How to Cite:
Mowafy, Z. M. E., Ismail, M. M., Ali, K. M., & Dawoud, M. D. G. (2022). Effect of gallium arsenide laser versus pulsed electromagnetic field on healing of pressure ulcers patients. *International Journal of Health Sciences*, *6*(S4), 3639–3650.
https://doi.org/10.53730/ijhs.v6nS4.9107

Effect of gallium arsenide laser versus pulsed electromagnetic field on healing of pressure ulcers patients

Zakaria Mowafy Emam Mowafy
Physical Therapy department for Surgery, Faculty of Physical Therapy, Cairo University, Egypt

Maged Mohamed Ismail
Department of General Surgery, Faculty of Medicine, Al Azhar University, Egypt

Khadra Mohamed Ali
Physical Therapy department for Surgery, Faculty of Physical Therapy, Cairo University, Egypt

Mina Dawoud Gergis Dawoud
Physical Therapy department for Surgery, Faculty of Physical Therapy, Cairo University, Egypt.
Corresponding author email: avatar_md_pt@yahoo.com

***Abstract*---**Purpose: to evaluate the effect of Gallium Arsenide laser versus pulsed electromagnetic field on healing of pressure ulcers. Methods of evaluation: - (Measurement of the ulcer surface area (USA), ulcer volume measurement (UVM) and the colony count (CC). Methods: 40 diabetic patients with pressure ulcers grade II, their ages ranged from 40 – 60 years, were divided randomly into two equal groups in number. Group (A) Gallium arsenide (Ga-As) laser group: This group was consisted of 20 patients who received the Gallium arsenide (Ga-As) laser therapy 3 times per week for 2 months in addition to the routine conventional treatment (dressing – manage bacterial contamination – relieve pressure, friction, and shear – remove necrotic debris – correct nutritional deficits). Group (B) PEMFT group: 20 patients who received the Pulsed electromagnetic field therapy (PEMFT) 3 times per week for 2 months in addition to the routine conventional treatment (dressing – manage bacterial contamination – relieve pressure, friction, and shear – remove necrotic debris – correct nutritional deficits). Results: Results showed that both the Ga-As laser and the PEMFT, were significantly effective in improving healing of pressure ulcers as manifested by the highly decreased USA, UVM and CC in both groups. Conclusion: both were

nearly equivalent and significantly effective in improving healing of pressure ulcers as manifested by the highly decreased USA, UVM and CC in both groups.

***Keywords*---**gallium arsenide (Ga-As) laser, pulsed electromagnetic field therapy, pressure ulcers.

Introduction

Pressure ulcer usually appears as an open wound due to the skin become so badly damaged that it breaks down or dies. The problem can present itself as a simple nuisance or as a life-threatening condition. A number of factors can contribute to the development of a pressure ulcer but the cause is unequalized pressure (usually in bony areas such as the heel of the foot, the elbow, the lower back or the shoulders) for an extended period of time because the patient is inactive, confined perhaps to a bed or wheelchair, [5,6,12,14,15].

Pressure ulcers can be serious, depending on how much the skin and tissues have been damaged. Deep ulcer can go down into the muscle, or even to the bone. If pressure ulcers are not treated properly, they can become infected. An infection in a pressure ulcer can be serious. Pressure ulcers also hurt a lot and make it hard for a person to move around. Pressure ulcers are an immense problem among older and disabled population. There are many studies in the literature about the aetiology, internal pressure, natural history and epidemiology of skin breakdown. There is relatively little information about factors that stimulate the repair of body tissues after breakdown. Specifically, there is a paucity of information about effects of mechanical stress on healing. This is a particularly important consideration for those areas such as the perineal and sacral tissues, [5,6,14,15,17].

Pressure ulcers usually develop over bony parts of the body that don't have much fat to pad them. Pressure ulcers are most common on the heels and on the hips. Other areas at risk for pressure ulcers include the base of the spine, the shoulder blades, the backs and sides of the knees, and the back of the head. Pressure ulcers may be caused by inadequate blood supply and resulting reperfusion injury when blood re-enters tissue. A simple example of a mild pressure sore may be experienced by healthy individuals while sitting in the same position for extended periods of time: the dull ache experienced is indicative of impeded blood flow to affected areas. Within hours, this shortage of blood supply, called ischemia, may lead to tissue damage and cell death. The sore will initially start as a red, painful area, which eventually turns purple. Left untreated, the skin may break open and become infected. Moist skin is more sensitive to tissue ischemia and necrosis and is also more likely to get infected, [5,6,5,15,17,25,27,30].

Laser is an acronym for light amplification by stimulated emission of radiation; it is a form of phototherapy which involves the application of monochromatic light over biological tissue to elicit a biomodulative effect within that tissue. Research into the role of low level laser therapy LLLT began in the late 1960s in Eastern Europe. The earliest experimental application of low power laser in medicine was

reported in 1968 by Endre and Mester in Hungary who revealed that a ruby laser treatment accelerated healing of mechanical wounds and burns. Since the 60s the volume of research into LLLT has grown and has focused to assess the value of LLLT in wound repair. Low-level laser light is compressed light of a wavelength from the cold, red part of the spectrum of electromagnetic radiation. It is different from natural light in that it is one precise color; it is coherent (it travels in a straight line), monochromatic (a single wavelength) and polarized (it concentrates its beam in a defined location or spot). These properties allow laser light to penetrate the surface of the skin with no heating effect, no damage to the skin and no known side effects. Rather, laser light directs biostimulative light energy to the body's cells which the cells then convert into chemical energy to promote natural healing and pain relief, [2, 3,7,10,11].

The Ga-As laser is pulsed wave with an average power output of 3mw and penetration depth of 10 cm as a result of its wave length which equal 904n. this laser have been most commonly used in lower doses for wound healing as they have deeper tissue penetration than the He-Ne laser. These lasers have the disadvantage that their light is invisible and therefore eye protection is required, [,16,18,19,,20,21,22,26]. The use of pulsed radio-frequency electromagnetic field (PEMF), also termed pulsed radiofrequency energy (PRFE) therapy has shown notable success in healing of chronic wounds. PEMF is a non-ionizing energy at the shortwave radiofrequency band of the electromagnetic spectrum, commonly at a frequency of 27.12 MHz. Since the introduction of PEMF in the 1950s, clinical studies on healing of chronic wounds have documented PEMF as a successful clinical therapy. Meta-analysis of the published clinical studies determined that PEMF therapy was statistically significant for wound healing outcomes, as well as pain and oedema. Human fibroblasts exposed to PEMF signal show p42/44 mitogen-activated protein (MAP) kinase activation, and increased cell proliferation,[1,8,9].

Material and Methods

Subjects

This study was carried out on40 diabetic patients with pressure ulcers grade II, their ages ranged from 40 – 60 years, were divided randomly into two equal groups in number. Group (A) Gallium arsenide (Ga-As) laser group: This group was consisted of 20 patients who received the Gallium arsenide (Ga-As) laser therapy 3 times per week for 2 months in addition to the routine conventional treatment (dressing – manage bacterial contamination – relieve pressure, friction, and shear – remove necrotic debris – correct nutritional deficits). Group (B) PEMFT group: 20 patients who received the PEMFT 3 times per week for 2 months in addition to the routine conventional treatment (dressing – manage bacterial contamination – relieve pressure, friction, and shear – remove necrotic debris – correct nutritional deficits). Measurements were conducted before starting the treatment as a first record and at the end of the treatment as a second (final) record.

Instrumentation

In this study the measuring tools and equipment were the Ulcer surface area (USA) measurement in cm^2, Ulcer volume measurement (UVM) in CC and the Colony count, while the therapeutic equipment were LASER therapy unit (Ga-As laser Device) and the JAMAV pulsed electromagnetic field unit,[1,2,7,9,10, 16,24,29.]

Procedures

Evaluation
Measurement procedures

Measurement of ulcer surface area (USA) in cm^2

The measurement of the ulcer surface area was conducted by tracing methods according to the following steps: A sterilized transparency film was placed on the wound or ulcer area. The ulcer parameter was traced by using the fine tipped-transparency marker. Each ulcer area was traced three times to establish measurement reliability. After tracing, the transparency film face, which faces the ulcer wound, was cleaned by a piece of cotton and alcohol. The carbon paper was placed over the metric graph paper $1mm^2$. The traced transparency film was placed over a carbon paper with a white paper in between and transcribed the tracing on metric graph paper. The number of square millimeters on the metric graph paper within ulcer wound was traced counted to determine the ulcer wound area. This area was converted to cm^2; the mean of the three trails was calculated and considered as a wound surface area (USA). The measurements of ulcer surface area was conducted pre-treatment and at the end of treatment after 2 months,[4, 13,18,30].

Ulcer volume measurement (UVM) in CC

The measurements of volume of the ulcer was conducted by isotonic solution according to the following steps: The sore prepared and the surrounding skin sand surrounding skin. The film was extended sufficiently beyond the same margin to ensure good adhesion. The ulcer then filled with sterile physiological saline by injection through the film. Another needle was placed at the highest point of the ulcer to allow air to escape. The volume of solution required to fill the ulcer was recorded to indicate the volume of the ulcer, [4,13,15,20,27,30].

Colony count: Semi quantitative culture of the wound surface area

A sterile cotton swab was rolled completely on the surface of the wound area, the swab material was emulsified well in a 5 ml sterile (0.9% NaCl), three serial 1:10 dilutions of the suspension was made with 0.5ml aliquots and 4.5ml of sterile saline per aliquot, a 0.1 ml aliquot of the original suspension and of each dilution was spread on the surface of the blood gar plate, all plates were incubated at 37C0 for 24 hours, the number of organisms per ml of the swab suspension was determined by counting the number of colonies on the plate that grew between 30 and 300 colonies, the number of colonies on the plate was calculated by multiplying the count in step 6 by the dilution factor, the count was done for each

colony count separately, and gram stain and key tests including oxidase, and catalase tests as well as colony morphology was performed to preliminary identify each colony count,[5,6,14,22,30].

Treatment procedures

Group (A) Ga-As Laser Group Figure (25)

Position of the patient: Prone lying position was the appropriate for sacral pressure ulcers, wound preparation: the wound was cleaned at first. Some abscesses were opened and pockets of pus was drained, and necrotic tissue was removed. Scrubbing the wound with a soft tooth brush followed by hydrogen peroxide, saline rinse and betadine, laser device preparation: the plug of laser unit was inserted into the main current supply, the on/off switch was switched on; now therapist must wear the protective eye glasses. Then set the treatment parameters of laser, continuous Ga-As Laser application: contact technique of laser application was used with the laser probe perpendicular on the surface, treating points at the ulcer margins was about 1 cm from the edge of the ulcer for about 20 minutes, frequency of application: applied three times/ week for two months, [2,3,10,11,16,17].

Group (B) PEMFT Group: PEMFT procedures

From the prone lying position which was the appropriate for sacral pressure ulcers. PEMF was applied three times/ weekly for two months. Each session was conducted for 20 minutes on the ulcer perimeter directly over sterile Vaseline gauze (sofa-tulle dressing) that covers the ulcer wound, with duration of treatment 20 minutes and a magnetic field ranged from 10 to 70 MT and a frequency ranged from 1.6 Hz to 50Hz. This apparatus is equipped with 10 therapeutic programmes namely the weakest, weak, mild, intermediate, strong and strongest electromagnetic fields. Programmes (1) & (9): are the intermediate programmes. Programmes (2) & (10): are the mild programmes. Programme (3) is the weak programme. Programme (4): is the weakest programme. Programmes (5), (6) & (7): are the strong programmes. Programme (8): is the strongest programme. A programme number (4) of the JAMAVA device which is the weakest programme that was used with a soothing North polarity of the magnetic pulses with frequency of 1.6 Hz with buttons 1,2,3 and 4 down while buttons 5 and 6 up,[1,8,9].

Data analysis

Measurement of the ulcer surface area (USA), ulcer volume measurement (UVM) and the colony count (CC)) were measured pre-treatment as a first record and after two months intervention as a second final record in both groups. Collected data were fed into computer for the statistical analysis; descriptive statistics as mean, standard deviation, minimum and maximum were calculated for each group. The t-test was done to compare the mean difference of the two groups before and after application and within each group. Alpha point of 0.05 was used as a level of significance,[23,28].

Results

As shown in table (1) and figure (1), the mean value of the USA in cm^2 before treatment was (20.360 ± 1.631) in the (Ga-As laser group), while after treatment was (11.200 ± 1.211) in cm^2 . These results revealed a highly significant decrease in USA in cm^2 ($P < 0.0001$). While in the PEMFT group, the mean value of the USA in cm^2 before treatment was (20.365 ± 1.454) in cm^2, while after treatment was (10.850 ± 0.811) in cm^2. These results revealed a highly significant decrease in the USA in cm^2 ($P < 0.0001$).

Table (1): Comparison of the mean values of the ulcer surface area (USA) measurement in cm^2 of the 2 records before and after treatment in both groups

	Before treatment		After treatment		Mean difference	T-value	P.value	Level of significance
	Mean	SD	Mean	SD				
Ga-AS laser application Group	20.360	1.631	11.200	1.211	9.16000	20.17	0.0001	Highly significant decrease
PEMFT Group	20.365	1.454	10.850	0.811	9.51500	25.56	0.0001	Highly significant decrease

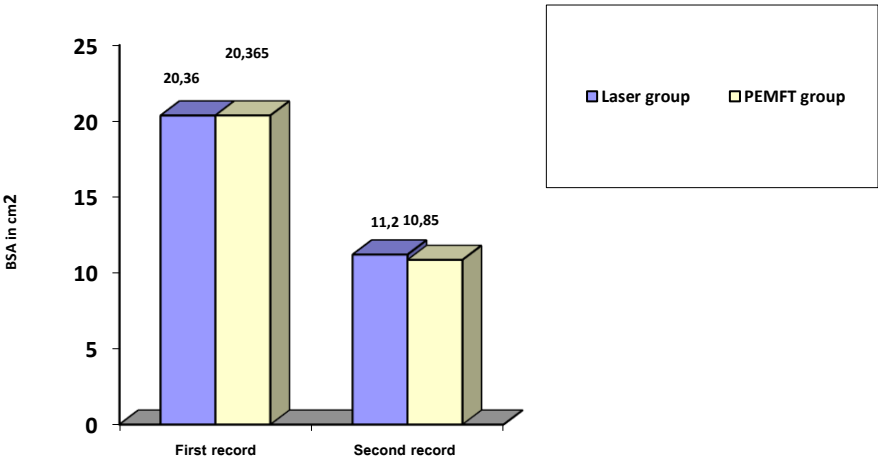

Figure 1. Bars representing the mean values of the ulcer surface area (USA) measurement in cm^2 of the 2 records before and after treatment in both groups.

As shown in table (2) and figure (2), the mean value of the UVM in CC before treatment was (18.400 ± 2.633) CC in the Ga-As laser group, while after treatment was (8.190 ± 1.422) CC. These results revealed a highly significant decrease, ($P > 0.0001$), while in the PEMFT group, the mean value of the UVM in CC before treatment was (18.394 ± 2.461) Cc, but after treatment was (8.699 ± 1.441) CC, these results revealed a highly significant reduction in the UVM in CC ($P < 0.0001$).

Table (2): Comparison of the mean values of the ulcer volume measurement (UVM) in CC before and after treatment in the two groups

	Before treatment		After treatment		Mean difference	T-value	P.value	Level of significance
	Mean	SD	Mean	SD				
Ga-AS laser application Group	18.400	2.633	8.190	1.422	10.2100	15.26	0.0001	Highly significant decrease
PEMFT Group	18.394	2.461	8.699	1.441	9.69500	15.20	0.0001	Highly significant decrease

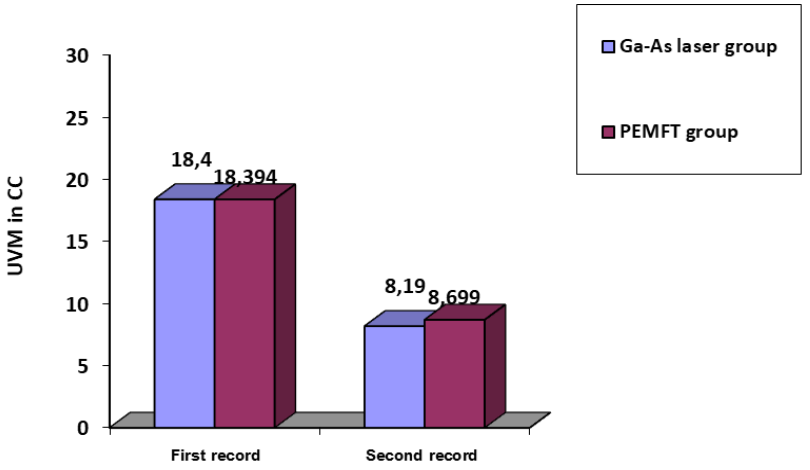

Fig (2): Mean values of the UVM in CC of the 2 records in both groups.

As shown in table (3) and figure (3), the mean value of the CC in cell before treatment was (26060 ± 3670) in the (Ga-As laser group), while after treatment was (260.5 ± 102.2) in cell. These results revealed a highly significant decrease in CC in cell ($P < 0.0001$). While in the PEMFT group, the mean value of the CC in cell before treatment was (26050 ± 802) in cell, while after treatment was (108.1 ± 24.1) in cell. These results revealed a highly significant decrease in the CC in cell ($P < 0.0001$).

Table (2): Comparison of the mean values of the s Colony Count in cell of the 2 records before and after treatment in both groups

	Before treatment		After treatment		Mean difference	T-value	P.value	Level of significance
	Mean	SD	Mean	SD				
Ga-AS laser application Group	26060	3670	260.5	102.2	25799.5	31.43	0.0001	Highly significant decrease

PEMFT Group	26050	802	108.1	24.1	25941.9	144.59	0.0001	Highly significant decrease

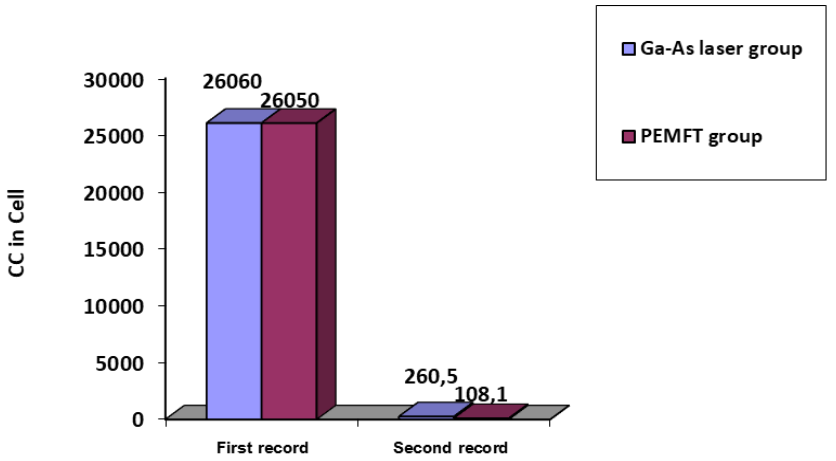

Fig (3): Bars representing the mean values of the Colony Count in cell of the 2 records before and after treatment in both groups.

Discussion

Pressure ulcer constitutes one of the major problems confronting the Healthcare professionals who are called upon to supervise the care of the severely disabled or debilitated patient. Every care provider is well aware of the complications manifested by the occurrence of ulceration in the chair or bed-ridden patient. Pressure ulcer prolongs patient morbidity and interferes with rehabilitation and medical maintenance. It may also frequently be implicated as a major contributing factor leading to the patient demise. Ulceration of the skin, especially over bony prominences, has undoubtedly plagued the disabled and debilitated patient since the beginning. Before the advent of antibiotic therapy, secondary infection of the ulcerations led to an early death, whereas today the patients usually survive for prolonged period, ,[5,6,13,14,15].

Pressure ulcers are localized areas of cellular necrosis, which usually occur over bony prominences, which are subjected for prolonged periods of time to pressure in excess of capillary pressure. Since normal cellular metabolism is dependent on the reception of nutrients and the elimination of metabolism, any condition which interferes with this exchange will affect the function of the cell. The circulating peripheral blood fulfills the metabolic needs of the cells so that alteration of the circulation in cellular changes. Prolonged circulatory interference ultimately leads to death of the cell. Pressure ulcers may be caused by inadequate blood supply and resulting reperfusion injury when blood re-enters tissue. A simple example of a mild pressure sore may be experienced by healthy individuals while sitting in the same position for extended periods of time: the dull ache experienced is

indicative of impeded blood flow to affected areas. Within hours, this shortage of blood supply, called ischemia, may lead to tissue damage and cell death. The sore will initially start as a red, painful area, which eventually turns purple. Left untreated, the skin may break open and become infected. Moist skin is more sensitive to tissue ischemia and necrosis and is also more likely to get infected, [4, 5, 6,7,14].

Illness is the most important causes of pressure sores. Even very elderly, disabled, or immobile patients who are otherwise healthy seldom develop them. They are a feature of the multi-organ failure that occurs in sick and traumatized patients of all ages. Failure of internal organs as lungs and kidneys is well organized, but death of peripheral tissue received less attention because it is less immediately life threatening. Pressure sores cause additional frequently severe trauma, however that increase pain and toxicity, slow recovery and can cause death. Impaired peripheral circulation due to atherosclerosis, arteriopathy, or vasculitis increases the risk of pressure sores, especially of the heels and feet. Virtually all diabetic foot sores are pressures, but arteriopathy is probably a less important etiological factor than neuropathy, ,[5,6, 12,13,14].

Laser systems vary in their technical and physical configuration, more specifically in their constructional design and the temporal characteristics of the emission. On its own, the laser is just a light source. However, what is required is a complete system made up of a beam transmission system and an end device to direct the radiation to the tissue to be treated, together with a means of controlling the effect. According to the wavelength, a quartz glass fiber, a fiber bundle, a hollow waveguide, or an articulated arm is used for transmission of the radiation. The end device can be, for example, a surgical microscope with a micromanipulator, an endoscope, or a slit lamp, [2, 3,10,11, 16,19].

Whenever electricity is generated, transmitted, or used, electric or magnetic fields (EMF) are produced due to the presence and motion of electric charges. Generally, these time-varying vector quantities characterized by a number of parameters, including their frequency, phase, direction and magnitude. An electromagnetic field is composed of two components; the electric field is created by the presence of an electric charge. It describes the magnitude and direction of die force it exerts on a positive electric charge (test charge). The magnitude of electric field depends on the difference in potential between charge-carrying bodies, including conductors, regardless of the amount of current that is flowing in them. The second component is the magnetic field which oscillates in perpendicular plane with the same frequency. The electric field is always perpendicular to the magnetic field,[1,8, 9].

The effect of prolonged exposure to MF on Red blood cells (RBCs) in albino rats. Results revealed that exposure of the animals to 50 Hz, 1G MF resulted revealed that in significant decrease of RBCs membrane elasticity and permeability as well as irregularity of cellular membrane. The study concluded that prolonged exposure to ELFMF has hazardous effects on RBCs membrane and affecting blood viscosity and it may be hazardous effect on RBCs membrane and affecting blood viscosity and it may be hazardous to physiotherapists. PMF has beneficial effect in aiding the regeneration process in damaged nerve fibers. It has been shown to

enhance nerve growth, regeneration, and functional recovery of the peripheral nerve. In the rehabilitative treatment of patients with organic lesions of the nervous system, magnetic and electrical stimulation were applied on 89 patients with clinical symptoms consisted of paralysis and paresis. Patients received combined treatment, including MF and an electrical stimulation protocal producing multi-level stimulation. A control group of 49 patients with similar conditions was included, and these patients received only electrical current. Results showed that combined treatment with MF and electrical stimulation was more effective, as indicated by radiographic and electromyographic investigations,[1, 8,9,12].

The findings of the present study showed that there was a highly significant decrease between the means of the second record USA (2) (after two months of the Laser application) and the first record USA (1) (pre-application) ($P < 0.0001$). Findings of the present study revealed that there was a highly significant decrease between the means of the second record USA (2) (after two months of the PEMFT application) and the first record USA (1) (pre-application) ($P < 0.0001$). Findings of the present study showed that there was a highly significant decrease between the means of the second record UVM (2) (after two weeks application of the Ga-As Laser) and the first record UVM (1) (pre- treatment) ($P< 0.0001$).

Also, findings of the present study showed that there was a highly significant decrease in the means of the UVM records; between UVM (2) and UVM (1) in the second study group (application of the PEMFT) ($P<0.0001$).Results of this study supported that there was a highly significant decrease between the means of the second record CC (2) (after two months of the Ga-As laser application) and the first record CC (1) (pre- treatment) ($P< 0.0001$). Also, findings of the present study showed that there was a highly significant decrease between the means of the second record CC (2) (after two months of the PEMFT application) and the first record CC (1) (pre- treatment) ($P< 0.0001$).

Results of this study supports the expectation that both the Ga-As laser and the PEMFT, were significantly effective in improving healing of pressure ulcers as manifested by the highly decreased USA, UVM and CC in both groups. These significant differences, between the first study (Ga-As laser application) and the second study (PEMFT application) groups, which were in the form of a highly significant decreases in the USA, UVM and CC, were consistent with those observed and recorded by Aaron et al., 2004; Adey, 2004; Alfredo et al., 2012; Asada, et al., 2007; Avci et al., 2013; Ay and Evcik, 2009; Bachl et al., 2008; Basso et al., 2013; Botti, 2008; Callaghan et al., 2008; Cavalcanti et al., 2016; Chen et al., 2016; Clijsen et al., 2019; Cotler et al., 2015; Fitzsimmons et al., 2008; Frigo et al., 2010; Gama, 2008; Goodman, 2009; Kheshie et al., 2014; Sinclair, 2007; Szymanska et al., 2013and Whitney, 2005. Both the Ga-As laser and the PEMFT, were significantly effective in improving healing of pressure ulcers as manifested by the highly decreased USA, UVM and CC in both groups.

Conclusion

Application of both the Ga-As laser and the PEMFT, were significantly effective in improving healing of pressure ulcers as manifested by the highly decreased USA, UVM and CC in both groups.

References

1. Aaron RZ, Cimbor DA and Simon BS, (2004): "treatment of nonunion fracture with electric and electromagnetic fields". ClinorthtopRelat Res (419):21-29.
2. Al Rashoud AS, Abboud RJ and Wang W et al., (2014): Efficacy of low-level laser therapy applied at acupuncture points in knee osteoarthritis: a randomized double-blind comparative trial. Physiotherapy, 100(3), 242-248.
3. Alfredo PP, Bjordal JM and Dreyer SH et al., (2012): Efficacy of low level laser therapy associated with exercises in knee osteoarthritis: a randomized double-blind study. Clinical rehabilitation, 26(6), 523-533.
4. Amirlak B and Shahabi L, (2017): Skin Anatomy. The integumentary system 7.2: layers of the skin.
5. Armstrong DG, Boulton AJ and Bus SA et al., (2017): Diabetic Foot Ulcers and Their Recurrence. N Engl J Med; 376:2367.
6. Attinger CE, Steinberg JS and Meyr AJ et al., (2010): Debridement of the Diabetic Foot Wound. In: Clinical Care of the Diabetic Foot, Second Edition, Armstrong DG, Lavery LA (Eds), American Diabetes Association, Alexandria. p.49.
7. Avci P, Gupta A and Sadasivam M et al., (2013): Low-level laser (light) therapy (LLLT) in skin: stimulating, healing, restoring. In Seminars in cutaneous medicine and surgery (Vol. 32, No. 1, p. 41). NIH Public Access.
8. Ay S and Evcik D, (2009): The effects of pulsed electromagnetic fields in the treatment of knee osteoarthritis: a randomized, placebo-controlled trial. Rheumatol Int 29:663-666.
9. Bachl N, Ruoff G and Wessner B et al., (2008): Electromagnetic interventions in musculoskeletal disorders. Clin Sports Med 27:87-105.
10. Basso FG, Oliveira CF and Kurachi C et al., (2013): Biostimulatory effect of low-level laser therapy on keratinocytes in vitro. Lasers Med Sci 2013 28(2): 367-374.
11. Baxter GD, Bell AH and Allen JJ, (2007): Low level laser therapy: current clinical practice in Northern Ireland. Physiotherapy.77:171–178.
12. Benbow MV, (2007): Diagnosing and assessing wounds. J. of Community Nurs; 21 (8): 26 – 34.
13. Biga LM, (2019) : Anatomy and Physiology. The integumentary system 5.1: layers of the skin.
14. Bluestein DK and Javaheri AL, (2008): Pressure ulcers: prevention, evaluation, and management, Am Fam Physicians. 2008; 78 (10): 1186-1194, 1195-1196
15. Calvin MY, (2008): “Cutaneous Wound Repair.” Laser and wounds, 15 (4): Pp 22-34.
16. Cavalcanti MF, Silva UH and Leal-Junior EC et al., (2016): Comparative Study of the Physiotherapeutic and Drug Protocol and Low-Level Laser Irradiation in the Treatment of Pain Associated With Temporomandibular Dysfunction. Photomed Laser Surg. [Epub ahead of print].

17. Chang AC Derman AB and Edward JG, (2011): A comparison of wound area measurement techniques: visitrak versus photography. Journal of plastic surgery vol.11 p.158
18. Chen YT, Wang HH and Wang TJ et al., (2016): Early application of low-level laser may reduce the incidence of postherpetic neuralgia (PHN). J Am Acad Dermatol. 2016;75(3):572-7.
19. Clijsen R, Brunner A and Barbero M et al., (2019): Effects of low-level laser therapy on pain in patients with musculoskeletal disorders: a systematic review and meta-analysis. Available from: https://www.ncbi.nlm.nih.gov/pubmed/28145397.
20. Cotler HB, Chow RT and Hamblin MR et al., (2015): The use of low level laser therapy (LLLT) for musculoskeletal pain. MOJ orthopedics & rheumatology, 2(5).
21. Da Silva JP, Da Silva MA and Almeida AP et al., (2010): Laser therapy in the tissue repair process: a literature review. Photomedicine and laser surgery, 28(1), 17-21
22. Frigo L, Fávero GM and Lima HJ et al., (2010): Low-level laser irradiation (InGaAlP-660 nm) increases fibroblast cell proliferation and reduces cell death in a dose-dependent manner. Photomed Laser Surg; 28 Suppl 1: S151-S156.
23. Hinton PR, (2004): "Statistics Explained"2nd Ed. Rutledge Taylor &Francis Group London Pp149-155.
24. Kheshie AR, Alayat MS and Ali MM et al., (2014): High- intensity versus low-level laser therapy in the treatment of patients with knee osteoarthritis: a randomized controlled trial. Lasers in medical science, 29(4), 1371-1376.
25. Koh TJ and DiPietro LA, (2011): Inflammation and wound healing: the role of the macrophage. Expert Rev Mol Med; 13:e23.
26. Law D, McDonough S and Bleakley C et al., (2015): Laser acupuncture for treating musculoskeletal pain: a systematic review with meta-analysis. Journal of acupuncture and meridian studies, 8(1), 2-16.
27. Nguyen DT, Orgill DP, and Murphy GF, (2009): The pathophysiological basis for wound healing and cutaneous regeneration. Biomaterials for treating skin loss. Wood head Publishing p.25-27.
28. Pipkin FB, (1984): Medical statistics made easy. Edinburgh London. Melbourne and New York.
29. Szymanska J, Goralczyk K and Klawe JJ et al., (2013): Phototherapy with low-level laser influences the proliferation of endothelial cells and vascular endothelial growth factor and transforming growth factor-beta secretion. J Physiol Pharmacol 2013;64(3): 387-391.
30. Whitney JL, (2005): Overview: acute and chronic wounds. Nurs Clin N Am. 40:191-205.
31. Widana, I.K., Sumetri, N.W., Sutapa, I.K., Suryasa, W. (2021). Anthropometric measures for better cardiovascular and musculoskeletal health. *Computer Applications in Engineering Education*, *29*(3), 550–561. https://doi.org/10.1002/cae.22202
32. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). Health and treatment of diabetes mellitus. *International Journal of Health Sciences*, *5*(1), i-v. https://doi.org/10.53730/ijhs.v5n1.2864