Successful Treatment of Recalcitrant Remaining Postoperative Wounds by Dual-Frequency Ultrasound

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Background and Objectives

The remaining wound problem that occurs after various operations, such as skin grafts, flap operations, and wound revision, is a problem for plastic surgeons. The remaining wounds tend to be slow in healing and often become chronic wounds, which sometimes leads to additional surgery. The principle of dual-frequency ultrasound is to activate fibroblasts in soft tissue and promote tissue regeneration and protein synthesis through a cavitation and microstreaming process. This study evaluated the effects of dual-frequency ultrasound on remaining wound healing

Materials and Methods

The retrospective study included eight patients who underwent various types of surgery and the application of dual-frequency ultrasound for remnant wounds. The number of treatments until the wound was completely epithelized according to the photographic findings and chart review were analyzed, and a four point subjective scale of satisfaction was used to analyze the level of satisfaction. Patients were treated daily for six minutes each day. Photographs were taken at each treatment session, and satisfaction surveys were conducted after all treatments were completed.

Results

An average of 6.3 days was needed for 50% epithelization of the patients' wounds and 14.3 days for complete epithelization. The average number of dual-frequency ultrasound treatments during the period was 10.7, and the patients were generally satisfied with the outcome of the wound after the dual-frequency ultrasound treatment.

Conclusion

Dual-frequency ultrasound can be a therapeutic tool to promote wound healing and prevent the remnant wound from becoming chronic. Dual-frequency ultrasound is safe, has few side effects, and is a useful tool to increase the completeness of the procedure.

Key words

Ultrasound; Wound; Radiation; Fibrosis

INTRODUCTION

Wound healing process is commonly divided into three phases; inflammation, proliferation and maturation. But, in fact, wound healing cascade occurs more delicate and complicated by response and communication between the wound healing cells and the inflammatory mediators. Delayed wound healing is result of hypoxia, infection, swelling and metabolic imbalance. Delayed wound like diabetic gangrene, pressure sore, venous ulcer and recalcitrant remaining postoperative wound is always concern of plastic surgeons, because it sometimes requires additional procedure. Consequently, it brings increase of cost and hospital day, also decrease of patient's satisfaction.

Recently, the energy based treatment; ultrasound, low-level laser therapy, light-emitting diodes, extracorporeal shock wave therapy, are getting more popular. Among them, LDM®-MED (Wellcomet, Karlsruhe, Germany) is ultrasound wound treatment modality that promote a wound healing process using a dual frequency system for mechanical micro-massage effect. In this study, we used LDM®-MED for recalcitrant wound treatment with favorable result.

MATERIALS AND METHODS

The retrospective study includes eight patients from May 2015 to May 2018 who underwent various types of surgery and the application of LDM®-MED for remaining wounds. The number of treatment until the wound was

completely epithelialized by photographic findings and chart review were done. And four-point subjective scale of satisfaction was used to evaluate satisfaction. We compared clinical outcomes to those of other literatures. Patients were treated daily or every other day for 6 minutes per day by Ulcus cruris mode (3/10 MHz dual frequency setting with intensity of 1.0 W/cm² and 2.0 W/cm² each for 3 minutes) of LDM®-MED dermatologic program. Ultrasonic gel was used as coupling medium during all treatments. Photographs were taken at each treatment session, and satisfaction surveys were conducted after all treatments were completed.

RESULTS

Tables 1 and 2 show the result of treatment. Total eight patients treated about their postoperative remaining wound. There are two patients who had radiation ulcer, and they required more treatment sessions, but eventually, totally healed (Fig. 1). The other six patients have simple postoperative wound without radiation (Fig. 2). The average periods for complete epithelization of radiation group is 70 days, the average treatment time is 28.5. In literature, Delanian et al.¹ reported 53% healing using pentoxifylline and vitamin E combination therapy. And, Delanian and Lefaix² also reported 7 of 8 patients experienced complete recovery of wound in 6 ± 2 months by pentoxifylline tocopherol clodronate triple-drug therapy. The average periods for complete epithelization of non-radiation group is 12.2 days, the average treatment time

Table 1. Result of Dual-frequency Ultrasound treatment in non-radiation patients

No.	Sex/Age	Previous operation	50% epithelization (days)	Complete epithelization (days)	Number of treatment	Satisfaction
1	F/24	Flap, Skin graft	11	20	19	Good
2	M/16	Skin graft	5	8	8	Excellent
3	M/55	Skin graft	5	17	12	Good
4	F/45	Flap operation	3	5	5	Excellent
5	F/43	Flap operation	4	11	10	Excellent
6	M/35	Flap & Skin graft	5	12	6	Excellent
Mean			5.5	12.2	10	

Table 2. Result of Dual-frequency Ultrasound treatment in radiation induced ulcer patients

No.	Sex/Age	Previous operation	50% epithelization (days)	Complete epithelization (days)	Number of treatment	Satisfaction
1	F/47	Radiation ulcer, Flap	50	95	37	Good
2	F/53	Radiation ulcer, Flap	22	45	20	Fair
Mean			36	70	28.5

Fig. 1. Wound after breast reconstruction on radiation therapy patient. (A) After 4 sessions. (B) After 14 sessions. (C) After 37 sessions.

Fig. 2. Inguinal dissection wound in malignant melanoma patient. (A) Before. (B) After 6 sessions. (C) After 19 sessions.

is 10. In burn and other raw surface wounds, 3 weeks has been traditionally used as cutoff point for surgical intervention like skin graft.³ Most of disrupted wound with soft tissue defect takes more than 3 weeks for complete re-epithelization. There were no complication nor recurrence of wound during the follow up period. Most of patients expressed satisfaction to the outcome of the wound after LDM®-MED treatment.

DISCUSSION

Wound healing process consists of local inflammation, granulation tissue formation, re-epithelization, and remodeling of extracellular matrix. These process are closely associated with collagen turnover as well as with a shifting of the balance between the processes of production and degradation in the involved connective tissue. And, this balance is controlled by mesenchymal cells and various enzymes like matrix metalloproteinases (MMPs). In recent, two theories to explain the pathophysiology of chronic wound healing were proposed. One is based on the over-expression of MMPs in the wound, another is connected with the under-expression of heat shock proteins (HSPs).

MMPs are involved in the full length of wound healing process, from the inflammation phase to the resolution phase. Abnormal high activity of MMPs in the wound disturbs the wound healing process by degradation of new extracellular matrix. So, many treatment pay attention to reduce the level of MMPs during wound healing period.^{4,5}

HSPs are involved in protein quality control process including apoptosis of abnormal proteins. So, if HSP-production is damaged by some reasons like radiation or diabetes, wound healing could be delayed. Many pharmacological strategies are developed to stimulate the HSP activity during wound healing process.^{6,7}

Theoretically, treatment suppressing MMPs and stimulating HSPs simultaneously is the ideal treatment. But, unfortunately, the optimal selected suppression of some MMPs in the wound does not necessarily coincide with the optimal strategy of HSP-stimulation.⁸ So, we need to approach to this complicated situation with dual treatment method. It is the theoretical basis of the Dual-frequency ultrasound treatment.

Ultrasound with its various mechanical, thermal and chemical effects on cells and tissues has had different applications in medicine and aesthetics for a long time.

One of the most important effects of ultrasound is a

micro-massage caused through large pressure gradients in an ultrasound wave. The amplitudes of the transient pressure oscillations in an ultrasound wave of moderate intensity are much higher than the atmospheric pressure and they fall down over half a wavelength (approximately 1 mm). The pressure used during conventional vacuum-massage is 100 to 1000 times lower.

This strong micro-massage effect of ultrasound can be increased further through the LDM® Technology. LDM®-MED (Local Dynamic Micro-Massage) is a new treatment method, which is qualitatively different from other types of massage. This technology uses two ultrasound waves of different frequencies with a rapid frequency modulation. Through this modulation new micro-massage effects, which are not present in a conventional ultrasound wave, can be obtained.

If the ultrasound frequency changes from 1 MHz to 3 MHz or from 3 MHz to 10 MHz with the intensity remaining unchanged, the pressure amplitudes in the tissue will be the same. The dimension of every micro-massage unit in the tissue will however be reduced from 0.75 mm to 0.25 mm (respectively from 0.25 mm to 0.075 mm). This presents the unique possibility to produce a dynamic modulation of the ultrasound micro-massage effects.

This possibility arises for the first time with the introduction of the new LDM®-Technology. In this technology the frequencies produced in one sonotrode (ultrasound head) will be exchanged very rapidly (between 100 and 1.000 times per second). Thereby a rapid pulsation of the pressure gradients in the tissue with the same modulation occurs. This is the new art of the micromassage which cannot be produced by conventional ultrasound applications.

Mechanical effects of ultrasound could be influenced till now only through the regulation of the ultrasound intensity. It can be named "vertical" control of the micro-massage.

Applying the LDM®-Technology one can vary the scale of the massage effects, which is defined through the wavelength of the ultrasound. While this change takes place in the direction of the wave translation, one can consider this additional possibility as a "horizontal" control of the micro-massage.⁸ This new type of micro-massage effect is considered key mechanism of Dual-frequency ultrasound treatment suppress the activity of MMPs and activate the HSP.⁹⁻¹¹

The postoperative recalcitrant wounds are not chronic wound yet, but considered process of becoming chronic. There are some studies on chronic wounds using Dual-frequency ultrasound,¹²⁻¹⁵ but not on acute wounds or

others. We want to expand a range of application of Dual-frequency ultrasound in wound therapy, and also hope Dual-frequency ultrasound could block the processing of chronicization.

In this study, every patients get complete cure of wounds without additional procedure. In comparison with data from other literatures, meaningful reduction of time for complete re-epithelization is shown. Although, we could not get any statistical mean from our study, we could get favorable treatment result from the Dual-frequency ultrasound treatment. Furthermore, Dual-frequency ultrasound doesn't make any pain or discomfort during treatment sessions. So, we expect this non-invasive, convenient wound therapy could become a reasonable alternative for surgical treatment for recalcitrant remaining wound.

The limitation of this study is that this study only includes eight patients, and is a retrospective study. And there is no pathologic study for objective evidence of wound healing process. Further large scale prospective studies with pathologic demonstration are needed to make more precise evaluation of effectiveness of Dual-frequency ultrasound treatment.

Dual-frequency ultrasound can be a effective therapeutic tool to promote wound healing and prevent the remnant wound from becoming chronic wound. Dual-frequency ultrasound is safe, has little side effects, and is considered a useful tool to increase the completeness of the procedure.

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CONFLICT OF INTEREST

The authors report no conflicts of interest.

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