

## Foot Ulcer Treatment by Ultrasound Technique

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**Abstract:** Ulcers are slow healing wounds. 15% of people with diabetes suffer from foot ulcer. The proposed method aims to deliver low-frequency ultrasound energy to the ulcer wound with less thermal effect and thereby increasing the healing rate. An aqueous hydro gel is used to fill up the wound cavity by eliminating direct contact with tissue and thus providing a painless treatment. Acoustic cavitation and micro streaming produced from ultrasound energy which has a huge range of effects even in bacterial reduction. The low frequency ultrasound (UTLF) increases vasodilation, endothelial growth factor and collagen. The important aspect of this paper is reduced healing time which depends on the size and depends of the wound. The paper focuses on designing a low frequency pulsed ultrasound wound healing accelerator for diabetic foot ulcer by increasing the blood flow in foot through ultrasound and to calculate the healing rate (manually).

**Key words:** Foot ulcer • Ultrasound • Hydro gel • Healing time

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### INTRODUCTION

30 million people around the world are affected by a common disease called diabetes mellitus. Lower extremity ulcer is developed in Fifteen per cent of patients during the course of their disease. Foot ulcer is seventh largest reason for death. Peripheral neuropathy, limited joint mobility, foot deformities, abnormal foot pressures, vascular disease and minor trauma, a history of ulceration or amputation and impaired visual acuity are the risk factors for developing foot ulcer. Prolonged low pressure over a bony prominence is the first mechanism of injury. Prolonged repetitive moderate stress is the other common mechanism of ulceration. Persons with diabetes have 15 times higher lower extremity amputations (LEA) rate than normal person without diabetes. Foot ulcer is the most common factor for lower limb amputations among diabetic[1] patients and diabetic foot ulcerations cause is peripheral sensory neuropathy. Infection is common and severe in diabetic persons. Foot ulcer is polymicrobial in nature. The size and depth of the ulcer, as well as a description of the margins, base and geographic location foot are evaluated. Classification of ulcer is done by Wagner system. Grade 0- Pre-ulcer, Grade 1- Superficial ulcer, Grade 2- Full thickness ulcer, Grade 3- Deep ulcer with abscess, or joint sepsis, Grade 4- Gangrene of a geographical portion of the foot, Grade 5- Gangrene or

necrosis of large portion of the foot which results in major limb amputation. Important goal in the treatment is to close the wound as fast as possible. Following technologies are used for wound management. Hyperbaric Oxygen Therapy (HBO), Vacuum Assisted Closure (VAC), Heat Therapy Laser Therapy Mechanical Constant Tension, Larval/Maggot Therapy (Bio debridement), Electrical Stimulation. The next step in this treatment is to reduce the occurrence of the ulcer again. The healing[2] rate of foot ulcer increases with the usage of hydrogel than standard method. Moist environment also plays an important role in healing. Depth, location, wound size, surface and discharge determines the dressing type. Most commonly used type is saline dressing.

**Ultrasound:** The tissues, which are non-thermal in nature the mechanical vibrations transmitted with a frequency above the limit of human audible range (>20 KHZ). This frequency limit will differ for each person. Ultrasound is used for both diagnostic and therapeutic purposes.

The electric field applied to the set of the piezoelectric crystals placed on the surface of transducers generates ultrasound waves. The sound waves and vibrations are produced by mechanical malformation of crystals.it is caused by electrical stimulation. This process is called piezoelectric effect. The frequency range used for therapeutic purpose is between 1.0 to 3.0 MHZ. Sound

waves consists of areas of both compression and rarefactions. When the particles are exposed to sound waves it will oscillate at a fixed point instead of moving with the wave. Heat is generated due to increase in molecular vibrations in tissue and the heat changes can be produced using ultrasound. Additionally there occur some effects due to the vibrations of. Cellular change is induced in tissues by energy released from ultrasound in two stages. First is Surface cavitation (creation and dissipation of tiny bubbles in the tissues) followed by Acoustic micro streaming (movement of fluids along acoustic boundaries, such as cell membranes). A number of biophysical effects that are non-thermal and relevant to wound healing [3], including alterations in cellular protein synthesis and release, blood flow and vascular permeability, angiogenesis and collagen content and alignment are as a result of these process.

**Coupling Medium:** For maximum energy transmission between medium, impedance should be similar between two media. The smaller the difference the greater the transmission. Hydrated polymer (hydrogel) dressings contain 90% water in a gel base, which helps regulate fluid exchange from the wound surface is used as coupling medium to minimize the difference. Hydrogels are mostly clear and they are available in three forms: amorphous hydrogel, hydrogel, sheet hydrogel.

**MATERIALS AND METHODS**

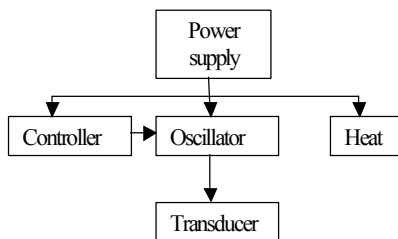


Fig. 1: Block Diagram Of Design

The foot ulcer treatment can be done by implementing an ultrasound device. The generator in the device converts voltage to electrical energy (higher frequency).this electrical energy is given to piezoelectric transducer operates with lower frequency (40 kHz-1 MHz) which converts it into mechanical energy. The mechanical energy is transmitted to transducer horn.an acoustic pressure output is created by the vibration of transducer horn. The intensity range is 1w/cm2 to 3w/cm2 for therapeutic purposes.

To eliminate the direct contact with the tissues the cavity of the wound is filled with hydrogel. Initially the sound waves penetrate deeply for healing from the core by inducing a pulsed ultrasound wave of frequency 40mhz. For normal healing, the ultrasound waves are moving towards the wound like hand pressing or hot bag treatment. The ultrasound waves are pushed against the bacterial cells present in the wound.as the bacterial cell wall is rigid it is destroyed by the repetition in the pressing of ultrasound waves. It leads to cell death and provides an accelerated healing.

The surrounding tissue of the wound can be treated by using 1Mhz ultrasound energy.it does not penetrate deep into the tissues and the healthy cells does not get affected by the superficial treatment. The low frequency ultrasound is mainly used to treat the patient with diabetic ulcer grade 0, 1, 2. The higher grade requires the debridement [4] removal so that the treatment is excluded. The ultrasound procedure is compared with conventional method. Wound size is taken as sample throughout the procedure.

**Discription of Circuit:** The power supply is given for the conversion of one form of electrical energy to electrical load. In this the energy is received from the source and the output power which is then transferred to load. Step down transformer is used to convert the high voltage to low voltage and low current power to high current power. The current can be increased by using layer gauze wire in secondary winding. A rectifier is used to convert the alternating current (AC) to direct current (DC).it flows only in single direction. This is called rectification.to obtain full wave rectification four diodes are used in the full wave bridge rectifier. The centre tapped transformer is not needed in this type of rectification. After rectification capacitors are used to filter the dc output, so that the load is supplied with constant dc voltage. The average dc voltage and ac portion of output is known as ripple voltage. The filter now is formed by the combination of resistors and capacitors with resistors.

Oscillator is used to generate low frequency pulsed ultrasound. It is also used for converting to alternating current from direct current. IC CD4093 and IC 4060 are used as CMOS devices. A controller is used for set and reset purposes in a system. 2051 microcontroller is used for providing flexible; cost effective solution to the application of embedded control. BC547 transistor is used for amplification and switching purposes. Heat sink is used for dissipating thermal energy into the surrounding

area and cools device. it is a passive heat exchanger with semi-conducting devices. The semiconductor devices used are of high power. Thermal grease or adhesives fill the air gap between the heat spreader and heat sink to improve the performance of heat sink. The heat sink transfers the heat to the surrounding air for the removal of heat.

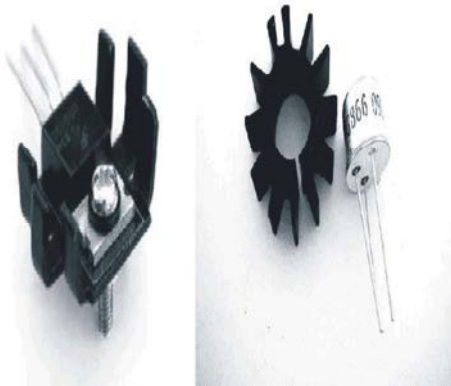


Fig. 2: Heat Sink Of Transducer

**Wound Size Measurement:** Opsite flexi grid is an adhesive film, transparent, with a unique wound measurement grid. Moisture vapour permeable, conformable and extensible are the properties of this film. moist wound healing environment for superficial wounds is achieved by using this film; it can also be used as secondary dressing. Some of the important Features of this film are Superior film with acrylic adhesive Waterproof film Simple, effective application technique, Adaptable to awkward areas, Unique wound measurement grid. Flexi grid op site is employed to measure wound size. Measure length (l) as the longest diameter and width (w) is taken perpendicular to length. Wound area is calculated as (l\*w).

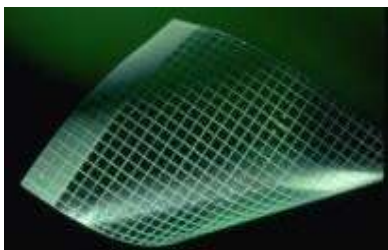


Fig. 3: Flexi Grid

**Comparison Study:** The ultrasound foot ulcer healer acceleration is studied through clinical trials. The study is carried out for ultrasound foot ulcer healer and conventional method with three patients each of them

having no other severe medical history. Healing rate is given by comparing UTLF procedure with the conventional method. The wound size during the entire procedure is taken as the sample.

Table 1: Subject Details

Subject	Gender	Age
1	M	43
2	M	49
3	F	50
4	M	46
5	F	37
6	M	55

Table 2: Wound size reduction through Conventional Method

Treatment Day	Wound size Approximately in cm <sup>2</sup>			
	Subject 1	Subject 2	Subject 3	Average
1 <sup>st</sup> Day	14	16	22	17.3
2 <sup>nd</sup> Day	13	14	20	15.6
3 <sup>rd</sup> Day	11	13	19	14.6
4 <sup>th</sup> Day	10	11	17	12.6
5 <sup>th</sup> Day	9	10	14	11
6 <sup>th</sup> Day	7	8	12	9
7 <sup>th</sup> Day	5	7	10	7.3

Table 3: Wound size reduction through Ultrasound Method

Treatment Day	Wound Size approximately (cm <sup>2</sup> )			
	Subject 1	Subject 2	Subject 3	Average
1 <sup>st</sup> Day	16	24	14	18
2 <sup>nd</sup> Day	15	22	12	16.3
3 <sup>rd</sup> Day	13	19	11	14.3
4 <sup>th</sup> Day	11	15	9	11.6
5 <sup>th</sup> Day	8	12	7	9
6 <sup>th</sup> Day	6	9	5	6.6
7 <sup>th</sup> Day	5	7	4	5.3

## CONCLUSION AND RESULT

The UTLF improved wound healing is almost twice the healing of the standard treatment with a significant difference in healing rate after several months. It is not possible to prevent all diabetic foot complications but it is possible to reduce their incidence through appropriate management and prevention programs. The following results are seen like Significant reduction in size and depth of the ulcers, reduction in amount of necrotic tissue amount and increase in amount of granulation tissue. Graphs are plotted between the wound sizes and the period of days for standard method and conventional method and the result of the two is compared. This study shows that the UTLF also had significant advantage over

the sharp debridement method in terms of patient satisfaction. It is beneficial in management of ulcers in the hospital and it can be used for both in patient and out patient population. The use of this technique eliminates the long waiting period experienced by patients before called for operation theatre for the scheduled debridement. It also eliminates the use of anaesthesia as it is painless. The other important aspect of this technique it can be used to manage patients on an outpatient basis. Therefore the patients need not stay and occupy beds in the wards for the treatment. They just need to come to the wound care clinic for the UTLF just like coming for dressing on a regular basis. The technique is easy to teach the wound care personal.

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