Effects of Microcurrent Stimulation Versus Pulsed Electromagnetic Field on Wound Healing in Burned Patients

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ABSTRACT

The purpose of this study was to evaluate the efficacy of the pulsed electromagnetic field therapy (PEFT) versus microcurrent electrical stimulation (MENS) on burned wounds healing by using wound surface area (WSA), maximum wound length (MWL) and duration of healing. Forty-five patients with dermal burn injuries on the forearm were participated in the present study and randomly divided into three equal groups; group A, which received pulsed electrical magnetic field with their traditional physical therapy program (positioning, splinting and range of motion exercises), group B, which was treated with microcurrent electrical stimulation with traditional physical therapy program and group C, which received only traditional physical therapy program. WSA and MWL had been measured 48 hours after burn injury (Pre), after 14 days Post (1), and after 28 days Post (2) from the beginning of treatment for all groups. Results showed that there were no significant differences in WSA and maximum length in MENS group and PEMF group as compared with the control group. In relation to WSA and MWL the study revealed that the results obtained in Group A were superior to that of Group B but with no significant difference after 14 days, on the other hand it was reported that after 28 days the results of group B was superior to that of group A but with no significant difference. On conclusion the present study revealed that both pulsed electromagnetic field and microcurrent electrical stimulation are effective in accelerating wound healing.
Key words: *Burn, Pulsed Electromagnetic, Micro Amperage Electrical Stimulation, Wound Surface Area and Wound Healing.*

INTRODUCTION

Burn is a coagulative necrosis of the skin and underlying tissue. Most burns are not life threatening, but each burn causes a significant amount of pain for the patient, and some degree of psychological trauma to all those involved[1]. Human skin possesses endogenous electrical properties that influence wound healing. The natural regenerative process can be enhanced by applying external electricity to the wound site[2]. The process of regeneration and repair following injury represents one of the most fundamental defence mechanisms of an organism against environmental damage. Biological processes such as inflammation, proliferation, wound contraction and remodelling lead to scar formation[3,4].

The management of open skin wounds constitutes an important clinical problem, the use of electrical stimulation should be considered as a therapeutic option for treating skin wounds. Several investigators have reporting a beneficial effect resulting form treatment of a variety of skin wounds with electrical stimulation[5]. It is believed that electric stimulation and electromagnetic fields play their roles in healing by guiding cellular movements that close wounds. It has been shown that this field can affect the orientation, migration and proliferation of cells such as fibroblasts and keratinocytes, which are of key importance in healing[6].

Electrical stimulation is based on the fact that human body has an endogenous bioelectric system that enhances healing of bone fracture and soft tissue lesions. When the body's endogenous bioelectric system fails, cannot contribute to the wound repair process, therapeutic levels of electrical current may be delivered into the wound tissue from an external source. The external current may serve to mimic the failed natural bioelectric currents, so that wound healing can be proceeded[7]. It was reported that microcurrent electrical neuromuscular stimulation (MENS) is better in enhancing cellular physiology processes than other current of higher amplitude, and it is effective in the management of open wounds. Micro current therapy uses extremely small amounts of electrical current to help in reliving pain and healing of the soft tissues of the body, and it is an alternate, non invasive approach for healing of acute and chronic medical conditions[8].

Pulsed electromagnetic field therapy is a physical therapy modality that has been widely used for increasing permeability of the cell membrane and blood circulation, increasing oxygen supply, stimulating healing process and epithelialisation of the injured tissues, accelerating bone healing, improving fibroblastic as well as osteoblastic activities, plus its anti-inflammatory and analgesic effects[9,10]. The use of low-frequency pulsed electromagnetic field (PEMF) for selective control of cellular function has given biology and medicine a new dimension, so it is called the electromagnetic medicine and there are successful results in its use in the treatment of un-united fractures[11]. The biological effects and interactions of magnetic fields with living organisms are very complicated. It is too early to give the mechanism, a lot of research activities are need to be carried out to give a satisfactory explanations for the phenomena, but the newly findings about the magnetic field effects on the biological and living systems are influences of the magnetic fields on properties of the biological liquid crystals and ionic motion[12].

The Purposes of this study were to: evaluate the therapeutic efficacy of both MENS and PEMF, detect which one of them would be more effective and better than the other in accelerating healing of the burned wounds and share in designing the optimal and ideal protocol for the treatment of the burned wounds.

SUBJECTS, MATERIALS AND METHODS

Subjects

Forty five male patients with partial thickness thermal burn injuries on the forearm involved in the current study; they were recruited from OM-El-Misrean burn unit. Their ages ranged from 25 to 35 years old. Diagnosis was made clinically by physician. The patients were randomly divided into three equal groups. Two study groups (one for PEMF and the other for MENS) and one control group. The first study group (A) composed of fifteen patients who received PEMF in addition to the traditional physical therapy routine "positioning, splinting and ROM exercises" and conservative treatment of the burn wound for one month. The second study group (B) composed of fifteen patients who received MENS in addition to traditional physical therapy routine and conservative treatment for the burn wound for one month, while the control group (C) composed of fifteen patients who received traditional physical therapy routine and conservative treatment for the burn wound only for one month also.

Inclusive criteria

All patients had burn with total body surface area "TBSA" of (25٪ to 40٪). The cause of burn with was the thermal injuries.

Exclusive Criteria

The exclusive criteria included patients who had diabetes, skin abnormalities, sever anaemia, inhalation injuries, skin graft, acute viral disease, acute tuberculosis, mental disorders or those with pacemakers[13].

Equipment

Measuring equipment

1- Planimetery method was used to measure the wound surface area that composed of sterilized transparent films, three fine tipped transparent marker with three different colours (Black, green and red), Metric graph paper (1 mm^2) and white paper[7.] This method was used to trace accurately by outline of the epithelial edge wound before treatment and after two weeks of the treatment as well as at the end of the fourth week of treatment[14].

2- Maximum length of the wound was measured by the use of metric graph paper and standard ruler.

3- Duration of wound healing.

Therapeutic equipment

1- Micro current unit device: Micro current 850 unit device (it has been manufactured in Taiwan for Chattanooga Group inks us 2003).

2- Pulsed electromagnetic field therapy unit: The treatment protocol was achieved by using JAMAVA® Pro MAGNETOTHEARAPEUTIC DEVICE

Procedures of study

Measurement Procedures

A- Wound surface (WSA)

It was calculated according to planimeter method by placing a piece of sterilized transparency film over the wound and tracing the wound perimeter on the film with fine tipped transparency marker. A separate transparency was used for each wound .The tracing was then placed over metric graph paper and the number of 1mm, the tracing was counted (only full 1 millimetre squares inside the perimeter was counted) and the area was converted to square centimetres[7].

B-Maximum length of the wound

The length of the largest distance between any 2 points on the periphery of the wound was considered as maximum length of wound and it would be measured using standard ruler[15].

C- Duration of wound healing

It was the time taken from the first of the study till maximum contraction of wound that occurred.

Therapeutic Procedures

All patients in the 3 groups (A), (B) and (C) were received the same traditional physical therapy routine in the form of, positioning, splinting, ROM exercises and conservative treatment for wound. Dressing was the same for all patients in the 3 groups as all dressing was changed once daily[16.] Therapeutic intervention for the study had been started at third day post burn for all groups as following:

1-Therapeutic Procedure for Group A (PEMF)

PEMF with frequency of 50 HZ was applied once daily, three times per week for one month. Each session was conducted for 20 minutes on the wound directly over sterile Vaseline gauze that covers the burn wound by a strap around the forearm to prevent germs or similar form being transmitted to other patients and avoid any allergic sensitization.

2-Therapeutic Procedure for Group B (Microcurrent Group)

The microcurrent unit was used for treatment, with constant current of 50% of duty cycle, at 0.3 Hz with modified square biphasic pulsed waveform and intensity of 600 microampers[17]. The electrodes (negative) were placed over the burn perimeter after being soaked in sterile 0.9% NaCl, and then carefully wrapped around the affected area. All patients were received the treatment for 45 minutes three session per week for total period of the study one month. The patients were instructed to remain in the same position for the treatment period[18].

RESULTS

Comparative Analysis among Groups of the Study

(A) Comparative Analysis of Patients Demographic Data

One way repeated measure analysis of variance (ANOVA) of the patients' age and TBSA for PEMF, MENS, and control groups revealed that there were no statistical significant differences (P>0.05) of mean value of patients at entry of the study.

(B) Comparative Analysis of Wound Surface Area

1- Comparative Analysis of Wound Surface Area at Pre Treatment:

Table (1) showed that, there were no statistical significant differences (P>0.05) of mean value of WSA among PEMF, MENS and control groups at entry of the study.

Table (1): Comparative analysis of the mean values of WSA among the PEMF, MENS and control groups at entry of the study.

Statistics	WSA(Cm^2) at Pre treatment		
	PEMF	MENS	Control
Mean	18.41	17.77	18
±S.D	3.77	4.64	4.53
F-value	0.08		
P-Value	0.9		
Sig.	NS		

2- Comparative Analysis of Wound Surface Area after 14 days of treatment (Post 1):

Table (2) and fig (1) showed the comparative analysis of the mean differences of WSA between the PEMF, MENS and control groups after 14 days of treatment (Post 1) and it revealed that there were highly statistical significance reduction (P<0.01) for mean values of WSA between PEMF and control group, and between MENS and control group while there were no statistical significance difference (P>0.05) for mean values of WSA between PEMF and MENS group after 14 days of treatment.

Table (2): Comparative analysis of the mean differences of WSA between the PEMF, MENS and control groups after 14 days of treatment (Post 1).

Statistics	WSA (Cm^2) Post I (after14 days of Treatment)					
	PEMF	Control	MENS	Control	PEMF	MENS
Mean	6.79	14.59	8.11	14.59	6.79	14.59
S.D±	1.86	3.77	2.47	3.77	1.86	3.77
MD	7.8		-6.48		-7.8	
P-Value	0.001		0.001		0.4	
Sig.	HS↓		HS↓		NS	

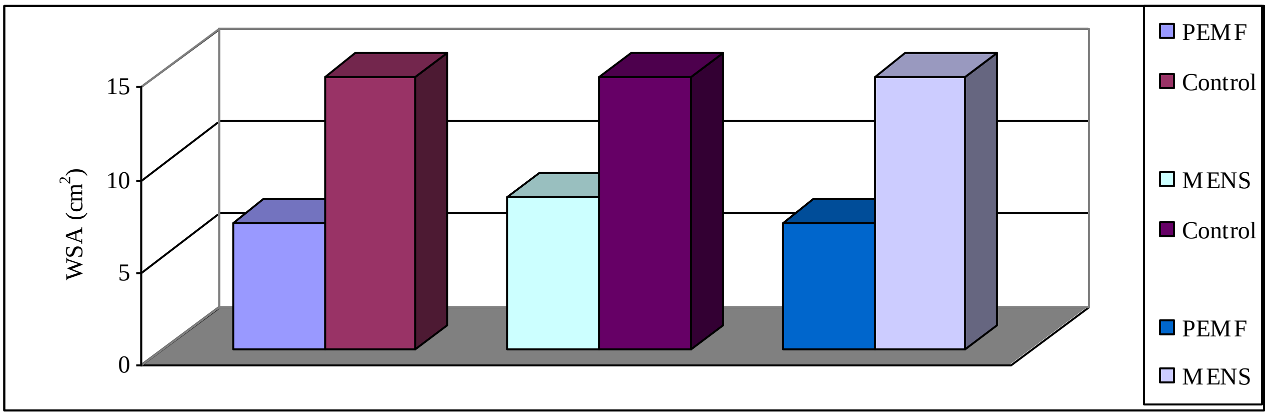

Fig. (1): The mean values of WSA after 14 days of treatment (Post I) for PEMF, MENS and control groups.

<u>3- Comparative Analysis of Wound Surface Area after one month of treatment (Post 2):</u>

Table (3) and fig (2) represented the comparative analysis of the mean differences of WSA between the PEMF, MENS and control groups after one month of treatment (Post 2) and it revealed that there were highly statistical significance reduction (P<0.01) for mean values of WSA between PEMF and control group and between MENS and control group after one month of treatment, while there were no statistical significance difference (P>0.05) for mean values of WSA between PEMF and MENS group.

Table (3): comparative analysis of the mean differences of WSA between the PEMF, MENS and control groups after one month of treatment (Post 2).

Statistics	WSA(Cm^2)(after one month of Treatment-Post2)					
	PEMF	Control	MENS	Control	PEMF	MENS
Mean	2.1	8.67	1.83	8.67	2.1	1.83
S.D±	1.47	4.01	1.52	4.01	1.47	1.52
MD	-6.57		-6.84		0.27	
P-Value	0.001		0.001		0.95	
Sig.	HS↓		HS↓		NS	

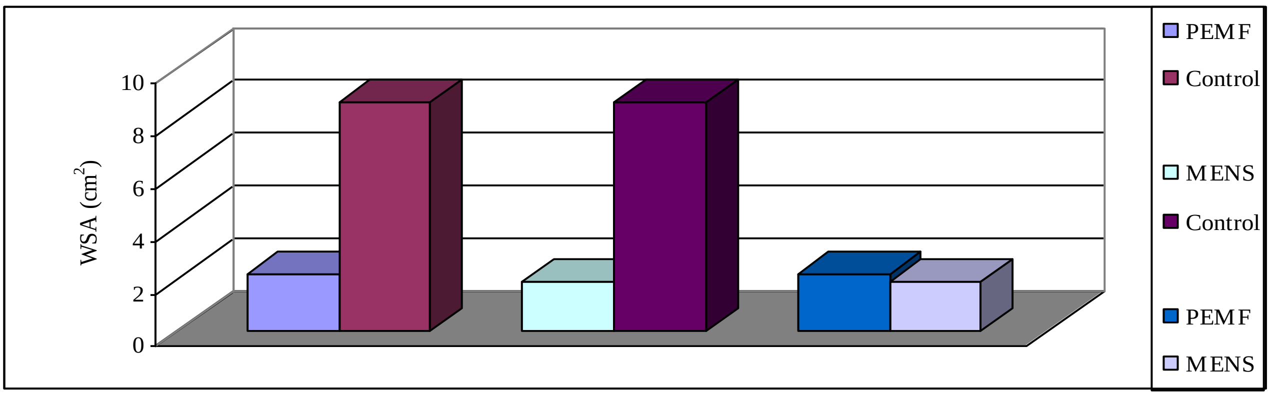

Fig. (2): The mean values of WSA after one month of treatment (Post 2) for PEMF, MENS and control groups.

(C)-Comparative Analysis of Maximum Wound Length:

1- Comparative Analysis of maximum wound length at Pre Treatment:

As observed in table (4), one way repeated measure analysis of variance (ANOVA) of maximum wound length for PEMF, MENS, and control groups revealed no statistical significant differences (P>0.05) of mean value of maximum wound length among PEMF, MENS and control groups at entry of the study.

Table (4): Comparative analysis of the mean values of maximum wound length among the PEMF, MENS and control groups at entry of the study.

Statistics	Maximum wound length (Cm^2) at Pre treatment		
	PEMF	MENS	Control
Mean	6.01	6.08	5.75
±S.D	1.008	1.08	0.84
F-value	0.4		
P-Value	0.6		
Sig.	NS		

2- Comparative Analysis of Maximum Wound Length after 14 day of treatment (Post 1):

Table (5) and fig. (3) represented the comparative analysis of the mean differences of maximum wound length between the PEMF, MENS and control groups after 14 days of treatment (Post 1) and it revealed that, there were highly statistical significance reduction (P<0.01) for mean values of maximum wound length between PEMF and control group between MENS and control group while there were no statistical significance difference (P>0.05) for mean values of maximum wound length between PEMF and MENS group after 14 days of treatment.

Table (5): comparative analysis of the mean differences of maximum wound length between the PEMF, MENS and control groups after 14 days of treatment (Post 1).

Statistics	Maximum wound length (Cm) Post I(after14 days of Treatment)					
	PEMF	Control	MENS	Control	PEMF	MENS
Mean	3.74	4.96	3.88	4.96	3.74	3.88
S.D±	1.08	0.91	0.93	0.91	1.08	0.93
MD	-1.22		-1.08		-0.14	
P-Value	0.004		0.01			
Sig.	HS↓		S↓		NS	

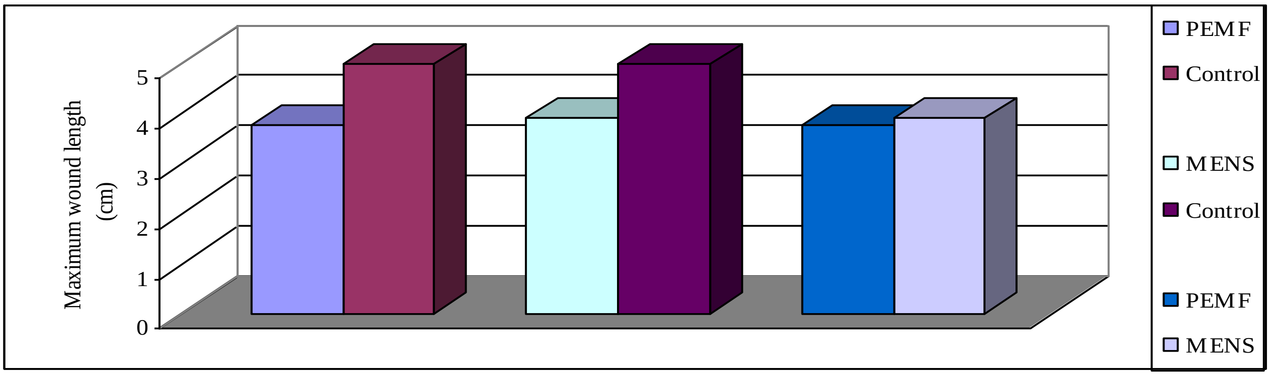

Fig. (3): The mean values of maximum wound length after 14 days of treatment (Post I) for PEMF, MENS and control groups.

<u>3- Comparative Analysis of Maximum Wound Length after one month of treatment (Post 2):</u>

Table (6) and fig (4) showed the comparative analysis of the mean differences of maximum wound length between the PEMF, MENS and control groups after one month of treatment (Post 2) and it revealed that there were highly statistical significance reduction (P<0.01) for mean values of maximum wound length between PEMF and control group and between MENS and control group while there were no statistical significance difference (P>0.05) for mean values of maximum wound length between PEMF and MENS group after one month of treatment.

Table (6): comparative analysis of the mean differences of maximum wound length between the PEMF, MENS and control groups after one month of treatment (Post 2).

Statistics	Maximum wound length (Cm) (after one month of Treatment-Post2)					
	PEMF	Control	MENS	Control	PEMF	MENS
Mean	1.68	3.66	1.34	3.66	1.68	1.34
S.D±	1.18	1.62	1.08	1.62	1.18	1.08
MD	-1.98		-2.32		0.34	
P-Value	0.001		0.001		0.76	
Sig.	HS↓		HS↓		NS	

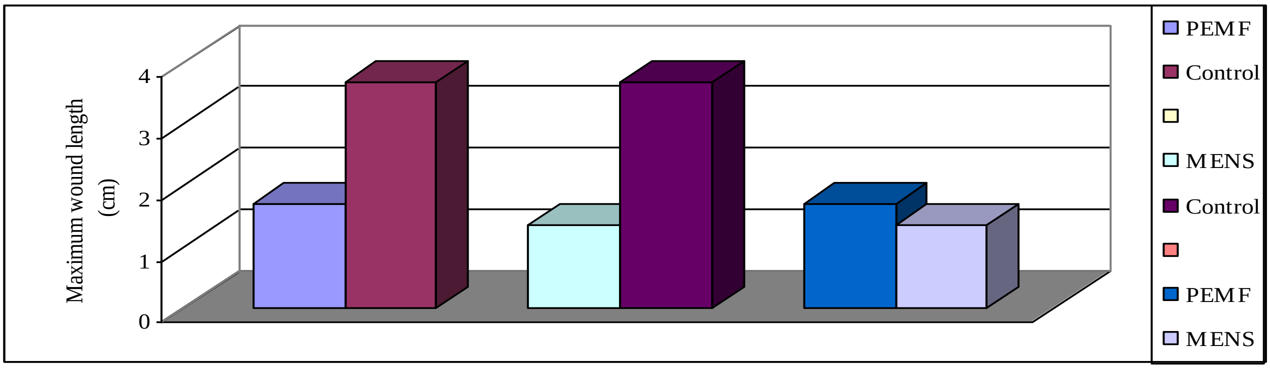

Fig. (4): The mean values of maximum wound length after one month of treatment (Post 2) for PEMF, MENS and control groups.

Comparative Analysis of duration of wound healing

Table (7) and fig. (5) showed the comparative analysis of the mean differences of duration of wound healing between the PEMF, MENS and control groups and it represented that, there were highly statistical significance difference (P<0.01) for mean duration of wound healing between PEMF and control group and between MENS and control group while there were no statistical significance difference (P>0.05) for mean duration of wound healing between PEMF and MENS group.

Table (7): Comparative analysis of the mean differences of duration of wound healing between the PEMF, MENS and control groups.

Statistics	Duration of wound healing (days)					
	PEMF	Control	MENS	Control	PEMF	MENS
Mean	19	26	19.4	26	19	19.4
S.D±	1.15	1.41	1.67	1.41	1.15	1.67
MD	-7		-6.6		0. 4	
P-Value	0.001		0.002		0.9	
Sig.	HS↓		HS↓		NS	

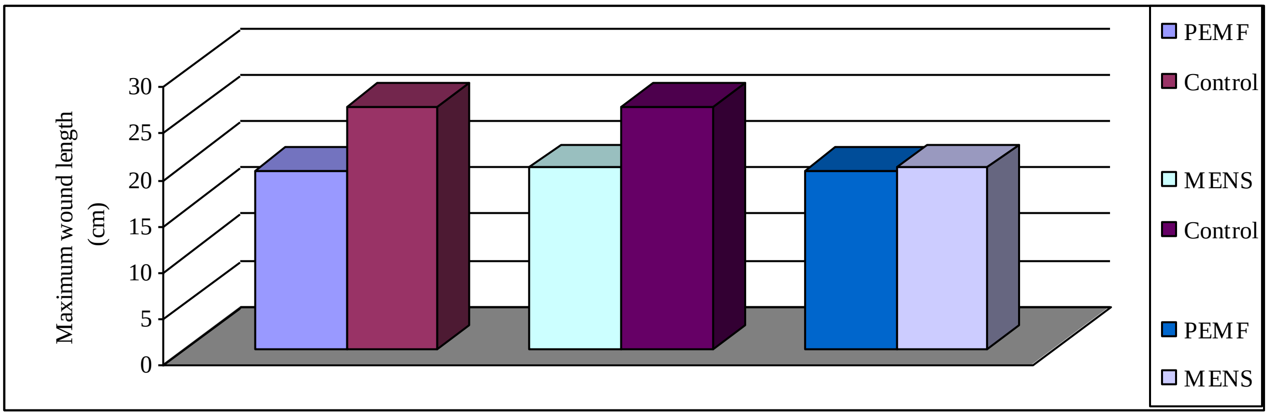

Fig. (5): The mean values of duration of wound healing for PEMF, MENS and control groups.

DISCUSSION

The current study was conducted to determine and compare between the effect of PEMF& MENS on acceleration of burn wound healing in patients. Forty five patients with partial thickness burn and WSA between 20-40%. Their age ranged from 25 to 35 and they were divided into 3 equal groups Group (A); received PEMF and standard physical therapy program which consisted of: positioning, splinting and ROM exercises, group (B) received MENS in addition to standard physical therapy program and group (C) received standard physical therapy program. In the present study all factors that might affect the rate of burn healing had been controlled as much as possible including age, cause, extent, and depth of burn, medical treatment and diet.

In the current study; wound surface area, maximum length and duration of healing were used as a measurement of healing of wound. The measurement procedures were conducted before treatment application, after 14 days and after 28 days.

ES and electromagnetic field have been shown to influence epidermal cell proliferation and migration (i.e. closure) and dermal fibroblastic activity (collagen secretion) that is why WSA measurement, maximum length as a result of ES and electromagnetic field on healing of burn wound were studied[19]. In the present study, measurement of WSA by tracing has been employed by Masjeske[20] who reported that the tracing method have been considered reliable method for measurement of WSA. He also reported that graph paper technique might be preferable in most clinical setting because it is low in cost and easy in use.

The results of our study showed that there were significant decrease in WSA as well as maximum wound length and duration of healing in PEMF group and MENS group compared to the control group while there were no significant difference between group A (PEMF) and group B (MENS) in the previous measurements.

In our study the polarity was reversed which was in agreement with Alon[21], who reported that, automatic reversal of the polarity is a major step toward minimizing the adverse chemical irritation. As well as this was explained by Demir et al.,[22], through increasing the breaking strength of the wound. Furthermore, Nossier and Abdel Zaher[23], reported that positive polarity enhanced ion transport, fibroblast migration, protein synthesis, and decreased vascular congestion, while negative polarity increased migration of epidermal cells, macrophages, and leukocytes in addition to decreased bacterial counts. Under both the cathode and anode there is increased transcutaneous oxygen. So, reversing the polarity may help to increase the rate of wound contraction and help to reach optimal rate of healing.

Low pulsed magnetic field (LPMF) is a very effective biophysical modality used in physical therapy and utilized for acceleration therapeutic purposes as well as in the area of diagnoses[24]. Published reports indicated that the PEMF stimulators may promote wound healing, but this depends on parameters such as frequency, intensity, exposure time and orientation of PEMF[25]. Data from several small, randomized controlled trials suggest that pulsed high-frequency electromagnetic energy may promote healing of chronic ulcers and soft tissue injuries. The results of this study concerning the effect of PEMF for promoting healing of dermal burn in humans confirm the observations of the following authors; Callaghan[26], studying wound healing under the influence of PEMF and he stated that PEMF accelerates wound closure and increases endothelial cell proliferation. Strauch et al.,[27] examined the effect of pulsing electromagnetic fields on the biomechanic strength of rat Achilles' tendons at 3 weeks after transection and repair. He showed that electromagnetic field enhanced Ca (2+) binding in the growth factor cascades involved in tissue healing, and achieved a marked increase of tensile strength at the repair site. Ahmadian et al.,[28] investigated the effects of extremely-low-frequency PEMFs on the synthesis of epidermal collagen. It was concluded that at 25 Hz under a field setting of 2 mT for the duration of 8 days, stimulation of skin at 2.5 h/day would cause increase in collagen synthesis in rat skin. In addition to the previous Athanasiou[25] investigated the effects of short duration PEMF on secondary healing of full thickness skin wounds in a rat model. According to their findings with the planimetry, there was a statistically significant acceleration of the healing rate for the first 9 days in the experimental group, whereas a qualitative improvement of healing progress was identified by histological examination at all time points, compared to the control group. It is believed that electromagnetic fields play its role in healing by guiding cellular movements that close wounds. It has been shown that fields can affect orientation, migration and proliferation of cells such as fibroblasts, myofibroblasts and keratiocytes, which are of key importance in healing[29,30].

On the other hand Shahar et al.,[31] examined the effect of high intensity, short duration pulsed electromagnetic fields (PEMF) on the healing of full thickness skin wounds in rats. And they concluded that this type of PEMF did not have a significantly beneficial effect on wound healing. As well as Milgram et al.,[32] reported on the use of short duration PEMF for secondary healing of skin wounds in rats, there was an increase of epithelisation in the treated group during early stages of wound repair, but there was no significant difference when compared to the control group.

Results of our study concerning the effect of MENS for promoting healing of dermal burn in humans confirm the observations of the following authors; Reger et al.,[33] who used 600 µA for 2 hours a day, 5 days a week for a whole month to treat 19 monoplegic adult minipigs with stage III and IV sores, found 28% more reduction in wound volume compared with the control. In addition to that Demir et al[22], found that significant decrease in polymorphnuclear leukocytes and macrophages numbers were found on the 10th day in the electrically stimulated group more than the sham ES and the laser groups, while there was increased level of hydroxyproline. On the other hand there were results opposed our finding .As in studies done by Byl et al.,[34] and Leffmann et al.,[17].

From the previous it was concluded that both pulsed electromagnetic field and micro amperage electrical stimulation were effective in accelerating wound healing.

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الملخص العربي

تأثيرات التنبيه الكهربي الدقيق مقابل المجال الكهرومغناطيسى النابض على التئام الجروح بمرضى الحروق

كان الهدف من البحث استكشاف دور التيار الكهربي الدقيق ودور المجال الكهرومغناطيسي في التئام الحروق و المقارنة بينهما لزيادة سرعة التئام الحروق . اشترك في هذه الدراسة 45 مريضا لديهم حروق من الدرجة الثانية بنسبة تتراوح بين 25-40 % وعمرهم بين 20-35 سنة وتم تقسيمهم عشوائيا إلى ثلاث مجموعات متساوية تتكون كل مجموعة من 15 مريضا:المجموعة الأولى (أ) وتتلقى العلاج باستخدام المجال الكهرومغناطيسي بالإضافة إلى العلاج الطبيعي التقليدي،المجموعة الثانية (ب) و تتلقى العلاج باستخدام التيار الكهربي الدقيق بالإضافة إلى العلاج الطبيعي التقليدي ، المجموعة الثالثة (ج) وتتلقى فقط العلاج الطبيعي التقليدي . وقد تم قياس سرعه التئام الجروح عن طريق: قياس مساحه السطح المحترق وقياس طول الحرق وأيضا المدة التي يستغرقها الجرح للالتئام وذلك قبل بدء التجربة (بعد مرور 48 ساعة من الحرق) وقد تم تكرار لقياسات في الأيام التالية بعد أربعه عشرة يوما وبعد شهر من بداية العلاج . ولقد أظهرت النتائج فروق ذات دلاله إحصائية بين المجموعتين العلاجيتين والمجموعة الضابطة.بينما لا يوجد فروق ذات دلاله بين المجموعتين العلاجيتين . وطبقا لهذه النتائج فانه يمكن ان نستخلص كفاءة كلاً من التنبيه الكهربي الدقيق والمجال الكهرومغناطيسي النابض فى التئام الجروح بمرضى الحروق .

الكلمات الدالة : (حرق ، المجال الكهرومغناطيسي النابض ، التنبيه الكهربي الدقيق ، مساحة سطح الجرح ، التئام الجروح) .