages and after 3 months of follow-up. Most of the previous studies investigated patients only for a few days; however, our study revealed that the beneficial effects of LLLT remain until 3 months after the surgery. Moreover, comparing LLLT to Bioptron light was a novel finding of this study, which showed LLLT to be superior to light in terms of pain and function (KSS) but similar regarding knee swelling. As a distinct modality, light therapy has also shown superior pain, function, and swelling outcomes than controls.

Another study on patients with THA patients uncovered that photobiomodulation therapy (PBMT), which was a combination of LLLT and light-emitting diode therapy in their study, had a significant impact on decreasing inflammation [27]. In the PBMT group, the VAS pain score and serum levels of inflammatory markers (TNF-α and IL-8) decreased more than those in the placebo group ($P <$ .05) [27]. Perhaps, the role of LLLT in reducing inflammation and muscle damage was the mechanism that improves recovery and reduces postoperative pain. There is animal evidence that PBMT is a safe, noninvasive, effective modality for modulating inflammation and regulating inflammatory markers, including IL-1β, IL-6, and TNF-α [16,42]. Moreover, an animal model of OA treated with PBMT exhibited improved cartilage recovery (greater optical densitometry) and reduced spinal cord sensitization [43]. Thus, PBMT has a possible promising role in cartilage recovery and relieving pain in OA. PBMT may also modulate inflammation induced by surgical injuries during TJA [44]; therefore, PBMT can have a therapeutic role after a TJA surgery.

Our study is not without limitations. First, there are few patients in each group, as explained in the method section on how sample sizes are calculated. The small sample size hindered the statistical analysis' ability to have high power. Second, we did not compare the clinical and radiological severity/grading of knee OA in patients before the surgery. However, the demographics between groups were similar, as shown in Table 1. Third, because this study was not blinded, it was not controlled for the placebo effect or the effect of acupuncture without a laser beam. Last but not the least, this study could not achieve a sex balance, and a majority of the groups were female patients.

Table 4
Comparison of outcomes of KSS between the 3 groups.

Variables	Before surgery	After surgery		Repeated measure ANOVA (*P* value)
		3 mo Postop.	1 y Postop.	
Knee score				
Control	43.4 ± 8.2	73.6 ± 9.1	87.5 ± 7.6	Group effect: .001[a]
Laser	41.7 ± 11.6	95.7 ± 4.4	97.4 ± 3.0	Time effect: <.001[a]
Light	42.8 ± 12.5	80.7 ± 8.6	90.6 ± 6.1	Interaction: .01[a]
P value	.9	<.001[a]	.01[a]	
Function score				
Control	48.7 ± 18.8	69.0 ± 5.1	84.9 ± 5.0	Group effect: .44
Laser	42.0 ± 16.1	82.3 ± 6.8	89.9 ± 4.6	Time effect: <.001[a]
Light	42.0 ± 18.3	76.3 ± 8.4	87.0 ± 7.5	Interaction: <.001[a]
P value	.5	<.001[a]	.07	

ANOVA, analysis of variance.
[a] Significant *P* value.

Table 5
Comparison of outcomes of KSS (knee score and function score) between binary groups.

Variables	Before surgery	After surgery	
		3 mo Postop.	1 y Postop.
Knee score			
Laser	41.7 ± 11.6	95.7 ± 4.4	97.4 ± 3.0
Light	42.8 ± 12.5	80.7 ± 8.6	90.6 ± 6.1
P value	.80	<.001[a]	.02[a]
Control	43.4 ± 8.2	73.6 ± 9.1	87.5 ± 7.6
Laser	41.7 ± 11.6	95.7 ± 4.4	97.4 ± 3.0
P value	.64	<.001[a]	.001[a]
Control	43.4 ± 8.2	73.6 ± 9.1	87.5 ± 7.6
Light	42.8 ± 12.5	80.7 ± 8.6	90.6 ± 6.1
P value	.87	.036[a]	.59
Function score			
Laser	42.0 ± 16.1	82.3 ± 6.8	89.9 ± 4.6
Light	42.0 ± 18.3	76.3 ± 8.4	87.0 ± 7.5
P value	1.0	.04[a]	.37
Control	48.7 ± 18.8	69.0 ± 5.1	82.9 ± 6.1
Laser	42.0 ± 16.1	82.3 ± 6.8	89.9 ± 4.6
P value	.56	<.001[a]	.06
Control	48.7 ± 18.8	69.0 ± 5.1	82.9 ± 6.1
Light	42.0 ± 18.3	76.3 ± 8.4	87.0 ± 7.5
P value	.56	.02[a]	.58

[a] Significant *P* value.

Conclusions

The study results show that the LLLT and Bioptron light therapy are safe, nonpharmaceutical, and noninvasive modalities in the rehabilitation protocol for patients undergoing a primary TKA. In the early stages of recovery following the surgery, it may be helpful in reducing pain and opioid consumption, improving ROM, and functional recovery. Regarding pain and functional outcomes, LLLT is superior to light therapy, but knee swelling measures are similar. In summary, LLLT could speed up patients' recovery and give them relief from acute pain after the surgery. To approve LLLT and light therapy as standard postoperative rehabilitation for primary TKA patients, further RCTs are required with larger sample sizes.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.10.016.

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