Efficacy of class IV diode laser on pain and dysfunction in patients with knee osteoarthritis: a randomized placebo-control trial

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Objectives
The aim of this study was to investigate the effect of class IV diode laser on knee pain and functions in patients with knee osteoarthritis.

Patients and methods
Fifty patients with a mean±SD) age of 55.68±8.88 years, height of 173.84± 4.946 cm, weight of 83.86±5.28 kg, and BMI of 27.78±1.89 kg/cm^2 were randomly assigned equally into two groups (25 patients in each group). Group I received a multiwave locked system laser plus exercises and group II received placebo laser plus exercises three times weekly for 4 weeks. Exercise program was applied for both groups three times weekly for 4 weeks. The exercises included range of motion, stretching, isometric, and isotonic resisted exercises to the quadriceps and hamstring muscles. Pain was evaluated using a visual analog scale and knee function by using the Western Ontario and McMaster Universities Index of Osteoarthritis (WOMAC). Statistical analyses were performed to compare differences between baseline and post-treatment results for both groups.

Results
Visual analog scale and WOMAC were significantly decreased in both groups after 4 weeks of treatment, with a more significant decrease gained in group I ($P>0.0001$).

Conclusion
Class IV diode laser combined with exercise was more effective than exercise alone in the treatment of patients with knee osteoarthritis. Multiwave locked system laser combined with exercise effectively decreased pain and WOMAC as compared with the placebo laser plus exercises group.

Keywords:
class IV laser, knee function, knee osteoarthritis, multiwave locked system, pain

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Introduction

Osteoarthritis (OA) is a group of conditions that lead to joint signs and symptoms, which are associated with defective integrity of articular cartilage that can affect the normal daily activities in the elderly with higher social and financial influences on either patients or society [1]. It is characterized by joint inflammation, synovitis, and articular cartilage degeneration with many clinical manifestations such as pain, reduced range of movement, crepitus, tenderness, impairment of muscular performance, and functional capability [2].

The most commonly involved joint is the knee with impaired life quality and associated morbidity [3]. Knee OA commonly affects the elderly, and especially women [4]. One-third of the people aged 65 years and older have knee OA, which is evident by radiography. The incidence of the OA tends to increase with aging, with increasing pain and disability of the lower limb, which can seriously affect one's life activities [3]. Although OA is commonly seen as a progressive pain, and chronic disorder with functional limitation, early therapeutic approach can minimize its symptoms [5].

The treatment includes several interventions, both pharmacological and nonpharmacological, according to the degree of joint destruction [6]. Treatment of OA aimed to relieve pain, increase the limited range of motion (ROM), and promote cartilage regeneration. Weight reduction and exercise alone or combined with patient education, electrical stimulation, magnetic field, ultrasound, and low-level laser therapy (LLLT) could relieve pain and improve function [7,8]. Although these modalities provide only symptomatic relief and cannot modify the degenerated cartilage structure, its side effect is low and comparable to the other NSAIDs [9]. Laser therapy was reported to have an analgesic effect that can relieve both acute and chronic musculoskeletal pain [10]. Moreover, it is commonly used in the treatment of degenerative knees OA in animals and humans. Studies on animals reported that LLLT decelerates the arthritic process by altering level of prostaglandin, increasing the levels of proteins, and improving the repair of degenerating cartilages by increasing the number of chondrocytes and the thickness of the articular cartilage [11,12].

Researchers investigated the clinical effect of laser in the treatment of knee OA. Some authors reported a positive effect on pain relief [13], whereas the other authors disagreed with this result [14,15]. These controversial results may be because of the differences in parameters (wavelength, dose, time, area, technique) used in treatments by different studies [16]. Thus, it is important to choose optimum parameters to achieve therapeutic response in patients with knee OA. In the previous studies, LLLT was used in the treatment of knee OA in specific points [17,18], with an average of 6 J/point. Scanning of the related area such as the quadriceps, hamstring, and the calf muscles was not easy. Because of the large area of laser radiation and low-power laser generator, the time of application will be too much or even not applicable. Now, the presence of new types of class IV lasers, which provide a high laser power (<0.5 W), help to deliver an adequate level of fluency (energy density) that is sufficient to cover a large area of treatment and to stimulate the physiological responses [19]. The safety of new high-power laser, which approved by Food and Drug Administration, helps to scan the related area in addition to stimulating specific points on the joint line.

The multiwave locked system (MLS) is a novel treatment used for a variety of diseases causing pain and inflammation. The MLS laser is a synchronized laser, which has continuous emission of 808 nm with pulsed emission of 905-nm diode lasers. In comparison with the LLLT, the synchronization of two laser wavelengths provides a high-power class IV laser (808 nm, with a maximum power 1 W, and 905 nm, with a maximum power of 25 W). The advantage of this combination is postulated to have a better penetrability and the possibility of increasing the emitted energy [20]. From the available literature, there was no study that investigated the effect of this combination on the deep articulating pain as in knee OA. Therefore, the objective of this study was to investigate the effect of class IV diode laser on knee pain and functions in patients with knee OA.

Patients and methods

Patients

A single randomized blinded placebo-controlled trial was approved by University's Ethics Research Committee. A rheumatologist who performed a baseline evaluation for all patients was blinded to the study purpose or design. Patients were subjected to imaging before the decision of accepting them in the trial. On the basis of radiographic finding, patients with grade less than or equal to 3 in the Kellgren and Lawrence grading of OA were included in the study. The estimated sample size was performed by GPower 3.1 program (Universitat Kiel, Germany) for windows with α errors of 0.05, power ($1-\beta$ error) of 0.80, effect size of 0.85, and using Wilcoxon–Mann–Whitney test for two groups in the analysis of data to detect changes in pain level. The effect size was based on the previous studies [21,22]. The estimated sample size was 48 patients. The number of samples was increased to 50 for possible dropout. A total of 50 male patients participated in the study. The patients were recruited from physical therapy and rehabilitation department of Al-Nour Hospital, Mecca, Saudi Arabia. A written consent was collected from the patients for participation in the study and to publish their results.

The inclusion criteria were as follows: (a) anterior or posterior knee pain for at least 3 months, (b) limitation in knee ROM and posterior knee muscle tightness, (c) BMI less than or equal to 30 kg/m^2, and (d) at least a score of 25 on the Western Ontario and McMaster Universities Index of Osteoarthritis (WOMAC) as self-reported disability questionnaire.

Patients were excluded if they had previous surgery, rheumatoid arthritis, fractures, more than 20° genu valgum or genu varum, previous intra-articular injection of corticosteroid or hyaluronic acid, or any cardiovascular, respiratory, or other musculoskeletal problems that interfere with patient participation in exercise. Patients were assigned randomly into two groups of 25 patients in each group. Group I received MLS plus exercises and group II received placebo laser plus exercises. Randomization was performed by online graphPad program (GraphPad Software, San Diego, California, USA) after assigning a specific number for every patient. Patients did not know which group they were assigned to and which treatment they would be given. The therapists were blinded to the group assignment as well, and therefore neither patients nor the therapist knew who was in which group.

Assessment

Patient's age, weight, height, and BMI were recorded. Pain level was measured by visual analog scale (VAS) and knee function using WOMAC.

Assessment of pain

The VAS was used for evaluation of pain for all patients. It is a line divided into 10 equal sections, with 10 representing 'unbearable pain' and 0 representing 'no pain'. Each participant was asked to indicate the level of his pain by marking on this scale. A ruler was used to measure the distance in centimeters from 0 to the marked point. It is an ordinal scale commonly used by researches, and it was shown to be a reliable and valid measure of pain [23]. Measurement was performed at baseline and 4 weeks after treatment.

Assessment of knee function

The lower limb and knee joint functions were evaluated by using WOMAC. The WOMAC scale could evaluate pain, stiffness, and lower limb and knee function. WOMAC is considered as a reliable and valid measure for evaluation of patients with hip and knee OA [24]. Five items of the WOMAC scale were used to measure pain, two items for stiffness, and 17 items for physical function. Each item was graded on a five-point scale of 0–4, where 0, no pain/limitation; 1, mild pain/limitation; 2, moderate pain/limitation; 3, severe pain/limitation; and 4, extreme pain/limitation [21]. After confirmation of its validity and reliability, an Arabic version of WOMAC was used in patients with knee OA [25].

Treatment

Multiwave locked system laser therapy

Mphi laser device (ASA, Arcugnano, Italy) was used in this study. It provides synchronized and overlapping continuous and pulsed emissions of Ga–Al–Ar laser emitted in a single handpiece. Mphi has continuous emission of wavelength 808 nm with peak power of 1000 mW, mean power of 500 mW, spot diameter of 2 cm, and spot area of 3.14 cm^2. Pulsed emission has a wavelength of 905 nm, peak power of 25 W, mean power of 54mWat, with a frequency of 1500 Hz, with the same diameter and spot area.

While the patient assumed a supine lying position, the affected knee was slightly flexed and supported with a pillow underneath. Laser was applied into two subphases: scan and trigger point subphases. In the scan phase, both the anterior and posterior knee surfaces were scanned, with an average area of 100 cm^2, time of application of 6 min and 17 s per session, and a total energy of 214 150 J. In trigger point treatment, laser probe was perpendicular and in contact to four points on the anterior knee surface around the patella and two points on the posterior knee surface on the medial and lateral hamstring insertion. The energy delivered was 2.14 J/cm^2, 6.175 J on each point in an average time of 16 s [21]. The total time of laser session was about 9 min. MLS laser was applied to all patients in group I three sessions/week for 4 consecutive weeks. Calibration of laser equipment was done by the manufacturing company. For placebo laser, patients in group II attended the physical therapy department and received sham laser with the same equipment, time, area, and points of application before applying the exercise program three sessions/week for 4 consecutive weeks.

Exercises

Exercise program was applied thrice a week for 4 weeks for all patients in both treatment groups. The program included (a) 5-min ROM exercise to lower limb joints in pain-free range from nonweight-bearing position, (b) 10 min stretching exercise to the hamstring and calf muscles, and (c) isometric strengthening exercise to the quadriceps muscle using sand bags while the patient raised his leg straight for 10 times for three sets with 5-min rest in between each set. The patient performed an isotonic resisted exercise, three sets of 10 times each, to the quadriceps muscle using Multigym device with a variable resistance according to patient tolerance. Hamstring strengthening exercise, three sets of 10 times each, was performed from prone lying position using sandbags [18,21]. The total time of exercise was about 45 min, plus the rest periods between different exercise modes according to patient tolerance. The patient was instructed to repeat the program of exercises at home and a handout prescription of exercises was given for all patients. Hot packs were allowed in case of muscle soreness after exercise.

Data analysis

Unpaired t-test was used to compare the mean values of patient's age, weight, height, and BMI for both treatment groups. Changes in VAS and WOMAC between groups were analyzed by Mann–Whitney U-test. Each group's results were analyzed by Wilcoxon's signed-rank test to compare between baseline and after 4 weeks. The level of statistical significance was set as P less than 0.05.

Results

The aim of the study was to investigate the effect of class IV diode laser on knee pain and functions in patients with knee OA. Fifty male patients participated in the study. Their mean age was 55.68±8.88, weight was 83.86±5.28, height was 173.84±4.946, and BMI was 27.78±1.89. They were randomly assigned into two groups of 25 patients in either group I or group II. Unpaired *t*-test was used to compare the demographic data of patients including age, weight, height, and BMI, and revealed nonsignificant changes in their means between the two treatment groups, as shown in Table 1.

Wilcoxon's matched-pairs signed-ranks test was used to compare between baseline and post-treatment results and revealed significant decreases in VAS and WOMAC in both group I and group II (Table 2). Mann–Whitney test was used to compare the baseline and post-treatment scores of VAS and WOMAC and showed nonsignificant differences in baseline results between both groups, as shown in Table 2. Significant decreases were observed in post-treatment results in either VAS or WOMAC, with a significant decrease gained in group I more than group II, as shown in Table 2.

Discussion

The aim of the study was to investigate the effect of MLS on knee pain and functions in patients with knee OA. MLS combined with exercise was effective more than placebo laser plus exercises in the treatment of patients with knee OA. MLS combined with exercise was more effective in decreasing VAS score and WOMAC subscales as compared with the placebo laser plus exercises group.

The result of the present study was consistent with those of the previous studies, which support the effect of LLLT in the treatment of arthritis. Researchers have found favorable analgesic, anti-inflammatory, and biostimulating effects of laser. Diode laser significantly reduces the chronic pain as in rheumatoid arthritis, chronic arthritis, and knee injuries [14,21,22,26,27].

In knee OA, the main aims of treatment are to relieve pain, to improve lower limb function, and to alleviate joint destruction by changing the inflammatory process. Laser diode can reduce pain indirectly by increasing the microcirculation [28], and increasing oxygenation to tissues with reduction of knee swelling [29] and the intensity of inflammation. Laser reduces the inflammatory process by altering prostaglandin synthesis, decreasing interleukin 1, enhancing lymphocyte response, and decreasing C-reactive protein and neopterin levels [30,31]. Laser therapy can reduce pain at the tissue level by altering the release of chemical mediators such as histamine and bradykinin, which are released from injured tissues [32], and decreasing the release of substance P, which decreases the threshold of pain [33]. These effects lead to an increase in the knee functional performance, and an improvement in the ambulation duration and quality of life [21]. Laser has a biostimulating effect as it influences the cellular metabolism through stimulation of cytochrome oxidase enzyme, which enhances the oxidative phosphorylation and increases ATP production, which in turn regulates other cellular processes leading to normalization of biological functions at the cellular level [34].

The result of the present study was contradictory to the finding of Gur *et al.* [14] and Tascioglu *et al.* [15], who found no significant effect of laser on pain in patients with knee OA. Although they used a semiconductor diode laser, the energy density delivered to patients (1.5, 2 or 3 J/point) was different from the present study (6 J/point). Laser was delivered at low power output of 11.2 or 50 mW and with different wavelengths (904 or 830 nm), which showed that the power output and the wavelength are important factors that the laser effect was dependent on [16]. In addition, it may provide evidence of the importance of the combination of wavelengths (808–905 nm) that was used in the current study. MLS is considered a high-power laser with two synchronized wavelengths (808 and 905 nm) resulting in deeper tissue penetration [19]. This combination may be able to reach a deeper area such as the knee joint and is responsible for pain relief and improving knee and lower limb function.

As the concentration of chromophores in skin and subcutaneous tissue increased, the absorption of laser

Table 1 Demographic characteristics of patients in both treatment groups

	Group I (mean±SD)	Group II (mean±SD)	*t*-Value	*P*-value
Age (years)	56.08±9.83	55.28±8.00	0.315	0.093[c]
Weight (kg)	82.64±3.78	85.08±6.29	−1.662	0.164[c]
Height (cm)	174.84±5.489	172.84±4.20	1.445	0.151[c]
BMI (kg/m^2)	27.06±1.43	28.49±2.06	−2.835	0.452[c]

[c]Nonsignificant changes.

Table 2 Changes in visual analog scale and Western Ontario and McMaster Universities Arthritis Index in both treatment groups

	VAS		*P*-value	WOMAC pain		*P*-value	WOMAC stiffness		*P*-value	WOMAC function		*P*-value
	Pretreatment	Post-treatment		Pretreatment	Post-treatment		Pretreatment	Post-treatment		Pretreatment	Post-treatment	
Group I (25 patients)	25.52	13.90	0.0001[a]	26.72	15.08	0.0001[a]	24.30	20.60	0.0001[a]	26.16	13.88	0.0001[a]
Group II (25 patients)	25.48	37.10	0.0001[a]	24.28	35.92	0.0001[a]	26.70	30.40	0.0001[a]	24.84	37.12	0.0001[a]
P-value	0.991[c]	0.0001[b]		0.543[c]	0.0001 [b]		0.544[c]	0.009[b]		0.746[c]	0.0001[b]	

Pretreatment and post-treatment values were expressed as mean rank. VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Arthritis Index. [a]Significant differences between baseline and post-treatment using Wilcoxon's matched-pairs signed-rank test, $P \leq 0.05$. [b]Significant differences between two treatment groups using Mann–Whitney test, $P > 0.05$. [c]Nonsignificant differences.

is increased. When the wavelengths increased up to 1000 nm, the penetration reaches deeper tissues and can reduce pain and inflammation in the deeper area such as the knee joint [19,35]. The optimum dose of the therapeutic laser is dependent on three factors: power output, wavelength, and time of application. Class IV laser with a longer wavelength (up to 1000 nm) over a longer period of time produces a higher therapeutic dosage, which is delivered to the tissue and can stimulate the tissues effectively [36].

The result of the present study indicates that exercise therapy alone or combined with MLS laser is clinically able to decrease pain and improve function. Exercise, when applied actively, was shown to be safe, economical, and effective in the treatment of patients with knee OA. Home-based isometric exercise of the knee extensor and flexor muscles has shown to have a beneficial effect on the long-term increase in muscle strength [37]. Stretching exercises to hamstring muscle when combined with isotonic muscle strengthening provide a useful treatment combination for middle-aged adult patients with knee OA [38]. Combined use of exercise with MLS laser has shown to have clinical significance in providing a potent effect in reducing pain and improving lower limb and knee function [18]. The reduction of pain and posterior knee muscles spasm and tightness in addition to the anti-inflammatory effect of laser may help decrease the inflammatory process. Moreover, MLS may recover the exercise muscles through improving muscle conditions, enhancing skeletal muscle contractile function, and postexercise recovery, which is considered as the cause for improving knee and lower limb function, as reflected in the improvement in WOMAC score.

Conclusion

Class IV diode laser combined with exercise was more effective than exercise alone in the treatment of patients with knee OA. MLS laser combined with exercise effectively decreased pain and WOMAC subscales as compared with exercise alone. MLS laser is an effective physical therapy modality that may provide better outcomes for patients with knee OA, especially when used in combination with exercise. Further studies may be recommended to investigate the effect of MLS on quadriceps muscle strength and recovery, as well as the changes in the inflammatory process inside the knee joint in patients with knee OA. In addition, the effect of MLS in the treatment of other types of painful and arthritic joints such as rheumatoid arthritis should be considered in future studies.

Limitation

All the recruited patients were male patients. All patients were instructed to perform a home exercise program and the exercise compliance was obtained from family members. Although the family members or the participants themselves reported any deficiency in the exercise prescription at home, we considered this a limiting factor in the present study.

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Conflicts of interest

There are no conflicts of interest.

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