

Does Microamperage Stimulation Intensity Affect Rate of Wound Healing of Burned Patients?

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ABSTRACT

The aim of this work was to detect the most effective intensity of microamperage electrical stimulation (MES) to decrease wound surface area (WSA) and accelerate wound healing of dermal burn. This study was a randomized, clinical trial, which conducted in Burn Unit of OM El-Massrien hospital, Egypt. Forty five (45) patients with dermal burn injuries on the upper extremity due to thermal cause were randomly divided into three equal groups: Group (I) received 100 μ A, Group (II) received 300 μ A, and Group (III) received 600 μ A for 21 days. The results showed a significant decrease in wound surface area in all groups in comparison before and after treatment. Also, the results showed that there was a significant decrease in wound surface area in comparison between group (I),(II) and (I),(III) at the end of treatment, but there was no significant difference between group (II) and (III). According to the mean difference, the most effective intensity was 600 μ A, 300 μ A, and 100 μ A respectively.

Key words: Burn, Electrical stimulation, Pulsed microamperage current, Wound healing.

INTRODUCTION

Burn is a coagulative necrosis of the skin that is caused by chemical, thermal and electrical agents; it exerts a catastrophic influence on people in terms of human life, suffering, disability and financial loss¹⁹.

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 involved²¹. Wound healing, the result of a complex tissue repairing process, is a continuing challenge in rehabilitation medicine. Despite some recent advances in understanding its basic principles, problems in wound healing continue to cause significant morbidity and mortality²².

Tremendous efforts have been made to substantiate the use of physiotherapy to stimulate wound healing. Several putative therapeutic approaches have been proposed,

including the use of antiseptics, growth factors, pressurized oxygen, and physical therapy modalities¹².

Living tissues possess direct-current electropotentials (an endogenous bioelectric system) that appear to regulate, at least partly, the healing process. Following tissue injury, a current of injury is generated, that is thought to trigger biological repair²⁴. When the body's endogenous bioelectric system fails, cannot contribute to 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 proceed^{13,14}.

In recent years, electrical stimulation of very low amplitude and frequency modulation has become an increasingly popular treatment modality²³. This form of stimulation has been referred to as microamperage electrical stimulation (MES). MES is defined as stimulations with a very low frequency (1 Hz or less) and low intensity or amplitude (1–1,000 μ A)^{11,16}.

Electric fields impact cellular functions by activation of ion channels and/or interfering with cell membrane actions. This impact differs according to the intensity used (micro-amperes). It also depends on the used type of electrical stimulation (direct, pulsed, or alternating current), the frequency and duration of treatment, and the type and exact placement of the electrodes^{6,10}.

Although microamperage electrical stimulation was supported by some good experimental evidences and clinical researches, for healing uncertainties' concerning the optimum dosages and the lack of a convincing mechanism of stimulation¹⁷. Despite the theoretical basis for using MES to treat cutaneous wounds, not only the little controlled clinical, experimental studies had been conducted to demonstrate its effectiveness, but also no controlled

stimulation variables used have yet been established.

We undertook this study in light of the growing enthusiasm for MES most effective intensity and the paucity of supporting evidence for its use. Our null hypothesis was, electrical stimulation (with different intensities 100 μ A, 300 μ A, and 600 μ A) of wound in burned patients would not show a significant effect on reduction of WSA.

MATERIAL AND METHODS

Forty-five patients (22 male and 23 female) from Burn unit of OM El-Massrien hospital engaged in this study. Patients had thermal burn injury of second degree with total surface body area from 25 to 40%. Their ages ranged from 20 to 40 years. They were free from any disease that can affect healing process and influence the results. Patients were excluded if they had diabetes, skin malignancy in the treated area, severe anemia, associated inhalation injury, or post skin grafting. Patients were randomly divided into three equal groups.

(1) Group I (G I): This group consisted of fifteen patients that received a micro-current electrical stimulation with intensity of 100 micro amperes.

(2) Group II (G II): This group consisted of fifteen patients that received a micro-current electrical stimulation with intensity of 300 micro amperes.

(3) Group III (G III): This group consisted of fifteen patients that received a micro-current electrical stimulation intensity of 600 micro amperes.

Ethical consideration

The study protocol was explained in details for each patient before the initial assessment and signed informed consent was obtained from each patient before enrollment in the study (or their families).

Measurements

Measurements of wound surface area 72 hours post-Injury, and after 21 days.

WSA measurement procedure: this measurement was conducted by tracing burn surface area using the graph paper technique

according to¹³ As follow: a sterilized transparency film was placed directly over the burn wound, and the burn wound perimeter was traced. Three tracing of each burn wound were made at each measurement session by the same investigator to establish measurement reliability through obtaining the mean of these three measurements. Then the traced transparency film was placed over carbon paper with a white paper in-between and transcribed the tracings onto metric graph paper, and the number of 1mm² within the wound tracing was counted and the area was converted to cm².

Treatment procedures

The treatment procedure had been started at the time of admission for all groups, in the form of emergency and medical care support. All patients received equivalent nursing care. Cleaning of the burn was performed three times per week by nursing staff, using betadine, followed by an application of topical antimicrobial agents and then dry dressing. Regular diet planned for all patients was sufficient to meet caloric, protein and vitamin requirements. Therapeutic intervention for the study was started 72 hours post-burn for all groups as following:

Each patient was placed into a comfortable supported position to allow the vision of the treated area.. The micro-current unit (Micro current 850,Taiwan) was used for treatment, with constant current of 50% duty cycle, 0.3 Hz, modified square biphasic pulses and the polarity alternated between negative and positive each second. This was performed for one hour a day, for three weeks (or until wound closure) at intensity of 100 micro-amperes, 300 micro-ampere, and 600 micro-ampere for GI, GII, and GIII respectively.

Statistical Analysis

Data were represented as mean and standard deviation (SD), Paired T test was used to compare the dependent variable (WSA), within each group to detect level of significant. Unpaired T-test was applied to compare the dependent variable (WSA), and independent (age, sex, TBSA, causes of burn) variables between groups of the study to detect

level of significance. The level of significance for P-values was < 0.05 .

RESULTS

Data concerning the patient demographic data (age, sex, TBSA, causes of burn) as well as WSA had been collected at the beginning of the study. Follow up

evaluation of the WSA had been performed after 21 days of treatment.

Demographic and clinical characteristic of the patients:

As shown in table (1), There were no statistical significant differences between the groups concerning general characteristics (age, sex, TBSA, or cause of burn). As well as clinical characteristics (WSA) at the beginning of the study. ($P>0.05$).

Table (1): statistical analysis of the demographic & clinical characteristics of patients between 3 groups at the beginning of the study.

Variables	Group I (n=15)	Group II (n=15)	Group III (n=15)	P- value
Age (years)	27.93 \pm 0.92	25.26 \pm 5.17	27.2 \pm 6.03	0.31*
Sex(male/ female)	7/8	9/6	6/9	0.561*
TBSA (%)	20.24 \pm 3.93	21.44 \pm 5.26	20.26 \pm 2.46	0.63*
Cause (flam/scald)	10/5	9/6	8/7	0.753*
WSA (cm ²)	18.12 \pm 4.17	20.44 \pm 4.19	19.88 \pm 4.97	0.7*

X= Mean, SD= Standard deviation, P-value = Probability level, WSA= Wound surface area and *Non- Significant

Results of wound surface area for all groups (before and after treatment):

The results showed that, the mean value before treatment for the 1st group (GI) was 18.12 \pm 4.17 cm² while after treatment, it was 5.69 \pm 2.57 cm² with a significant improvement in the wound surface area ($P=0.000$). The mean value before treatment for the 2nd group (GII) was 20.44 \pm 4.19 cm² while after

treatment, it was 2.36 \pm 1.64 cm² with a significant improvement in the wound surface area ($P=0.000$). The mean value before treatment for the 3rd group (GIII) was 19.88 \pm 4.97 cm² while after treatment, it was 2.03 \pm 1.69 cm² with a significant improvement in the wound surface area ($P=0.000$) table (2) and figure (1).

Table (2): Comparison of WSA(cm) between pre and post treatment within the Same group.

Groups	Mean		Standard deviation		t-value	P- value
	Before treatment	After treatment	Before treatment	After treatment		
G I	18.12 cm ²	5.69 cm ²	4.17 cm ²	2.57 cm ²	16.69	0.000*
G II	20.44 cm ²	2.36 cm ²	4.19 cm ²	1.64 cm ²	22.28	0.000*
G III	19.88 cm ²	2.03 cm ²	4.97 cm ²	1.69 cm ²	16.25	0.000*

P-value = Probability level , and* - Significant

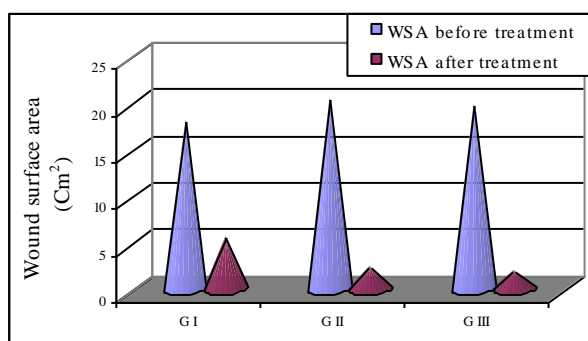


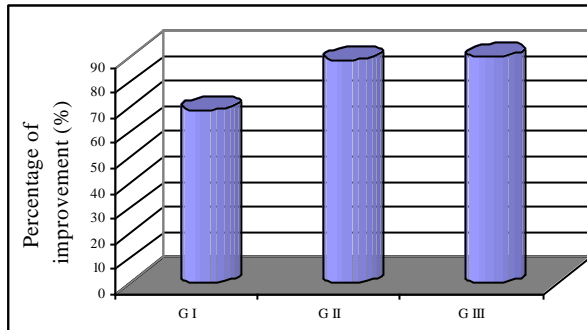
Fig. (1): Comparison of wound surface area before and after treatment for the three groups.

Percentage of improvement in all groups:

The percentages of improvement for the GI (100 μ A), GII (300 μ A), and GIII (600 μ A), were 68.60%, 88.45%, and 89.79% respectively as shown in table (3) and figure (2).

Table (3): Percentage of improvement in each group of microcurrent stimulation.

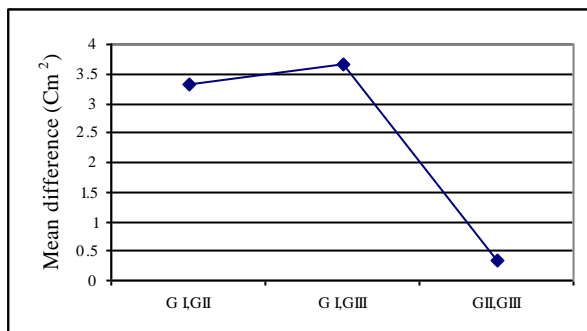
Groups	Mean		Percentage of improvement %
	Before treatment	After treatment	
G I	18.12cm ²	5.69 cm ²	68.6%
G II	20.44cm ²	2.36cm ²	88.45%
G III	19.88cm ²	2.03cm ²	89.79%

**Fig. (2): Percentage of improvement in WSA in GI, GII, and GIII.****Results of wound surface area between all groups after treatment:**

The results of this study showed that, there was a significant decrease in wound surface area between GI and GII with the mean difference of 3.33cm² (P=0.000), Also the results showed that there was a significant decrease in wound surface area between GI and GIII with the mean difference of 3.66cm² (P=0.000). On the other hand, there was no significant difference between group GII and group GIII with the mean difference of 0.33 (P=0.590) table (4) and figure (3).

Table (4): Comparison between the all groups after end of the treatment.

Groups	Mean	Mean difference	t-value	P- value
100μA	5.69 cm ²	3.33 cm ²	4.23	0.000
300μA	2.36 cm ²			
100μA	5.69 cm ²	3.66 cm ²	4.6	0.000
600μA	2.03 cm ²			
300μA	2.36 cm ²	0.33 cm ²	0.53	0.590
600μA	2.03 cm ²			

**Fig. (3): The mean difference between all groups at the end of treatment.****DISCUSSION**

Delayed wound healing specially in burn injury is continuing challenge in rehabilitation medicine despite some recent advances in understanding of its basic principles and problems in wound healing that continue to cause significant morbidity and mortality. A great number of studies had been conducted on acceleration of wound healing, attainment of normal breaking strength and prevention of

keloid and scar formation by using many physical methods such as therapeutic ultrasound, laser therapy and electrical stimulation⁵.

Electrical stimulation for wound healing was found to increase the rate of healing by more than 50% further more; the total number of wounds healed is also increased. However, optimal delivery techniques for electrical stimulation therapy have not been established to date and further research is needed to identify which electrical stimulation devices are most effective & which wounds respond best to this treatment and which intensity is most effective in each type of stimulation².

This randomized clinical study was conducted to evaluate the appropriate dosage claimed to accelerate wound healing (100, 300 or 600 μA of microamperage electrical stimulation).

In the current study, all factors that might affect the rate of wound healing had been controlled as much as possible including

the cause, site and depth of wound, age, sex, TBSA %, and diet. The results of this study revealed that, there were significant differences in WSA after 21 days of microamperage application between the GI, GII groups and between GI, GIII. While no significant difference between GII and GIII that could prove the efficacy of this method of treatment in decreasing WSA and guide the most appropriate intensity (300 μ A, or 600 μ A). According to the mean difference, the most effective intensity was 600 μ A, 300 μ A, then 100 μ A respectively.

This was in agreement with Fekry et al.,⁸, who studied the effect of micro-amperage stimulation in improving the quality of burn wound healing in Guinea Pigs. They found that Micro-current electrical stimulation is an effective therapeutic modality whether used with intensity of 100,300, or 600 μ A when used with a frequency of 0.3 Hz, at 50 % duty cycle for an hour a day with a current density of 5.09, 15.28, or 30.56 μ A/cm².

Our results are supported by the findings of Fekry et al.,⁸ Lee et al.,¹⁵, who stated that; Many experiments on the effect of electrical field exposure have demonstrated individual cells migration toward electrodes (galvanotaxis) determined by the strength of the field and the polarity of the electrodes.

Wolcott et al.,²⁵ treated patients with ischemic ulcers using low intensity direct current (LIDC) ranged from 200 – 800 μ A. They used 200 – 400 for normally innervated skin and 400 – 800 μ A for denervated skin. They found marked reduction in WSA among electrical stimulation (ES) treated patients compared to the non-treated ones.

Moreover, studies carried out on humans had proven the efficacy of ES in enhancing wound healing. Gault & Gatens⁹, reported twice the rate of healing of 106 ischemic skin ulcers in human patients using LIDC ranging from 200 to 800 μ A using the same parameters as Wolcott et al.,²⁵.

The reduction of WSA after the application of micro-amperage electrical stimulation may be attributed to several factors. Electrical stimulation was reported in many studies as a method that decreases edema, debrides necrotic tissue, attracts neutrophils and macrophages, stimulates

receptor sites for growth factors, stimulate growth of fibroblasts and granulation tissue, increase blood flow, induce epidermal cell migration, inhibits bacteria and reduce numbers of mast cells^{3,7}.

Intact skin has an electrical potential difference with the epidermis negative in relation to the dermis. Wounded skin demonstrates the existence of a natural bioelectric current called the current of injury (COI), in which the wound and adjacent epidermis become positively charged in relation to the uninjured tissue. This COI is thought to trigger biological repair. As healing progresses, the wound becomes increasingly negative through the proliferative stage with a wound closure rate of 1 mm per day. When healing is complete, the epidermis returns to its normal negatively charged state in relation to the dermis²⁰.

Lee et al.,¹⁵ hypothesized that these currents may be a normal controlling factor in wound healing. theoretically, either amplification or augmentation of the COI through ES may facilitate the healing process.

According to Canseven & Atalay, (1996) when a +ve current (I_s) is applied to the wound side, in the same direction with the natural injury current (I_n), the magnitude of the effective injury current (I_e) will be equal to the magnitude of I_n & I_s ($I_e = I_n + I_s$) and in the same direction. So, bioelectric feedback mechanism of the healing process of the applied current would be stronger than that in the self healed wounds, since the effective injury current level is higher than the natural injury current.

Our results were also in agreement with Reger et al.,²³, who used 600 μ A 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. They found 28% more reduction in wound volume compared with the control.

On the other hand, Byl et al.,³, who treated surgically induced partial-thickness, full-thickness, and incisional wounds in Yucatan pigs with microamperage (100 μ A, 1 h/day, 50% duty cycle). They found that no differences were found in tensile strength, collagen density, or visual appearance between the sham and treatment lesions. They concluded that, their study did not provide any

evidence to support the use of microamperage to expedite wound healing in the Yucatan pig, they also stated that further studies were needed to determine whether a critical interaction exists between the size of the electrode and that of the wound, density of the current, duration of the treatment, polarity of treatment electrodes, acuity or chronicity of wounding, and effectiveness of microcurrent stimulation for wound healing.

Also, Leffmann et al.,¹⁶ used 100- μ A electrical stimulation of 0.3 Hz on a 50% duty cycle for 14 days using small sized electrodes (0.41 x 0.14 cm) for 2 hours/day. Their results showed no significant difference between the experimental and the control group. Possible factors that might have affected their results include; leaving the wound uncovered to lose its moisturizes, and the treatment protocol used.

Conclusion

In summary, our study showed that electro-membrane microcurrent therapy is effective in acceleration of burn wound healing, and determined that the most effective and appropriate intensity of MES current was 600 μ A, 300 μ A, then 100 μ A respectively.

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الملخص العربي

هل شدة التنبيه بالتيار الميكرو- أمبيرى تؤثر على معدل التئام الجروح لدى مرضى الحروق ؟

الهدف من البحث تحديد أفضل شدة للتيار الميكرو - أمبيرى يمكن استخدامها لتقليل مساحة جروح الحروق وزيادة سرعة التئام الجروح . أجريت هذه الدراسة في قسم الحروق بمستشفى أم المصريين بمصر على 45 مريض لديهم حروق من الدرجة الثانية . وقد تم تقسيمهم عشوائياً إلى ثلاث مجموعات متساوية: المجموعة الأولى تكونت من 15 مريض تلقوا علاج كانت شدة التيار الميكرو - أمبيرى 100 ميكرو أمبير ، المجموعة الثانية تلقت 300 ميكرو أمبير ، المجموعة الثالثة تلقت 600 ميكرو أمبير . تلقت المجموعات الثلاث العلاج لمدة 21 يوماً أو حتى التئام الجروح . ولقد أظهرت النتائج فروق ذات دلالة إحصائية بين المجموعتين العلاجتين الثانية والثالثة و المجموعة الأولى و كانت أفضل النتائج قد تم الحصول عليها عند استخدام التيار الميكرو أمبيرى شدة تيار 600 ميكرو أمبير وأعقبه باستخدام 300 ميكرو أمبير ، وأخيراً 100 ميكرو أمبير .