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# Diabetic Wound Healing Aid -A Doctor's Assistive Device: Optimum Healing for DFU

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**Abstract:** Diabetic Foot Ulcers represent a significant health issue. Currently, clinicians and nurses mainly base their wound assessment on visual examination of wound size and healing status. Based on studies, it is learnt that optimal outcomes are not obtained due to insufficient training, suboptimal assessments and treatment methods, failure to refer patients appropriately and poor access to specialist foot care teams. In this paper, a detailed overview of the project undertaken to develop a foot care device as an assistant for doctors is presented. The device conducts a programmed wound assessment followed by the automated cleaning of wound including removal of exudate, advanced automated wound recognition and treatment of diabetic wounds by appropriate administration of drugs.
**Keywords**: Diabetes mellitus, Diabetic neuropathy, Exudation, Diabetic foot ulcer, Amputation

## I. INTRODUCTION

According to global estimates, 370 million people are diabetic and the number is increasing by day and 25% of people with diabetes are prone to diabetic foot ulcers [DFU] during their lifetime. Without early and optimal assessment wound can progressively worsen and lead to amputations. It is estimated that in every 20 seconds, a lower limb is amputated due to the complication of diabetes and interestingly 85% of these amputations can be avoided by incorporating an effective care plan [2]. Surgery in patients with diabetic foot ulcers are becoming more common. Foot complications are a major cause of clinical admissions in diabetic patients, and comprise a disproportionately high number of days within the confines of a hospital because of multiple surgical procedures and prolonged length of stay.

Diabetic foot ulcer [DFU] is a major complication of diabetes mellitus. It occurs in 15% of people with diabetes and precedes 84% of all diabetes-related lower-leg amputations [2]. Mortality following amputation ranges at 50-68% at five years, which is comparable or worse than most malignancies. Risk factors implicated in the development of diabetic foot ulcers include infection, age, diabetic neuropathy [6], peripheral vascular disease, cigarette smoking, poor glycemic control, previous foot ulcerations or amputations, and ischemia of small and large blood vessels. [1] Foot ulcers are painful, susceptible to infections and are very slow to heal. Prior history of foot disease, foot deformities that produce abnormally high forces of pressure, renal failure, oedema, impaired ability to look after oneself (e.g. visual impairment) add further risks to diabetic foot ulcer. Moreover, the cost of treating DFU is estimated at $15 000 per year per individual in the United States of America.

## II. DIABETIC WOUNDS

Diabetes mellitus is a metabolic disorder that impedes the normal steps of the wound healing process. It can be virtually harmless if controlled, but the state of abnormally high blood glucose levels associated with the condition can lead to some serious complications. If left uncontrolled for a long time, or if diabetic patients fail to adapt their lifestyles in order to manage the disease, they will have more difficulty preventing complications from occurring.

### *A. Cause of Diabetic Wounds*

The main concern with diabetic wounds is poor or delayed healing. Healing problems are caused by the peripheral arterial diseases and peripheral neuropathy that can occur with diabetes, wherein the small blood vessels in different parts of the body, especially in the extremities (hands and feet), grow narrower and reduce the blood circulation to those areas leading to a reduced supply of oxygen and nutrients to

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the body tissue and nerves, which is necessary for healing [1]. Over time, nerves in these areas may become damaged, decreasing the sensation of pain, temperature and touch, making patients vulnerable to injury.In most patients, peripheral neuropathy and peripheral arterial disease play a central role and DFU re commonly classified as Neuropathic, Ischaemic and Neuroischaemic.

Peripheral neuropathy may predispose the foot to ulceration through its effects on the sensory, motor and autonomic nerves:

- The loss of protective sensation experienced by patients with sensory neuropathy renders them vulnerable to physical, chemical and thermal trauma.
- Motor neuropathy can cause foot deformities, which may result in abnormal pressures over bony prominences.

Loss of protective sensation is a major component of nearly all DFU's. It is associated with a seven fold increase in risk of ulceration as there is a decrease in awareness of pain and other symptoms of ulceration and infection.Poor arterial supply and microangiopathy contribute to poor ulcer healing in neuroischaemic DFUs

### *B. Types of Diabetic Wounds*

The most common wound types are those of external origin and wounds of internal origin. Due to peripheral neuropathy, wounds of external origin, such as skin cuts, burns, bumps and bruises, may often go unnoticed by the diabetic patient and delayed treatment can put the patient at risk for further complications. [6]Wounds of internal origin, such as skin ulcers, ingrown toenails or calluses, can lead to the breakdown of skin and surrounding tissue, increasing the risk of bacterial infections. Wounds are generally classified as necrotic, sloughy, granulating, epitheliasing, infected and malordous.

Wounds are graded based on depth into six types according to the Wagner Ulcer Classification System [5]. Grade 0 refers to an intact skin wherein there are no open lesions however there might be deformities or cellulitis. Grade 1 ulcers are superficial wounds through either the epidermis or the epidermis and dermis. These wounds maybe of partial or full thickness. Grade 2 wounds penetrate to tendon or capsule but the bone or joints are not involved. In this grade, the ulcers extend even to the deep fascia without abscess or osteomyelitis. Grade 3 wounds penetrate to bone or into a joint. It represents deep ulcers with abscess, osteomyelitis or joint sepsis. Grade 4 wounds comprises of gangrene localized to a portion of forefoot or heel. Grade 5 wounds includes wounds with extensive gangrenous involvement of the entire foot.

### *C. Prevention of Diabetic Wounds*

Prevention of diabetic wounds is critical for diabetic patients to ensure a normal and active healthy life. It is important to remember that diabetic wounds can be disabling and life threatening in some cases. Prevention should begin with:

- Controlling diabetes by following your doctor's recommendations for treatment and lifestyle modifications that include a healthy diet, regular exercise, cessation of smoking and regular monitoring of blood glucose levels
- Daily inspection and cleaning of your extremities as they are more prone to ulcers and injuries.
- Carefully trimming the nails with a safe nail trimmer.
- Always wear dry, clean socks to help protect your feet, and never walk barefoot.

## III. DIABETIC WOUND HEALING AID

The Diabetic Wound Healing Aid is a device that is designed to fully take control of the wound healing process. Presently, the device is designed as a healing aid to diabetic foot ulcers [DFU]. The device conducts a [7] [8] programmed wound assessment followed by the automated cleaning of wound including removal of the exudate, advanced automated wound recognition [7], treatment of diabetic wounds by appropriate administration of drugs and provides an inbuilt mode for selection of appropriate dressing.

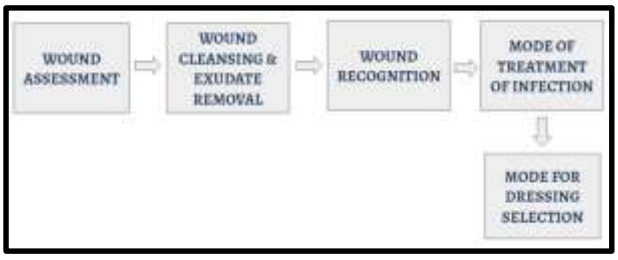


Fig. 1 Block diagram

Diabetic wound healing aid, in order to provide better wound management of Diabetic Foot Ulcers, provides:

### *A. Wound Assessment*

Sensation Test : Based on subjective assessment with the help of thermoelectric cooling principle (Peltier Effect) of TEC -12706.Blood flow rate : Based on heart beat felt at the

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foot sole , the Pulse Sensor SEN-11574 senses the pulses hence the vascularity on the region can be ensured. Temperature: Based on temperature variation on foot, the Temperature Sensor LM35 can detect the temperature values hence the DFU Classification. Wound Assessment is done by MATLAB programming. This includes Smoothing and filtering of the wound image: filtering, Image skin tone , Edge operations on the image : Median filtering, Grey scale image, Edge and boundary of the image

Multidimensional image: This assessment includes a sensation test [8] at the site of wound wherein a subjective risk analysis is done using a Peltier device. The sensation test is done on certain demarcated positions based on the diabetic foot screen test sites. The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors. Thermoelectric coolers (TEC or Peltier) TEC1-12706 12V 92W create a temperature differential on each side. One side gets hot and the other side gets cool.

A thermoelectric cooling (TEC) module is a semiconductor-based electronic component that functions as a small heat pump. By applying DC power source to a TEC, heat will be transferred from one side of the module to the other. It creates a cold and hot side.

This sensor is placed at 8 different points of foot and asking the patient if he feeling sensation. This is the subjective analysis for wound assessment.

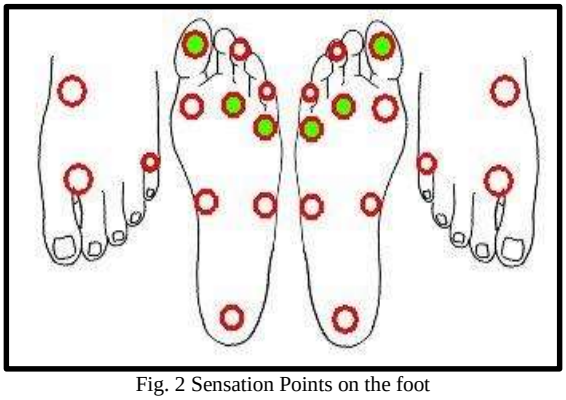

Fig. 2 Sensation Points on the foot

Pulse Identification is the second wound assessment done in the diabetic wound healing aid. Pulse Sensor Amped is a plug-and-play heart-rate sensor for Arduino and Arduino compatibles. The sensor itself consists of an infrared emitter and detector mounted side-by-side and pressed closely against the skin. When the heart pumps, blood pressure rises sharply, and so does the amount of infrared light from the emitter that gets reflected back to the detector. The detector passes more current when it receives more light, which in turn causes a voltage drop to enter the amplifier circuitry. The wounds are classified based on the size, depth, edge [7] and colour of the wound [5].

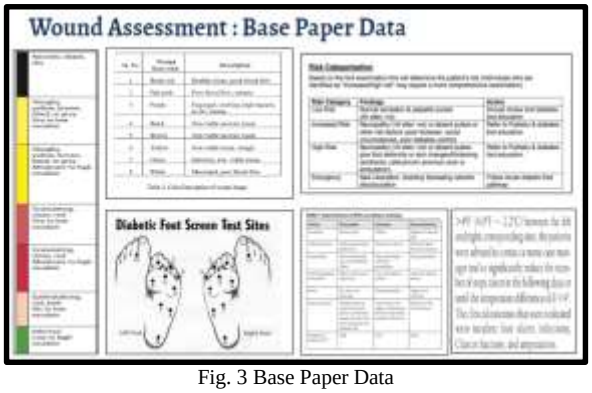


Fig. 3 Base Paper Data

### B. *Wound Cleansing*

The quantity of the cleaning solution is decided based on the wound type. Wound cleansing is done by applying negative pressure. In NPWT we are applying a pressure in the range of 75-125 mmHg. The range and time period of pressure applied vary with wound size and stage. Applying negative pressure will help increase blood flow in that part and will ultimately fasten the healing process. The wound exudate is removed after the cleaning solution is administered with the help of driving motor which works on an Arduino programme. Based on the type of wound that is obtained after wound assessment, the wound cleaning is carried out with the help of motor, l293d (motor driver) Arduino programming. The cleaning solution is administered on the wound for a fixed time duration. After cleaning is the exudate removal, which is again driven with the help of motor, l293d (motor driver) Arduino programming. The exudate removal pressure range varies from 20 mmHg- 200 mmHg.The exudate for the five classes of wounds are classified based on the exudate range as Dry, Dry to low exudate, Moderate to high exudate, No to low exudate and Low to high exudate

### C. *Wound Recognition*

Wound Recognition is completed by matlab programming.Matlab programming for edge operations same as that of wound assessment.The operations such as Smoothing and filtering of the wound image which includes filtering, Image skin tone , Edge operations on the image :

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Median filtering, Gray scale image, Edge and boundary of the image and Multidimensional image.Matlab programming is used for identifying the type of wound namely Necrotic : Black, Sloughy : Yellow, brown, black, grey, Granulating : Red and Epithilialising : Red & pink

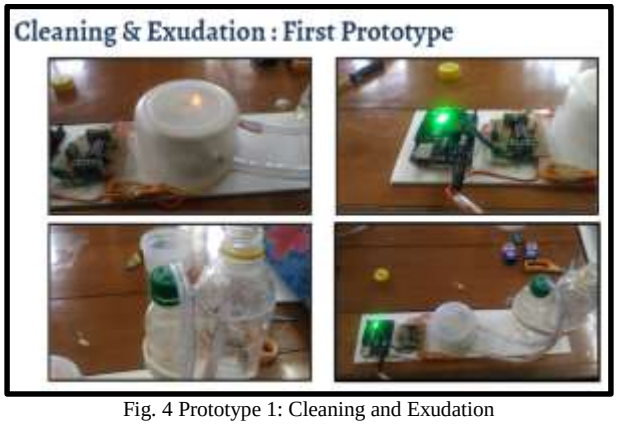


Fig. 4 Prototype 1: Cleaning and Exudation

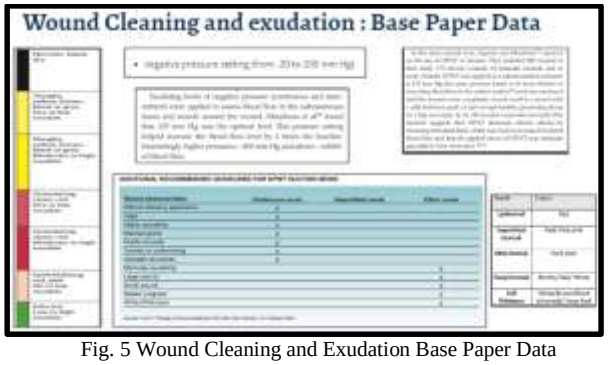


Fig. 5 Wound Cleaning and Exudation Base Paper Data

*D. Wound Recognition*

Wound Recognition is completed by matlab programming.Matlab programming for edge operations same as that of wound assessment.The operations such as Smoothing and filtering of the wound image which includes filtering, Image skin tone , Edge operations on the image : Median filtering, Gray scale image, Edge and boundary of the image and Multidimensional image.Matlab programming is used for identifying the type of wound namely Necrotic : Black, Sloughy : Yellow, brown, black, grey, Granulating : Red and Epithilialising : Red & pink.


Fig. 6 Necrotic Wound

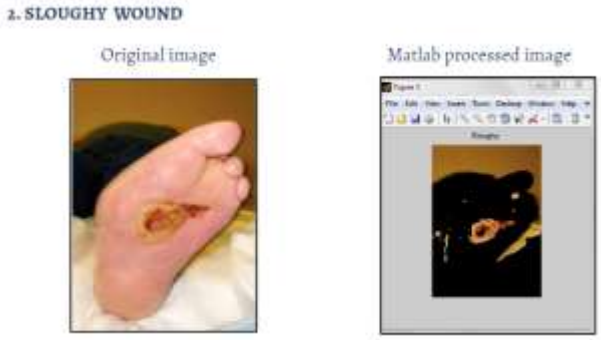


Fig. 7 Sloughy Wound

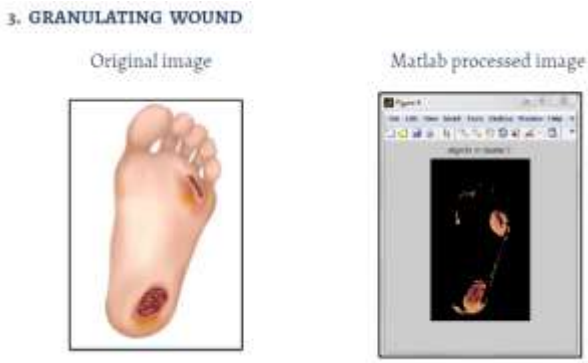


Fig. 8 Granulating Wound

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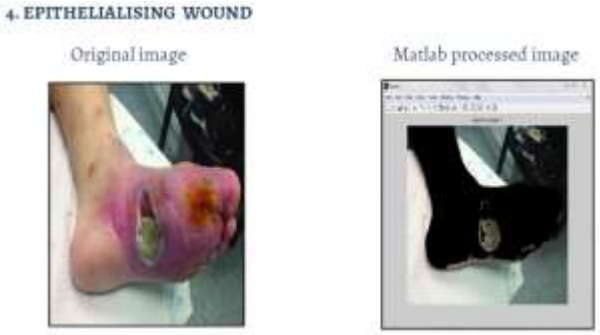


Fig. 9 Epitheliasling Wound


Fig. 10 Infected Wound

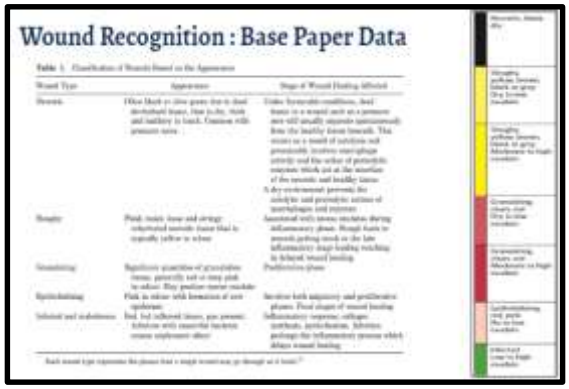


Fig. 11 Wound Recognition Base Paper Data

*E. Wound Treatment and dressing*

| WOUND TYPE | TYPE OF DRUG |
|---|---|
| Necrotic | Spray |
| Sloughy | Powder |
| Granulating | Spray/Powder |
| Epithelialising | Spray |
| Infected and Malodorous | Powder |

Table 1 Wound Type and Type of Drugs

Based on the type of wound recognized, the wound is subjected to either spray type, powder type or solution type treatment.

Wound treatment in the Diabetic Wound Healing Aid involves differentiating the wounds based on the previous steps and predicts the appropriate treatment for each section of the classified wound types. The preferred treatment method is carried out based on an arduino programme which drives the motor which controls the spray type and powder type treatment.Based on the type of wound that is obtained after wound assessment, the appropriate mode of treatment and dressing can be chosen.The process is carried out by Arduino programming with the help of motor, l293d (motor driver) Arduino programming.The treatment mode is classified as Powder Type, Spray Type and Solution Type.Dressing is classified for each type of wound as Primary Dressing and Secondary Dressing.

The last stage of the device gives a mode that helps doctors decide the type of wound dressing required for the particular wound. A primary wound dressing is the piece of gauze or material that is placed directly on top of the wound itself. It may have an anti-bacterial ointment or some kind of medication on it. It ought to be wet in order to keep the wound from drying out.Secondary wound dressings secure the primary wound dressing in place. Secondary wound dressings provide several important functions other than just securing the primary:

- Hold the primary dressing in the intended location.
- Supports the wound site especially when an implant, catheter, drain or graft has been inserted. A secondary wound dressing may be required to protect and support the wound and device. A cast or heavy wrap is an example of this type of wound dressing.
- Protects the wound site. The wound dressing keeps the wound from further trauma, either from mechanical sources such as friction, motion or environmental factors like moisture or temperature.
- Provides an environment for optimal healing. This is a situation where the wound requires a closed environment for the primary dressing to function.

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- Provides treatment to the wound. This situation is a working synergistic relationship between the primary and secondary.

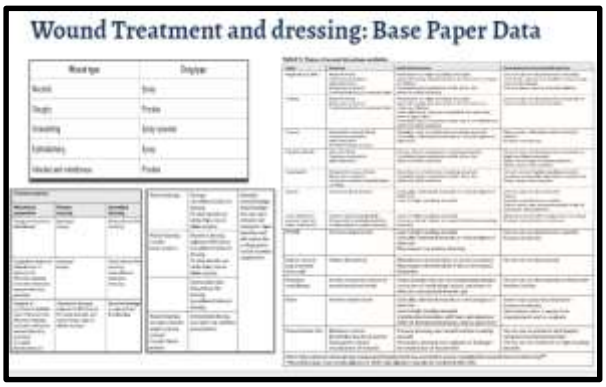


Fig. 12 Wound Treatment and Dressing Base Paper Data

## IV. RESULTS

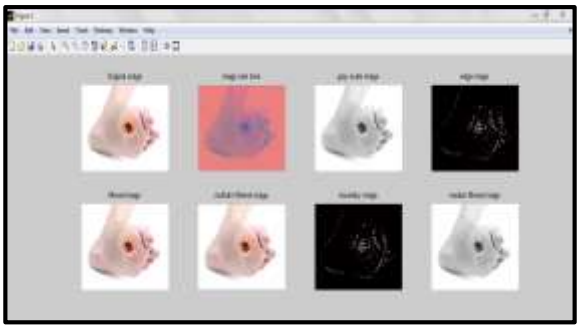

Fig. 13 Image Processing of Diabetic Wounds

- Better Wound Management: In Diabetic Foot Ulcers are Appropriate aid for Wound Assessment through MATLAB processing, Channel for Wound cleansing action, Wound recognition through MATLAB processing after manual debridement, Channel for Selecting and providing the Mode of Treatment of infection, Mode: Dressing Selection
- Use of appropriate cleaning solution and exudate removal: Less chance for the wound to get subjected to fungal infections.
- Use of treatment modes leads to Less side effects based on oral drug delivery and Optimal Healing.
- Wound analysis conducted on various stages are depicted in the images below. The images are being processed in various of the wound using MATLAB processing.


Fig. 14 Initial Stage of Diabetic Foot Ulcer

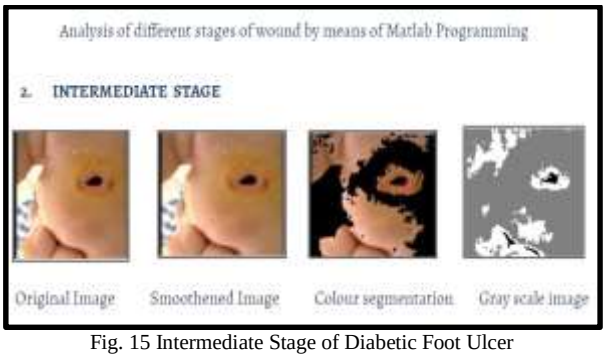


Fig. 15 Intermediate Stage of Diabetic Foot Ulcer

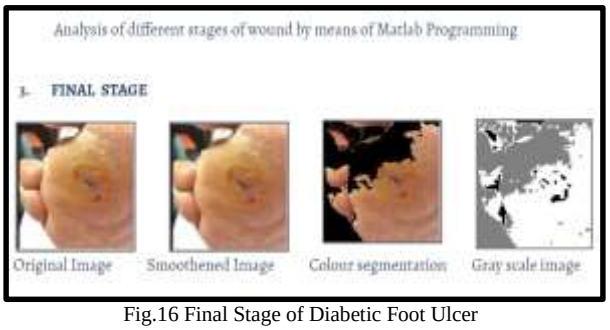


Fig.16 Final Stage of Diabetic Foot Ulcer

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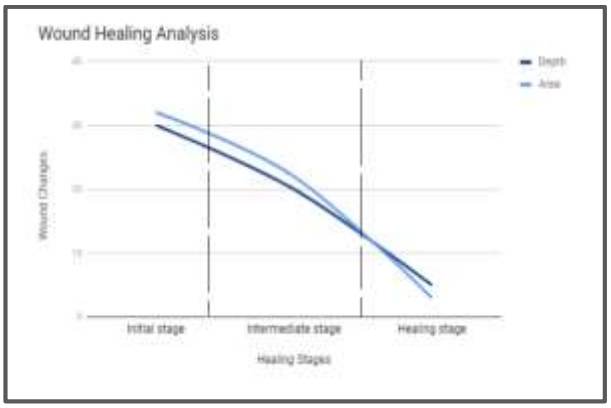


Fig. 17 Wound Healing Analysis

## V. CONCLUSION

The Diabetic wound healing aid is a device that takes up the wound healing process and assists doctors in deciding the correct dosage of appropriate drugs and administers the drug to effectively enhance wound healing. The device goes through a series of processes that starts with wound assessment where the wound based on blood flow rate, wound area sensitivity and temperature, is ideally analyzed without any human interference. Automated wound cleaning and exudation is done after which a subjective analysis of the wound is carried out based on the size and colour of the wound bed.

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## REFERENCES

[1]. The myofibroblast in wound healing and fibro contractive diseases , G Gabbiani* Department of Pathology, CMU University of Geneva, Switzerland *Correspondence to: Professor G Gabbiani,Department of Pathology CMU,1 rue Michel-Servet, 1211 4, Switzerland.

[2]. Diabetic foot ulcers in a multidisciplinary setting An economic analysis of primary healing and healing with amputation. Authors J. APELQVIST MD,G. RAGNARSON-TENNVALL,J. LARSSON,First published: May 1994,Department of Internal Medicine. University Hospital, S-221 85 Lund, Sweden.

[3]. Effects of photostimulation on wound healing in diabetic mice. Authors Wei Yu MD,John O. Naim PhD,Raymond J. Lanzafame MD. First published: 1997.

[4]. A systematic review of topical negative pressure therapy for acute and chronic wounds Authors D. T. Ubbink,E. A. Nelson.

[5]. Wound image analysis classifier for efficient tracking of wound healing status Authors: Sundeep Kumar and B. Eswara Reddy,Associate professor, Department of Information Science & Engineering,SEA CET, Bangalore, IndiaProfessor, Department of Computer Science & Engineering,JNTUA College of Engineering, Anantapur, AndhraPradesh, India.

[6]. Bakker K, Apelqvist J, Schaper NC on behalf of the International Working Group on the Diabetic Foot Editorial Board. Practical guidelines on the management and prevention of the diabetic foot 2011. Diabetes Metab Res Rev 2012; 28(Suppl 1): 225-31.

[7]. Image Processing Based Wound Assessment System for Patients with Diabetes Using Six Classification Algorithms

[8]. Varun kumar C; Malathy V Jaya Engineering College, chennai, India

[9]. Wearable Multimodal Skin Sensing for the Diabetic Foot James Coates; Department of Engineering and the Environment, University of Southampton, ,Andrew Chipperfield; Inst. of Developmental Sciences — Faculty of Medicine, University of Southampton, and Geraldine Clough ;

[10]. National Institute for Health and Clinical Excellence. Diabetic foot problems: inpatient management of diabetic foot problems. Clinical guideline 119. London: NICE, 2011. Available at: http://publications.nice.org.uk/diabetic-foot-problems-cg119. Accessed March 2013.

## BIOGRAPHY

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