PROSPECTIVE STUDY ON VACUUM ASSISTED CLOSURE THERAPY IN TREATMENT OF SOFT TISSUE INJURIES ASSOCIATED WITH GUSTILO ANDERSON COMPOUND GRADE IIIB FRACTURES

DISSERTATION SUBMITTED FOR

MASTER OF SURGERY DEGREE EXAMINATION

BRANCH-II (ORTHOPAEDIC SURGERY)

APRIL 2015

THE TAMIL NADU

DR.M.G.R. MEDICAL UNIVERSITY

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CERTIFICATE

This is to certify that this dissertation entitled "**PROSPECTIVE STUDY ON VACUUM ASSISTED CLOSURE THERAPY IN TREATMENT OF SOFT TISSUE INJURIES ASSOCIATED WITH GUSTILO ANDERSON COMPOUND GRADE IIIB FRACTURES** " is bonafide work done by Dr. Venu Madhav .H.V under my direct guidance and supervision in the department of orthopaedic surgery, Madurai Medical College, Madurai-20

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Last but not the least, I express my gratitude to the patients for their kind co-operation

DECLARATION

I, Dr.Venu Madhav H. V., solemnly declare that the dissertation titled "**PROSPECTIVE STUDY ON VACUUM ASSISTED CLOSURE THERAPY IN TREATMENT OF SOFT TISSUE INJURIES ASSOCIATED WITH GUSTILO ANDERSON COMPOUND GRADE IIIB FRACTURES**",is prepared by me. And this is submitted to "The Tamil Nadu Dr.M.G.R.Medical University", Chennai, in partial fulfillment of the regulations for the award of MS Degree branch II Orthopaedics.

Place- Madurai Dr.Venu Madhav H V

Date-

PROSPECTIVE STUDY ON VACUUM ASSISTED CLOSURE THERAPY IN TREATMENT OF SOFT TISSUE INJURIES ASSOCIATED WITH GUSTILO ANDERSON COMPOUND GRADE IIIB FRACTURES

ABSTRACT

Back ground

The Primary objective of this prospective study is to study the rate of infection, number of days required for formation of healthy granulation tissue, healing of soft tissue injury and number of days of hospital stay and cost effectiveness associated with Gustilo Anderson compound grade IIIb fractures treated by Vacuum Assisted closure therapy.

Methods

Seventeen patients with Type IIIb open fractures were included in this study..All these patients had undergone wound debridement and fracture fixation. This wss followed by application of Vacuum Assisted Closure (VAC) The infection rate analysed by clinical findings and investigations.

Results

The infection rate was low when compared to literature study of conventional dressings. The primary wound coverage can be done earlier wound healing was also faster in patients.

Conclusion

This is a simple and low cost method for treating soft tissue injury associated with severe open fractures. It can be done even in peripheral hospitals with low resources.

Key words: VAC, Gustilo Anderson compound grade IIIb fractures, sterile dressing, continues and intermittent mode.

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INTRODUCTION

Introduction

Gustilo Anderson compound grade IIIb Fractures are fractures with extensive soft-tissue damage, definite periosteal stripping, massive contamination & the fractured ends are exposed[1].

Open fractures need good coordinated management of both bones and soft tissue injury to achieve good healing and to avoid infection. Blood supply of bone is derived from the nutrient vessels to the bones and also from surrounding muscles and soft tissue structures.

Earlier the soft tissue injuries were managed by conventional methods like regular wound debridement, saline dressing, dry dressing etc and the disadvantages according to a study by caudle and stern[2] are incidence of infection was 59% similar studies by cierny et al[3] on incidence of wound infection in open tibial fractures were 20.8% and 83.3% in early and delayed skin cover cases , more number of debridement were required , longer duration was taken for healing, longer duration were required to make the wound fit for soft tissue coverage & hospital stay was prolonged.

The aim of this prospective study is to know the rate of wound infection, number of days required for making the wound fit for skin cover procedures, number of days required for formation of uniform granulation tissue bed in the wound, number of days of hospital stay and healing of soft tissue injury in Gustilo Anderson compound grade IIIB fractures treated by Vacuum Assisted Closure & by stabilization of fracture

The mechanism of VAC therapy is very simple. An open-cell structured foam is cut according to size and shape of the wound and then it is kept on the wound bed, a suction drain with perforations only in the end of the tube is laid on the foam. Then the entire wound is then sealed with an opsite or a transparent membrane which is adhesive then the other end of the suction tube is connected to a vacuum machine, once the wound is sealed and the machine is switched on the fluid from the wound is drawn through the foam into a canister which can be disposed subsequently. By this the edema from the wound is removed , new blood vessels are formed (angiogenesis) & hence leads to formation of healthy granulation bed & all this leads to earlier skin cover procedures of the wounds

Incidence of infection in a study by Mehbod et al[4]. and Mooney *et al*[5]. showed drastic decrease when compared with saline dressing and also the duration of hospital stay was reduced, number of debridement required were also few.

The indirect effects of VAC therapy are reduced morbidity, earlier return to work, & cost effectiveness

AIM OF THE STUDY

AIM

The AIM of this prospective study is to study the rate of infection, duration required for formation of healthy granulation bed, duration required for making the wound fit for skin cover procedures, duration of hospital stay, and duration of healing of soft tissue injury in Gustilo Anderson Compound Grade IIIB fractures treated by Vacuum Assisted Closure therapy

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Epidemiology

Gustilo Anderson compound grade IIIB fractures are encountered in high energy trauma, representing one of the challenging clinical problems in which multidisciplinary approach is required[6]. According to estimated data more than 4.5 million compound fractures occur per year in India. And road traffic accidents are considered the most common cause of these compound fractures.

These fractures involve significant morbidity as the skin barrier is lost and the chance for contamination is high[6].

Gustilo Anderson classification[6]

• Grade I: Wound size will be less than 1cm in diameter without contamination, fracture pattern will be simple without comminution and skin crushing will be absent.

• Grade II: : Wound size will be more than 1cm in diameter and less than 10cms without contamination, fracture pattern will be simple with minimal comminution and skin crushing will be minimal.

• Grade III: Further divided into grade IIIA, grade IIIB and grade IIIC

Grade IIIA-: wound size will be more than 10cm in diameter with

contamination, fracture pattern will be complex with comminution and skin crushing will be present but wound cover is possible by approximating the wound edges.

Grade IIIB-: wound size will be more than 10cms in diameter with gross contamination, fracture pattern will be complex with comminution and skin crushing will be present periosteal stripping will be present.

Grade IIIC-: any wound size , fracture associated with neurovascular deficit is considered compound grade IIIC

WOUND HEALING – PHASES

Human Body responds to wounds in a complex way and it is highly ordered sequence of cellular and biochemical changes. For wound to heal in a successful manner it involves series of overlapping stages or phases[7,32]:

1.Coagulation and Inflammation Stage,

2. Cell Proliferation stage and Repair of the Extra Cellular Matrix stage and

3. The remodelling phase.

These three phases are distinct, but may also overlap with time during the healing process of the wound.

1. **First stage- Inflammatory phase-** it is characterized by arrest of bleeding and inflammation.

After any tissue Injury, damaged cells release many chemical substances like thromboxane A2 and prostaglandin 2-alpha these are potent vasoconstrictors and these control the bleeding in the wound. Multiple chemokines like epidermal growth factor (EGF)[33], fibronectin protein, fibrinogen factor, histamine, platelet-derived growth factor (PDGF), serotonin protein, and von Willebrand's factor are released which causes coagulation and formation of clot around the wound. Then vasodilatation of capillaries occur secondary to the release of histamine which causes the migration of inflammatory cells to wound site. Complement cascade gets activated by the release of granules from the platelets, C5a is one of a potent chemoattractant to neutrophils. The wound site is infiltrated by neutrophils and macrophages later. Infection is primarily prevented by neutrophils, inflammatory mediators such as cytokines, enzymes and growth factors, are released by macrophages which help in clearing wound of all dead tissue.

Second stage- **proliferative phase** begins after two to three days and may last for several weeks. The principle events in this stage are a. Cell migration, b. cell multiplication, c. angiogenesis and d. formation of Extra Cellular Matrix.

The main cells in this stage are a. fibroblasts, b. endothelial cells and c. keratinocytes. Both fibrous and non fibrous components of Extra Cellular Matrix are secreted by fibroblasts which leads to regeneration of damaged tissue. For the formation of new healthy ECM the damaged proteins must be degraded by an enzyme called matrix metalloproteinases (MMPs). New blood vessels are formed by endothelial cells which are also necessary for regeneration of tissues. Then Epithelial cells multiply and migrate on the newly formed granulation tissue and forms epithelial layer.

Third stage- This is the final phase, the **remodeling phase**, in which scar tissue replaces intact skin. It is characterized cellular component formation and degradation of the scar tissue by the enzyme called proteases. In one year the wound reaches maximum strength. Deposition of collagen is continued for a long period, but after 21 days the net increase in collagen deposition plateaus. Non-healing wounds often get arrested in any of these phases, and shows continues inflammation or proliferation. Debridement of a chronic wounds temporarily speeds up the wound healing process but eventually the healing gets arrested. This phenomenon can be explained by

A- Effects of aging of proliferating cell

B- Repeated ischemia-reperfusion injury

C- Bacterial colonization with the accompanying inflammatory response.

HISTORY OF WOUND HEALING[8]

Wound management can be divided era wise into 3 phases :

- Empiric wound management – extending from pre history upto 1860's
- Antisepsis and aseptic surgical practice resulting from recognition of bacterial pathogenesis of infection (1863 – 1940)
- Antibiotic period (1940 to present date)

PREHISTORY TO 1860'S

The earliest medical writings dealt extensively with wound care eg. 7 of 48 case reports in the Smith Papyrus (1700 BC)[9] are about wounds and their management. Early in history, in Mesopotamia (2100 BC) wound management consisted of clearing the wound with beer and then applying poultice containing drugs and turpentine.

In Egypt wounds were also on occasion irrigated with wine and covered with salve of fat and honey amid elaborate incantations to the gods.
Hippocrates (466-370 BC) of Greece recommended wound management by washing it with wine, bandaging it and pouring more wine over it.[10]

ANTISEPSIS AND ASEPSIS (1863-1940)

Louis Pasteur[11] (1822-1895) is responsible for recognizing bacteria as a cause of infection.

Joseph Lister[12] (1827-1912) applied carbolic wound dressing to a compound fracture, hence later known to be called as Father of Antisepsis.

ANTIBIOTIC ERA (1940 TO PRESENT)

Alexander Fleming[13] is credited with the discovery of penicillin in 1929.

Antibiotics were highly effective in treatment of surgical wound injury and early wound healing.

CONVENTIONAL TREATMENT METHODS

Standard treatment for all established wounds incorporates common principles employed in the management of all wound types. These include the removal of necrotic tissue through aggressive debridement that is achieved through debridement using sharp instruments, autolytic debridement by endogenous enzymes which are present in commercially available wound care products and proper moisture balance achieved through the selection of the proper wound dressing. For most of the chronic and acute wounds, saline-moistened cotton gauze has been the standard treatment of choice.

Therefore, wet-to-moist conventional gauze dressings require close maintenance and excess dedicated nursing time. Moreover, the removal of a wet-to-moist dressing that has been allowed to dry may injure the wound again by removing the just formed granulation tissue and thereby lead to delayed wound healing. This procedure also causes considerable pain, impedes the healing process and increases the risk of infection.

Gauze dressings may appear much less expensive per dressing when compared to the modern synthetic dressings but the conspicuous increase in the labor costs and ancillary supplies such as gloves used and the biohazardous waste disposal substantially increase the total cost of conventional dressing.

TOPICAL NEGATIVE PRESSURE WOUND THERAPY

NPWT is a novel technique for a managing an open wound by submitting the wound to either intermittent or continuous sub-atmospheric pressure (Morkywas and Argenta 1997)[14] Negative pressure is obtained by transferring away the gas molecules that are present in the wound away by using a suction pump.

With respect to the type of dressing used to fill the wound, there are at present two types of Negative Pressure Wound Therapy in practice[15].

I. FOAM BASED TECHNIQUE

II. CHARIKER-JETER TECHNIQUE[15]

FOAM – BASED TECHNIQUE

Originally developed by Argenta and Morykwas[14] in 1997 . The foam used is cut according to the shape of the wound and the foam is placed over the wound . The wound may be lined before applying the foam. There are two types of foam used.

I. GranuFoam - Black polyurethane foam which is available on Drug Tariff

II. Vers-Foam - White polyvinyl alcohol foam commonly used when there is a possibility of adhesion of the foam to the wound. Vers-Foam is not usually available on Drug Tariff.

The foam is secured over the wound and sealed in place using an adhesive film drape and a TRAC system. TRAC stands for Therapeutic Regulated Accurate Care systems . Plastic tubing is used to connect the dressing to the console that applies the suction force. V.A.C. systems are usually commenced under supervision in secondary care centers and the patient is then discharged with the suction console but the disposals like GranFoam dressing and canisters need to be provided to the patient.

POLYURETHANE(PU) OR POLYVINYLALACHOL (PVA) FOAM

PU foam is black and also very easily deformable whereas PVA foam is white and is stiffer and requires higher pressures to deliver vacuum. Choice of the foam is totally dependent on the treating surgeon. The foam is covered airtight with an adhesive drape through which a small hole is made and a TRAC (Therapeutic Regulated Accurate Care) pad applied over the hole. The adhesive

dressing applied creates a completely sealed environment for moist healing of the wound and the TRAC pad is connected to the vacuum generator which acts as a source for suction and drainage. Pressures achieved at the TRAC pad-foam interface are constantly monitored by the VAC machine.

VERS FOAM

Vers-Foam dressing which is white in colour happens to be more dense and has a higher tensile strength. It is usually pre-moistened with sterile water. Due to its in adherent properties, it finds itself extremely useful in grafts in wounds and those associated with pain. It is generally recommended in sites where the growth of granulation tissue into the foam needs to be in a more controlled manner or the black foam is not tolerated due to pain. The minimal disadvantage is the necessity to maintain a higher levels of negative pressures of about 125mm Hg.

CHARIKER- JETER TECHNIQUE[15]

It is a more recently developed NPWT systems.It utilizes flexible drains and gauze and are referred to as the Chariker-Jeter technique.

Moistened gauze is used to fill the wound before VAC application.. A silicone drain is inserted and sealed using an adhesive film drape. The silicone drain is attached to the suction console.

HISTORY OF VAC

Thousands of years ago, the Chinese were applying cups that contained heated air to wounds so that, when the air inside the cups cooled, there would be slight reduction in pressure.

NPWT was first used successfully in the early 1950s to manage exudate and accelerate the process of wound healing (Raffel, 1952; Silvis et al, 1955)[16,17]

Chariker et al (1986) described a simple but unique technique in which a drain tube that was wrapped in gauze was used to assist in the treatment of wounds that were complicated by draining enterocutaneous fistulae.

The initial achievements that were pretty significant in wound management and thereby surgery was the cleanliness of the wound(Pare I 1545) and removal of pus (Lister 1867) . There have been many giant leaps in the area of wound managements. All these advances are mainly due to the thorough and complete understanding of the patterns involved in the process of wound healing. An analytical approach is now adapted for wound management that is the consequence of years and years of research and pragmatic experience. All these novel methods have not only improved the efficacy rates of wound care but also been able to handle complicated situations.

One among the newest concepts that is being brought into practice and will tend to change the phase of wound management from now on include is the Negative Pressure Wound Therapy(NPWT). It is quite a known fact that sub-atmospheric pressures applied at the wound site will tend to drain all the unwarranted fluid that accumulates and thereby impeding a healing process and also it influences of growth of the cells thereby bringing about re-epithelialistaion by now . Considering the positive effects of creating a negative pressure by connecting to a drain is good if the drain is large in volume and intensity and taking that into consideration, a buried drain is not going to cause much of a harm and can be retained in place until wound heals delivering negative pressure.

Evangelista Torricelli is credited with introducing the first man-made vacuum when he turned over a column of mercury in a glass tube yielding the world's first barometer (and ultimately lending his name to common unit of air pressure). Since that time, numerous uses for this intriguing physical state have been discovered.

The application of NPWT in order to promote wound healing was first described in Russian medical literature for patients having infected breast wounds. These original reports actually described the application of a topical suction-cup-type apparatus to the surface of the wound to create negative pressures of around

80mm Hg Subsequent reports have described the successful management of EC fistulae and open abdominal wounds using flat drains that delivered negative pressure under compliant plastic films . In these reports surgical gauze was being used to create an interface between the surface of the wound and the vacuum source.

In western medicine, the first use of a vacuum in suction bells popularized in the nineteenth century by Junod

The concept of applying sub atmospheric pressure to a wound bed was proposed more recently in 1993 by Fleischmann and colleagues[18] , who described a technique of porous polyvinyl alcohol foam wrapped around suction drains, which were introduced into a wound sealed with a polyurethane drape and attached to a suction apparatus at 600 mm Hg. Fleishchmann et a1 (1993)[18] carried out the first investigative studies into NPWT using foam as a wound contact layer. This description in German presented 15 patients who had open fractures that were treated in this manner. No infections were noted in this group, and an apparent increase in granulation tissue formation was described.

In 1997, Drs. Louis Argenta and Micahel Morykwas[14] presented their experience using the vacuum- assisted would closure device (VAC : KCI, San Antonio, Texas) They presented their 9- year experience with 175 chronic wounds,

94 sub acute wounds, and 31 acute wounds. In a simultaneous second paper, they presented their animal laboratory experience over; the same 9-year period.

In these landmark studies, wounds had enhanced granulation tissue and all were treated successfully to closure of the wound. The investigators noted that the wound care system effectively managed difficult wounds with ease and postulated that the technique improved local blood flow, removed chronic edema, and reduced bacteria counts in the wound bed.

More important advances in wound management have occurred recently as a result of expansion of knowledge regarding healing process at the molecular level. This has lead to the development of wound care methods which have greatly improved the capability of wounds to heal with lesser complications. A orchestrated approach to wound care has developed through extensive research. This has resulted in the development of efficient wound care algorithms and thereby creation of a reconstructive ladder in surgical practice.

The concept of using vacuum to create a suction force which would enable the drainage of wounds to promote wound healing is quite well known. If excess fluid is not sufficiently removed from a wound after surgery, its components may serve as both physical and chemical obstacles to wound healing. To add up on it, the basic concept of mechanical forces influencing the growth and shape of

tissues is well reported. A buried drain can have negligible affect on surrounding tissue. Thus the development of application of suction topically across the wound surface to provide a solution that is capable of removing excess fluid and ECM and promoting a reduction in wound size.

INTRODUCTION TO VAC

The pioneers of vacuum-assisted closure therapy was Dr Louis Argenta and Dr Michael Morykwas[14]. by the application of VAC therapy the blood, edema serous fluid are removed by suction effect , it reduces infection rate by closing the wound from external contamination and by sealing off the oxygen at the surface for bacteria and it increases localised blood flow to the wound bed by the formation of new blood vessels in the wound bed, thereby supplying abundant oxygen and nutrition to promote the accelerated healing process.

Other names of VAC therapy system include

- topical negative pressure,
- sub-atmospheric pressure,
- sealed surface wound suction,
- vacuum sealing and
- foam suction dressing.

The alteration in macroscopic and microscopic structure of wounds is the key to success in healing of acute as well as chronic wounds.

Many factors have been reported to affect the wound environment adversely, such as

1. vascular disease,
2. diabetes,

3. pressure,

4. infection,

5. environmental stress,

6. age,

7. nutrition,

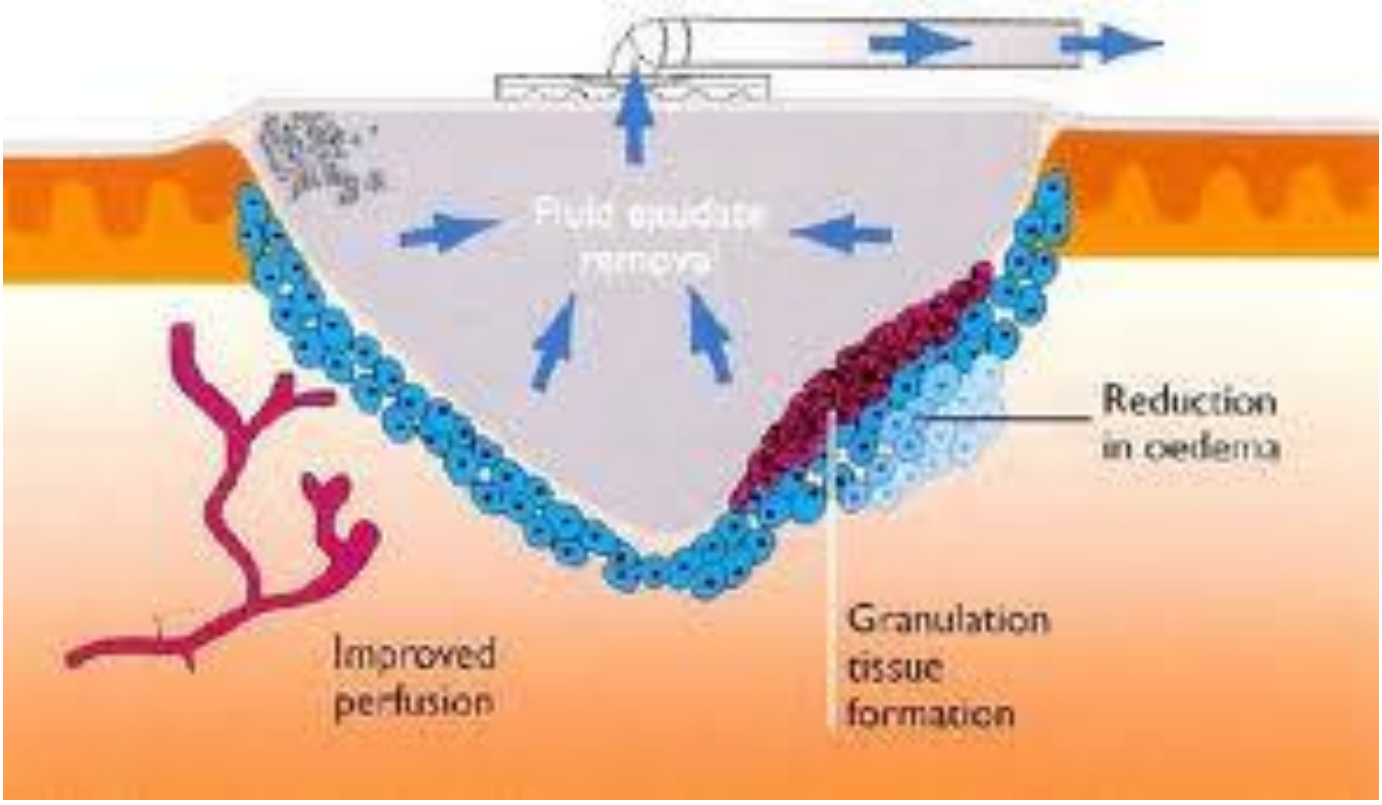
8. immune status and

9. pharmacologic agents.

The VAC therapy changes the environment of wound by

1. reducing infection
2. by removing inflammatory/interstitial wound exudate
3. formation of new blood vessels
4. by macrostrain and microstrain effect
5. removal of harmful enzymes

By these effects of vac therapy in acute wound or in chronic wound a healthy granulation bed is formed at the base of the wound.


Fluid exudate removed
Reduction in oedema
Improved perfusion
Granulation tissue formation

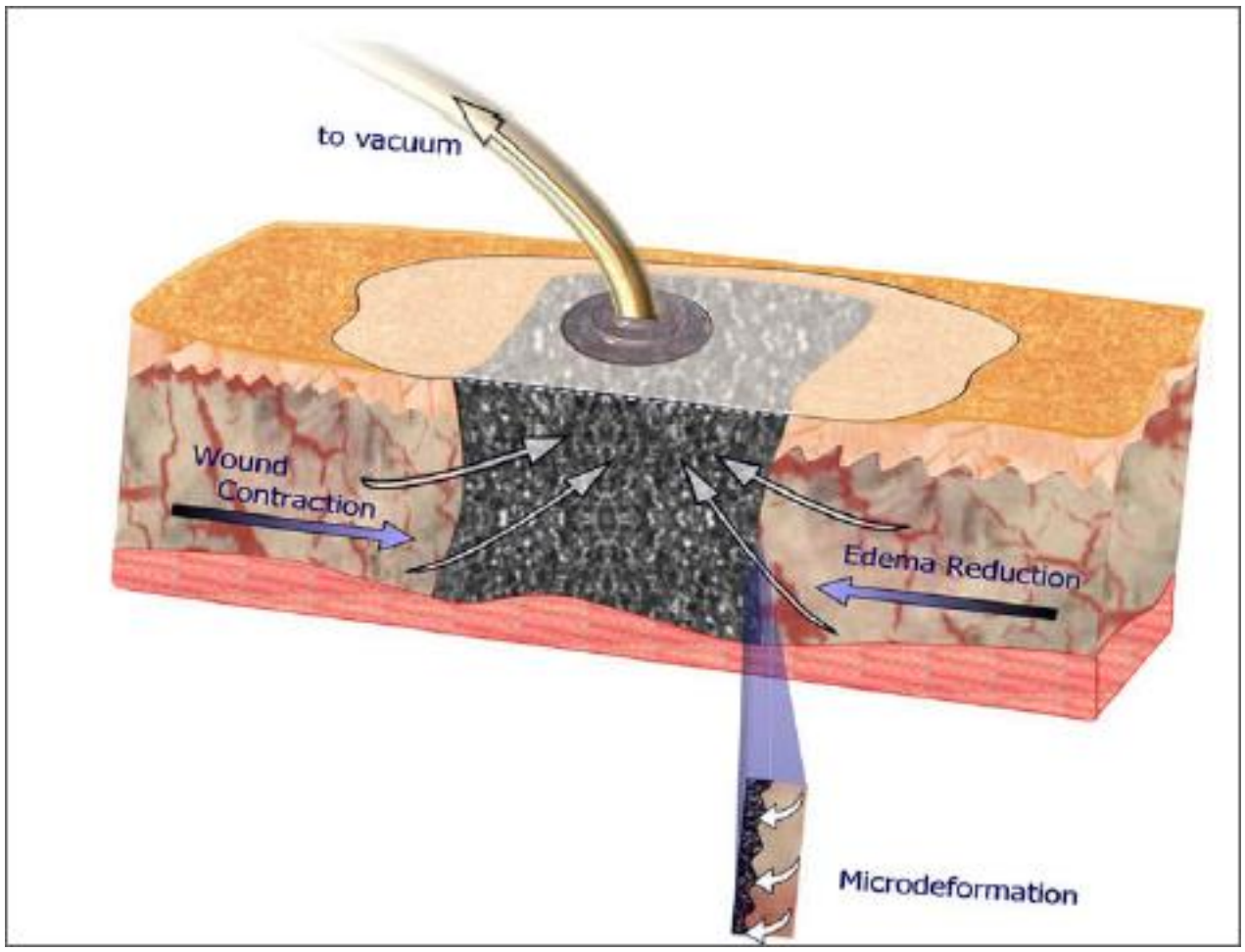
MODE OF ACTION

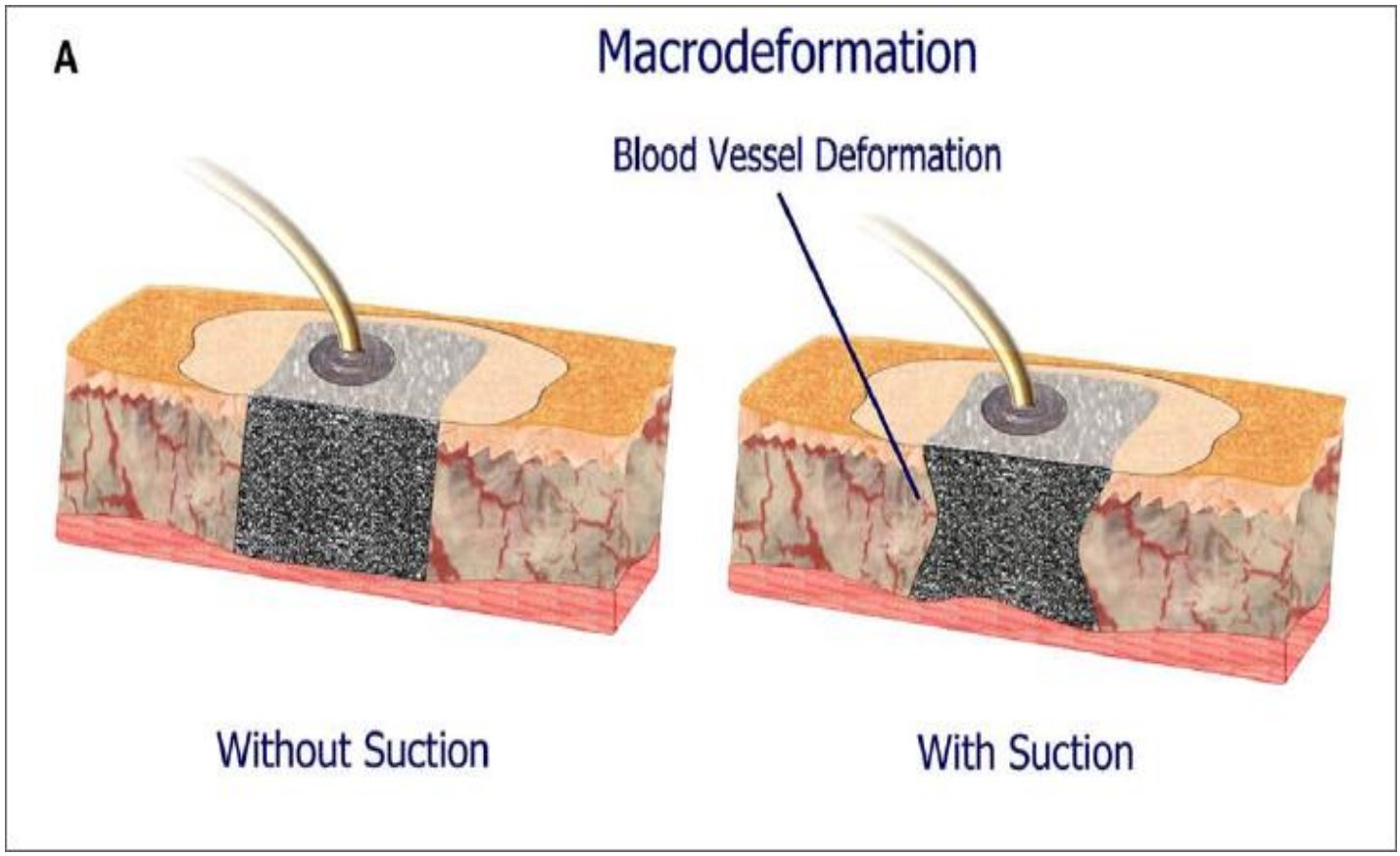
- The Sub atmospheric pressure by vac therapy in the wound causes wound healing by secondary or by tertiary intention by the following effects
    1. Removes oedema from the wound,
    2. Formation extracellular matrix and formation of granulation tissue,
    3. Increasing blood supply to the wound by forming new blood vessels,
    4. It also removes harmful infectious material and enzymes from the wound bed
    5. By causing mechanical effects on the cells.

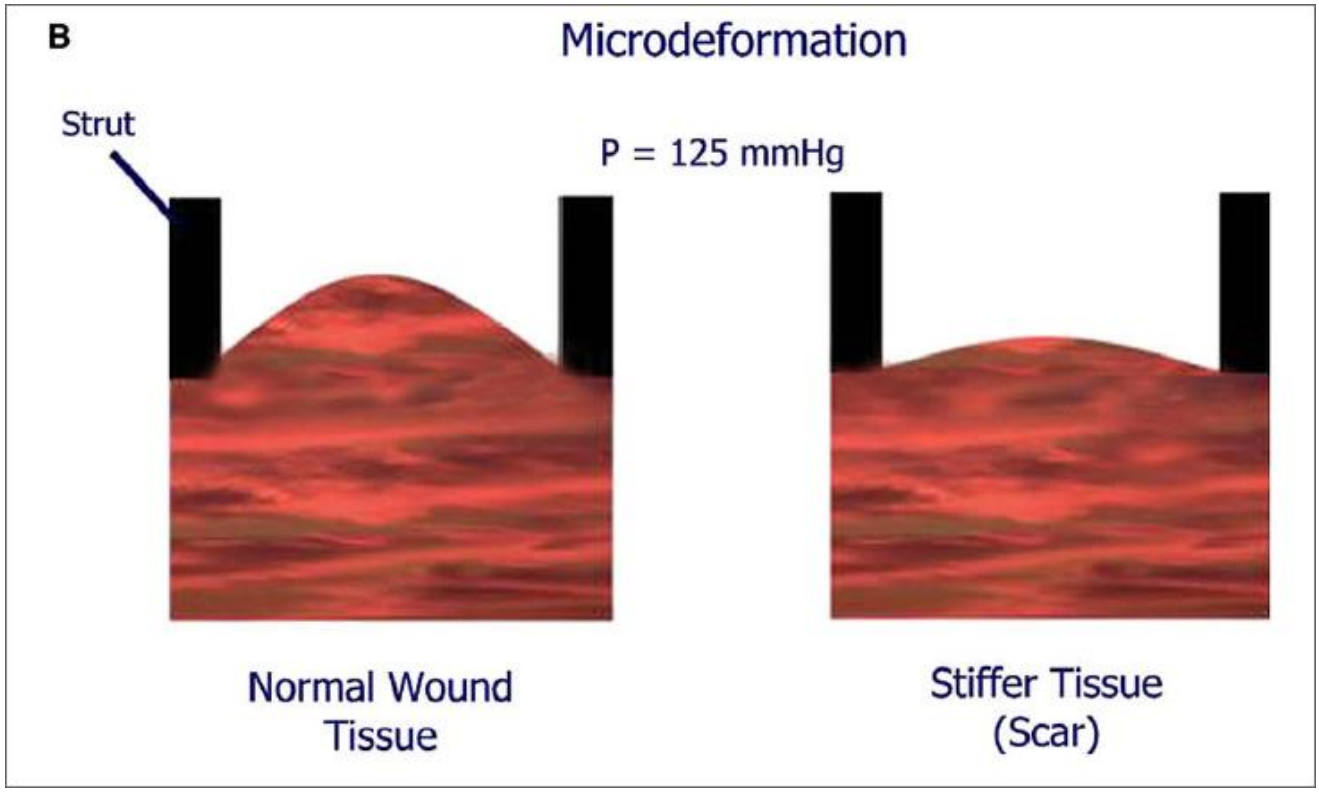
a) Macro strain is centripetal force on the wound bed which draws the wound edges together

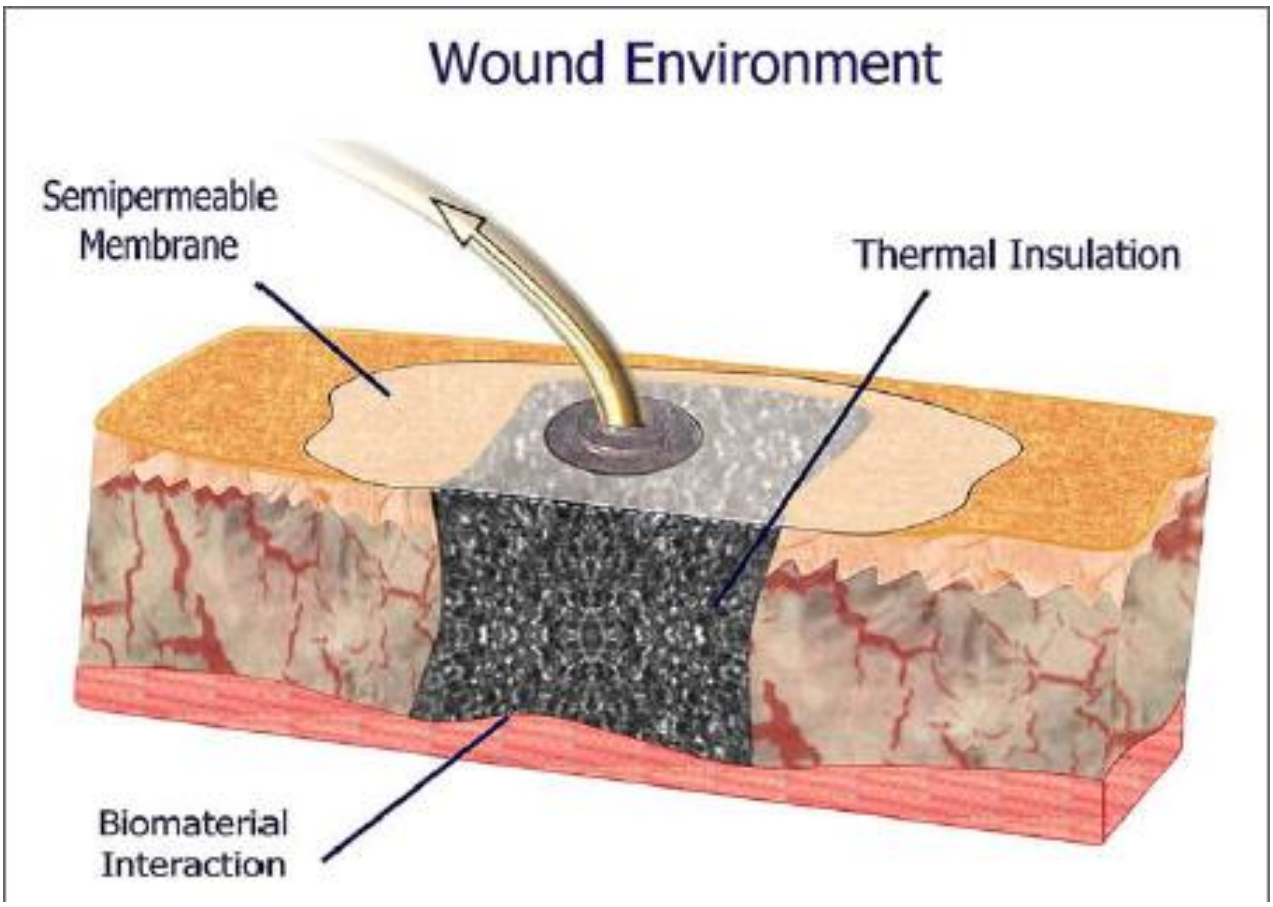
b) Micro strain is the microscopic effect of vacuum on the wound bed which leads to
    a) Stretching of cells
    b) Tissue perfusion is increased
    c) Cell division
    d) Proliferation of fibroblasts

all these creates an environment for wound healing at cellular level of the wound.

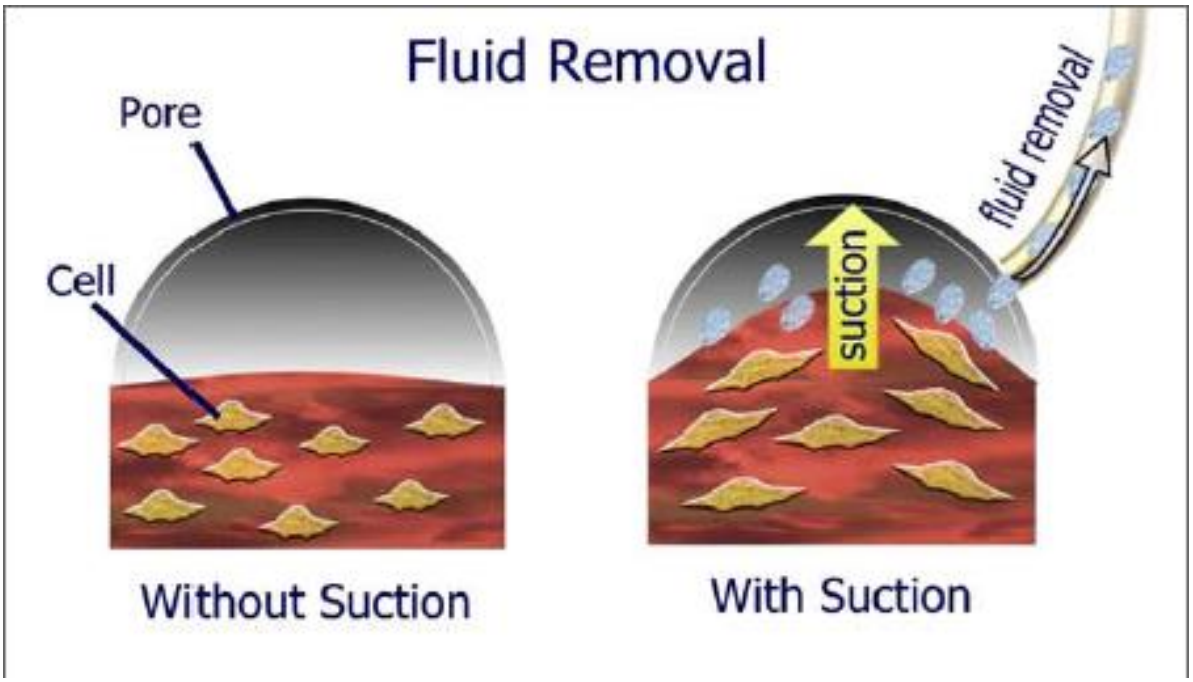

to vacuum
Wound
Contraction
Edema Reduction
Microdeformation


A
Macrodeformation
Blood Vessel Deformation
Without Suction
With Suction


B
Microdeformation
Strut
P = 125 mmHg
Normal Wound Tissue
Stiffer Tissue (Scar)



VAC therapy helps the wound to maintain moist and warm environment as well as it acts as an insulating layer for foreign contamination



The suction effect is distributed uniformly over the wound bed which causes removal of the edema and the fluid from the wound bed

PRACTICAL TIPS

The VAC dressing can also be used in patients with multiple wounds. After applying the VAC in a airtight manner to the main wound, the tubing is allowed to pass through the other wounds the patients has and appropriate incisions are made over the tubing upon the smaller wounds and airtight dressings are applied over them also thereby providing a negative pressure environment in the smaller wounds also.

The problem of obtaining an airtight seal in hair-bearing areas can be solved by laying the occlusive VAC film into hydrocolloid dressings that seem to adhere more strongly to these areas.

Another practical aspect is to practice putting some lignocaine into tube thereby reducing pain while removing the dressing.

Applying Compound Benzoin Tincture to the surrounding skin, letting it dry and there after applying the adhesive dressing also helps in giving it a better adhesion.

TECHNICAL ASPECT

The most commonly used dressings in NPWT are foam and moistened cotton gauze.

Vacuum Assisted Closure advocates open-celled reticulated foam dressing in order to evenly distribute the negative pressure all across the wound surface. A transparent film is then used to cover the wound which prevents bacteria from reaching it and also seals the wound thereby creating a vacuum. Foams that contain silver or other antibiotics are also being used nowadays..

Moistened gauze can also be employed instead of foam in order to cover the wound surface. Non adherent moistened gauze is gently placed over the wound bed and is covered by a adhesive film dressing. An antimicrobial gauze can also be used instead.

A plastic tubing is then connected to the dressing (foam or gauze) which leads into a canister and from there into a suction device. The constant suction, as previously mentioned removes the excess exudates into the canister. The pressure set in the vacuum device can be altered according to the wound type ranging from about -5 to -125mmHg .This can also be adjustable to higher pressures, depending on the device used(41)

APPLICATION OF VAC

Sequence of Application :

1. Wound Preparation

2. Placement of Foam

3. Sealing with Drapes

4. The Application of Negative Pressure

Prerequisites and method of VAC application

1. **Debridement**

   Swab for culture is taken from the wound before through debridement of the wound. Slough, necrotic tissue, and any pus from the surface of wound is removed surgically.

2. **Lavage**

A thorough wound lavage is done to remove bacterial colonization and dead and necrotic tissue.

3. **Foam placement**

The foam is cut according to the size and shape of the wound and is placed on the wound.

4. **Precautions at the periphery**

Around 20 % of the wounds goes for maceration in wounds treated by vac therapy. So the foam should be cut adequately.

5. **Insertion of draining tube**

A draining tube is embedded in the foam which is connected to a collecting on the other end.

6. **Sealing of the wound**

Apply the transparent adhesive membrane(opsite) over the dressing and make sure that the wound is completely sealed from the environment . If needed multiple sheets can be used to cover the wound fully. The adhesive membrane should cover the foam the suction tube properly and should not give any leak in the dressing.

7. **Draining tube is now connected to canister and one more draining tube from the canister is connected to suction apparatus**.

8. **Start the VAC machine**

As the machine is started the foam starts to collapse and shrink as the suction force causes the foam to contract. The pressure in the machine can be adjusted according to the size of wound but a range of 100 to 150mm of mercury is adequate for most of the wounds.

9. Removing of dressing – the adhesive tape should be removed gently to avoid irritation of surrounding skin and the foam can be removed by pouring normal saline and the removing the foam makes it easy and less damage to the underlying granulation tissue .

1% lignocaine solution can be sprayed over the wound surface if the dressing change cause pain either through the draining tube or by injecting into foam with pump at low pressure (50 mmHg).

Wound Healing in VAC therapy[19]

By the application of vac therapy the micro and macro mechanical effects and forces help in promoting wound healing by the following ways

1. Increases cell division,
2. Promotes neoangiogenesis and
3. Promotes local elaboration of the growth factors[33].

The intermittent application of negative pressure causes change in the cytoskeleton of the cell structure in the wound bed, which triggers a cascade of events which increases the rate of division of cells and subsequently lead to formation of healthy granulation tissue.

Bcl-2 protein and NGF/NGFmRNA are the apoptotic modulation related proteins and their expression is increased by application of vac therapy which may promote the wound healing process.

MMP-1, 2, 13 mRNA depresses the degradation of collagen and gelatine and VAC causes depressing effect on MMP-1,2,3,mRNA and promotes wound healing.

Endothelin Type A and Type B receptor are vasoconstrictor receptors and studies have shown that VAC causes vasoconstriction by these receptors-mediated vasoconstriction but this vasoconstriction may be compensated by endothelium-dependent vasodilatation which is more effective.

A balance between the accumulation of collagenous and noncollagenous extracellular matrix components is required for proper wound healing.

Remodelling of metalloproteinases (TIMPs) by matrix metalloproteinases (MMPs) and the tissue inhibitors also play a important role in wound healing.

If this regulation fails then it has been suggested that not only wound healing is affected but also other deleterious effects like cardiovascular disease, inflammatory and tumor growth and invasion also occur.

The application of VAC therapy in wounds has shown enhanced granulation tissue formation, increased wound area reduction, increased cell

division which is possibly induced by increased tension force on the cells, decreases local oedema and also interstitial tissue oedema, which in turn causes increased perfusion of the periwound area.

The inhibitory factors are removed continuously along with removal of oedema fluid.

ISSUE OF DEFINING THE APPROPRIATE NEGATIVE PRESSURE

For almost over half a century from now, the consequences of exposing wounds to negative pressure is being studied in detail but still there is no clear evidence stating the adequate pressure intensity, prescribed duration of treatment, and interval needed between treatments to provide the most efficient therapy. In 1997, Morkywas et al clearly showed that microvascular blood flow to a wound site increases 4 times the baseline values with sub atmospheric pressures of 125 mmHg, while the blood flow was inhibited at negative pressures greater than or equal to 400 mmHg.

Based on this result of Morkywas, sub atmospheric pressure of 125 mmHg became the most common pressure setting while using this technique. However, previous to that research, Russian physicians were refining NPWT. In 1987, Usupov and Yepifanov[42] used a rabbit model and concluded that in order to avoid any tissue damage, pressures in the active drainage systems must not exceed –

80mmHg and that lower pressures were less likely to cause postoperative hemorrhage. The same study also demonstrated occurring of new tissue hemorrhage of previously coagulated vessels with pressures that measured less than – 120 mmHg to – 125 mmHg.

Aside from inconsistencies in pressure levels that were noted between Morkywas et al and the Russians ,there were also conspicious differences in pressure intervals between them both. Morkywas et al stated that optimal results were obtained when VAC was applied continuously for the first 48 hours followed by the intermittent regimen (5 minutes on and 2 minutes off).

In 1986, the Russian researchers then published a study that revealed that negative pressure wound therapy could be successful when applied twice daily for a period of 2.5 to 3 hours[42] The disparity in findings between both underscored the need to define the pressure intensity parameters, prescribed duration of treatment, appropriate interval between treatments, suggested mode of application, and probable timing of application to provide the most efficient and cost effective therapy.

In 2004, Wackenfors et al[43] from Sweden conducted a study which was published in which inguinal wounds in pigs were observed subjecting them to pressures ranging from 50 to 200mm Hg and the microvascular blood flow was

observed .Laser Doppler was then used to measure the blood flow in which the sum of all erythrocytic motion was quantified in a volume of 1mm, there by providing a platform to reliably perform measurements in small, closely spaced skin areas.[44]

The findings of this study was then correlated to predict how NPWT affects microvascular blood flow with specific consideration of tissue type and the distance of blood flow from the edge of the wound , parameters that were not focussed in to the work done by Morkywas et al. The results of the study found out that NPWT induced a conspicious increase in micro vascular blood flow upto a few centimeters away from the wound edge, which might accelerate formation of granulation tissue and the process of wound healing[43].

Conversely, nearer to the edge of the wound, negative pressure resulted in hypoperfusion that increases along with increasing subatmospheric pressure with the possible result of ischemic tissue damage. Furthermore, the type of tissue is also a predominant factor : the increase in perfusion occurred closer to the wound edge in muscle as compared to subcutaneous tissue (1.5 cms as to 3 cms at negative pressures of 75 mmHg).

Wackenfors and her team later proposed that a proper decision is to be made when selecting the amount of sub-atmospheric pressure for NPWT treatments.

The vacuum should be adequately robust enough to drain the wounds and arrest superficial bleeding. At the same time, the vacuum should not create a significant ischemic zone impeding the healing of the wound. Based on the findings, the investigators finally concluded that when treating stiff muscular tissue , a negative pressure of approximately 10mmHg may be reasonable, thereby limiting the extent of the zone of hypoperfusion to 1 cm from the edge of the wound. When treating softer tissue like fat and subcutaneous tissue, which is more vulnerable to hypoperfusion, the application of a even lower negative pressure, equal to 75 mmHg, may be beneficial. Although such pressure recommendations are uncommon among NPWT practices, the Russian literature authorises the use of these pressures during treatment.

CHRONIC WOUNDS

Chronic wounds are wounds that fail to heal in the normal healing phases of inflammation, proliferation, and maturation. They represent a heterogeneous group of wounds of multiple cause and conditions, such as pressure ulcers, diabetic ulcers, venous stasis ulcers, vasculitic ulcers, and chronic non healing wounds resulting from trauma or dehisced surgical wounds. The use of NPWT has profoundly changed the management of these patients, who often are poor surgical candidate and have failed previous operations. Such wounds often area burden to

caregivers, because of the multiple frequent dressing changes, and are incapacitating to the patient.

Chronic wounds often exhibit progressive edema, compromise of perfusion, and elevated levels of proteolytic enzymes and cytokines that inhibit granulation tissue formation and epithelialization. The fluid that is drawn from the wound by the NPWT system is rich in cytokines, acute –phase proteins, and proteolytic enzymes, suggesting that inhibiting factors are removed from the wound. The removal of interstitial fluid and inhibitory cytokines leads to a less favorable environment for bacteria and wound behavior, which becomes more like an acute wound.

Thus, NPWT has proven useful in managing such wounds and allows for easier wound care, particularly for wounds that are difficult to dress and lose significant amounts of fluid. Wounds that have been stagnant for weeks, months, and in some cases, years, usually demonstrate a return to the normal healing progression and, ultimately, to a healed state . Diabetic foot wounds have demonstrated a particular benefit, with one recent multicenter, randomized, controlled trial showing a statistically significant improvement in wound healing time .

EXPOSED BONE OR TENDON[20-22]

Wounds in which there is exposed bone, tendon, or other hardware have been treated successfully with negative pressure therapy. For wounds with exposed bone and intact periosteum, NPWT promotes granulation tissue – either bridging the time for definitive wound closure or enabling a more simple surgical option (e.g., split-thickness skin grafting).

In orthopedic trauma, the use of NPWT has allowed for primary closure with a high rate of success and is becoming a primary mode of treatment for open fracture sites. NPWT also has been useful in dealing with bone without periosteum, such as following a scalp resection for turn or. The exposed calvarium can be burred down until punctuate bleeding is noted from the diploic space.

NPWT assists in promoting granulation tissue formation in such wounds, ultimately leading to skin grafting. It also is possible to perform the skin grafting immediately after burring the outer table of skull in a single – stage approach .

Exposed tendon also has been treated with negative pressure therapy. If the tendon is healthy with viable paratenon, the NPWT promotes early granulation of such wounds. A nonadherent dressing beneath the foam may minimize desiccation and trauma to the tendon. NPWT often promotes granulation

tissue completely covering the tendon, enabling simple techniques (eg., skin graft) rather than formal flap closure.

If there is exposed hardware in the wound, it may be possible to salvage this with NPWT. Enough healthy granulation usually can be induced from the surrounding tissue to enable secondary wound closure or flap coverage, without the need to remove the hardware. The amount of exposed hardware that can be salvaged in this fashion is variable, but usually is only a few centimeters. The quality of the surrounding tissue and overall status of the patient must be considered. In dealing with exposed hardware, sound surgical priniciples should be followed. In the setting of large areas of hardware exposure or infection, the hardware needs to be removed and alternative fixation established.

FASCIOTOMY SITES/EXTRAVASATION INJURIES

Fasciotomy wounds are ideally suited for management with NPWT . Edematous muscle and tissue can be decompressed more rapidly, thus shortening the interval between fasciotomy and wound closure. In most instances, the fasciotomy wound can be closed secondarily, rather than requiring a skin graft for wound coverage .

Another benefit may be related to the ability of NPWT to remove unwanted by-products of tissue injury. The fluid removed from such wounds is believed to be rich imunoglobin, and it has been speculated that the removal of this fluid by an NPWT system also results in faster serum clearance. Although human studies are still in progress, this effect has been demonstrated in a rabbit model.

Based on the knowledge that local and systemic toxins could be evacuated from a wound using the NPWT, laboratory tests were performed to examine its role in extrinsic toxic substances. Early application of the NPWT to a site of doxorubicin injection in a pig model prevented ulcer formation. In humans, several case reports have examined the successful use of NPWT in the setting of toxic bites or extravasation injury .

SKIN GRAFTS/ARTIFICIAL SKIN[23-25]

NPWT has proven to be a useful tool in skin-grafting procedures. By assisting in creating a more vascular and cleaner wound bed, it can augment the percentage take of a subsequent skin graft. In some cases, vacuum sponge dressings have allowed skin grafts to be performed in areas that originally had sparse granulation tissue or exposed bone or tendon.

The skin graft is bolstered to the wound bed by the sponge, which conforms to the wound shape and helps to eliminate any dead space and reduce shear forces . The skin graft is protected from adhering to the sponge by a nonstick dressing (dashed line).

In addition, the vacuum-sealed sponge serves as an excellent fixation device for skin grafts. The skin graft is harvested, fenestrated, and placed on the wound bed in the usual fashion. A single layer of a permeable nonadherent dressing , like Adaptec or Xeroform, is placed between the skin graft and the dressing sponge. As air is evacuated from the sponge, it traps the skin graft between the sponge and the underlying tissue. Also, it conforms to the wound bed, thereby acting as natural splint to hold the graft against the wound. This firm approximation of the graft, along with the edema-and bacterial-reducing property of the negative pressure system, is believed to help reduce failure due to shear forces, fluid collection, and infection. Several studies examined the usefulness of this technique and found that it facilitates skin grafting and may increase the take rate .

This same principle has been applied to artificial dermis, such as Integra and other skin substitute products. NPWT increased take rates and decreased the time required for vascularization. Traditionally, Integra is not ready for a

secondary skin graft for 2 to 3 weeks ; however, when managed with NPWT, secondary skin graft often can be applied in 1 week, with a 93% skin graft take .

SALVAGE PROCEDURES

NPWT can also be extremely helpful salvage of difficult cases. This wound management technique can be applied as a "last resort" or even as a standby procedure until the patient becomes healthy enough to cope up with surgery. Wounds that need salvage procedures are necrotizing fasciitis involving large areas of skin loss,abdominal dehiscence. These wounds can be disturbingly large with unhealthy wound beds. The patients also happen to be unsuitable candidates for immediate major reconstructive surgery that requires a good cardiovascular status. . Use of negative pressure therapy in situations like these may significantly lower the reconstructive requirements of the wound.

ADJUNCT TO SURGERY

AN IDEAL METHOD TO MAINTAIN SKIN GRAFTS UPON A SUITABLE WOUND BED REQUIRES FIRM FIXATION ON WOUND, AVOIDING SHEARING FORCES, ADAPTATION TO CONCAVE OR CONVEX SURFACES, EVACUATION OF SUB-GRAFT SEROMA AND HAEMATOMA AND MOST IMPORTANT OF ALL, MINIMIZATION OF INFECTION.

SPLINTAGE OF GRAFT USING NPWT FULFILS MOST OF THESE CRITERIA AND VARIOUS STUDIES HAVE SHOWN TAKE RATES OF OVER 90%

WOUND DRESSINGS

Dressings generally are selected based on the characteristic features of the wound at any given point during the process of healing. Exudative wounds will need an absorptive dressing (hydrocolloid, foam, alginate, hydrofiber) whereas dry wounds might need a dressing that provides adequate hydration (hydrogel). The type of dressings will change periodically as the wound progresses through various stages of wound healing. Synthetic wound dressings effectively maintain a moist environment by inhibiting the loss of water vapor from the wound. Moist wound environments aids in the process of epithelialization and healing.

FUNCTIONS OF IDEAL SYNTHETIC DRESSING :-

- It removes excess exudate and toxic components;
- Should permit gaseous exchange;
- Should provide thermal insulation;
- Should protect against secondary infection.

Synthetic wound dressings are available in a wide variety. Some of the unique features of each are described subsequently. These dressings are often used in conjunction with silver or other topical agents that are intended to limit infection and speed healing. The following dressings may be used on acute or chronic wounds depending on the nature of the wound.

HYDROCOLLOID DRESSING

These are composed of adhesive, absorbant, and elastomeric components. Carboxymethycellulose is the commonest absorptive ingredient. They are not permeable to water but permeable to moisture . In addition, they also facilitate autolytic debridement, they are self – adhesive,they mould well, provide light to moderate absorption of exudates and can be left in place for many days,hence minimizing skin trauma and disruption of healing. They are highly beneficial for light to moderately exuding, acute or chronic partial – or full – thickness wounds, but they are not useful on infected wounds. The hydrocolloid forms a gel on prolonged contact with the wound fluid.

FOAM DRESSINGS

The composition of foam dressings vary widely. They usually consist of a polymer, often polyurethane. These have small, open cells that holds fluids. Some of the forms of foam dressings have a covering the top surface that is waterproof .It

may or may not have any adhesive coating on the border or the wound contact side. The foams easily permeate water and gas. They also absorb light compared to heavy exudates. Patients with venous leg ulcers with compression dressings usually benefit with such dressings.

FILM DRESSING

This is a single thin sheet of polyurethane that is transparent and coated with an adhesive on one side. It allows free passage of gases and moisture but does not let in any wound fluids. Film dressings are impermeable to bacteria , retain moisture, thereby allowing observation of the wound , and do not necessitate a secondary dressing. The adhesive is inactivated by moisture and therefore will not stick to the moist wound bed or to moist skin. Excessive fluid buildup may break the adhesive seal and lead to leakage. Film dressings are beneficial for superficial wounds with minimal exudates. They are commonly used to attach a primary absorbent dressing, in a way as a secondary dressing. The dressing remains in place for about seven days if significant amount of fluid does not collect. It is hard to apply a film dressing due to self – sticking. It must be placed beyond the wound edges by at least 1-2cm.The split skin graft donor site is ideally dressed with film dressings.

ALGINATE DRESSINGS

Calcium or calcium – sodium salts of natural polysaccharides that are obtained from brown seaweed forms the major source for alginate dressings. The alginate forms a hydrophilic gel when it comes into contact with sodium rich wound fluid as a result of ion exchange. This hydrophilic gel can absorb upto 20 times its weight and the rate of re-injury is averted by its property of not adhering to the wound. In heavily exuding wounds, where there remains constant exudates to prevent its drying, the dressing can be kept in place for more than 7 days.

Film dressings supplement the alginate dressing holding them from drying out and holding them in place.

HYDROFIBER DRESSING

The characteristic feature of hydrofiber dressing is the presence of sodium carboxymethylcellulose fibers in them that help in maintaining a moist wound environment by absorbing large amount of exudates thereby a gel is formed.

Specifically useful in highly exuding wounds.

HYDROGEL SHEETS

These are made of cross linked polymers arranged in a three-dimensional framework. Since they have a high water content, they provide moisture to the wound. But depending upon their composition they can also absorb a significant amount of fluid. They have the following advantages as a Negative Pressure Wound Therapy device:

- Adequate hydration of the dry wound beds
- Provide a soothing and cooling feel and hence reduces pain
- Simple in application and removal

These do have some disadvantages like :

Wounds may require frequent dressing change, every 1-3 days

These are not effective in wound with heavy exudates

A variant, Amorphous hydrogel, is similar in as aspects except for the cross linking. These have the advantage that they provide moisture to a dry wound and also causes autolysis of necrotic material by forming an eschar. Other ingredients that the gel may contain are collagens, alginate, complex

carbohydrates, etc. In shallow dressings, another dressing a second cover may be useful.

COLLAGEN-BASED DRESSINGS

Collagen plays a pivotal role in all aspects of wound healing, unlike previous concepts that they provide only the structural support within a wound. When a wound is formed, the collagen gets exposed and platelets aggregate around this exposed collagen. These platelets now produce growth factors and cytokines that attracts all the inflammatory cells. The collagen and other protein debris in the wound gets degraded thus producing factors that attract fibroblasts. These fibroblasts start producing matrix metalloproteinase along with collagen which in turn produces factors attracting more fibroblasts, vascular endothelial cells and also epithelial cells. These together form the granulation tissue. The non-viable collagen is degraded by the MMPs. Sometimes when too much of MMPs are produced, they destroy the normal collagen too and this occurs in chronic wounds. Collagen based dressings basically act by stimulating the fibroblasts. These contain purified collagen that are obtained from porcine, bovine or avian sources.

Infected wound are defined as those having a bacterial count of 10^5 colony forming units per gram of tissue. The bacteria need not always invade the tissue,most wounds are either contaminated or colonized by them. The concept of

‘critical colonization’ was put forward to emphasize that bacterial growth can delay wound healing even in the absence of infection. This requires gentle irrigation with normal saline or occlusive dressings or antiseptics.

SKIN GRAFTS

Skin grafts are mainly used in the management of venous leg ulcers,burns wound and diabetic foot ulcers.

Skin grafts are proposed to assist wound healing. They provide dermal collagen, growth factors and a biological occlusion that protects the wound.

Skin grafts can be autograft, that is from the same individual, or allograft, that is from another human being.

Skin grafts are used only when the wound has sufficient granulation tissue to support the graft.

Autologous skin graft is a painful procedure and moreover sometimes the recipient wound is so large that an autologous tissue graft would not be sufficient. Skin substitutes are available nowadays that help in treating chronic wounds.

The damaged epithelial and dermal components of skin are replaced biologically by bioengineered skin substitutes that help in wound healing. They

provide conditions and all the biological factors necessary for proper wound healing.

SKIN SUBSTITUES

The main advantage of skin substitutes is that they promote re-epithelialisation. They provide a protective covering preventing bacterial influx and at the same time allowing fluid and gaseous exchange. These are generally used prior to skin grafting or used temporarily as specialized dressings.

There are two types of skin substitutes, cellular and acellular types. Cellular skin substitutes contain fibroblasts and keratinocytes. They are incorporated in a collagen or polyglactin matrix. The acellular varieties contain only the matrix that are usually composed of fibronectin, hyaluronic acid or collagen. The matrix is so constructed that the host cells can freely pass through. A few skin substitutes incorporate into the wound itself forming a neodermis.

There are a variety of skin substitutes depending on the biological material used. The following describes some of the products currently available to treat burns wound and other skin wounds:

- alloDerm® (LifeCell Corporation, Branching, NJ, USA) – acellular, de-epithelialized cadaver dermis.

- Apligraf® (Organogenesis, Inc., Canton, MA, USA) – neonatal keratinocytes and collagen seeded with neonatal fibroblasts.
- Biobrane® (UDL Laboratories, Inc., Rockford, IL, USA) – Silicone,collagen and nylon mesh.
- Dermagraft® (Advanced BioHealing, Inc., Westport, CT, USA) – Polyglycolic acid or polyglactin – 910 seeded with neonatal fibroblasts.
- Epicel® (Genzyme Biosurgery, Cambridge, MA) – autologous cultured keratinocytes.
- GraftsJacket® (Wright Medical Technology, Inc., Arlington, TN, USA) – Freeze dried acellular human dermal matrix.
- Integra® Dermal Regeneration Template (Integra LifeSciences Holding Corp., South Plainsboro, NJ, USA) – silicone, collagen, and glycosaminoglycan
- Oasis® (Healthpoint Ltd., Fort Worth, TX, USA) – derived from porcine small intestinal submucosa.
- OrCel® (Forticell Bioscience, Inc., New York, NY, USA) – normal human allogeneic skin cells (epidermal keratinocytes and dermal fibroblasts) are cultured in two separate layers into a Type I bovine collagen sponge.

- Promogran® (Systagenix wound management, London, UK; Formerly marketed by the professional wound care business of Ethicon Inc, a Johnson & Johnson company) – bovine collagen and oxidized regenerated cellulose.

THE FUTURE

NPWT combines both open and closed modalities ot treatment and adheres to the principles of DeBakey in being short, safe, and simple. It is undoubtedly proved to be useful in a wide variety of wounds, but their use in general practice is clinician dependent and in many cases idiosyncratic. According to the Cochrane report, there are no high quality trials conducted on this topic. Most of the studies done have small sample sizes and other methodological limitations such that the results are scrutinized with a lot of caution. Several random controlled trials are necessary to investigate these issues and this may be a challenging problem for people doing research in wound healing as there are a lot of difficulties in the assessing and measuring of healing in wounds.

NPW therapy is a highly beneficial method for a wide range of wound though it may not be useful in a few. NPWT has been compared to traditional dressing methods in terms of 'time to healing' or epithelialisation in other words but this is an inappropriate comparison as NPWT is mainly intended for wounds with heavy exudates or those with cavitary lesions. NPWT is a useful tool in

transforming a wound to a point where more Traditional dressings or simpler surgical methods for reconstruction can be used. Although a pragmatic addition at present, NPWT is a well deserved addition to the armamentarium of wound healing and reconstruction.

SPONGE TYPE

Two types of sponge are available.

1. Polyurethane foam (black in colour)-

For wound contraction and formation of granulation tissue this foam is used.

Its pore size of 400 to 600 mm. it is larger and lighter.

2. Poly vinyl alcohol foam(white in colour) -

Its a dense sponge with pore size much smaller when compared to polyurethane foam. This foam is used when the granulation tissue required is less and the application of vac is painful in the patient. This sponge needs higher negative pressure for collapse.

Variable sizes of these sponges are also available.

THE PHYSICAL BASIS OF VAC THERAPY

VAC therapy affects the wound healing by many modalities like physical effect of suction force on the wound, topical pressure effect of the suction over the sponge, shearing forces created at the wound bed, and alteration of the wound's atmosphere and its composition. All these mechanisms combine together and trigger a complex environmental, physical, biological & chemical conditions of the wound that affect the healing of the wound. It is difficult to fully understand all these mechanisms and their integrated role due to implications of various clinical conditions.

Suction forces

The suction effect created on the foam and further on the wound bed causes reversal of lymphatic flow and the oedema and fluid in the wound bed is removed thereby reducing the infectious load as these fluid contain abundant bacteria and removal of oedema creates space for formation of granulation tissue.

VAC also helps in formation of granulation tissue over the exposed bones & tendons

Shearing forces

The tissue growth is accelerated by alternating hypoxia & reperfusion which is created by application of cyclical tensile force created by the VAC therapy. Cyclical shearing forces and deformation of the underlying wound surface is done by intermittent operation of VAC relay which helps in faster regeneration of the tissue.

Alteration of atmosphere of wound

decreasing the pressure of atmosphere reduces the partial pressure of oxygen according to Dalton's law and vacuum therapy affects in the same manner

the benefits of combining increased supply of oxygen by formation of neoangiogenesis and sealing the atmospheric oxygen supply at the surface of wound bed helps in treating anaerobic infectious organism.

TREATMENT PLAN

First the basic reason for wound should be identified and other diseases which hinder the wound healing should be identified and treated properly. It is very important to improve the general condition of the patient before starting vac therapy. The main objectives of vacuum therapy must be defined first and endstage should also be defined. Like end stage of vacuum therapy is formation of uniform

granulation bed or reduction of wound size by 1 or 2 cms.

The main objectives of vacuum therapy are:

- to reduce the inflammatory secretion and to remove the oedema of the wound
- to form new blood vessels for increased supply of oxygen
- help in faster generation of granulation tissue
- decrease the wound
- prepare the wound bed for definitive management like SSG of flap cover

With the above benefits vacuum therapy also seals the wound from the external atmosphere and provides moist atmosphere to the wound by which it acts as a barrier to infectious organism. And the mobility of the patient can also be provided by vacuum therapy.

CHARECTERISTICS TO IDENTIFY PATIENTS RESPONDING TO VAC THERAPY

Characters which help in identifying patients who respond to vac therapy can be broadly classified into wound features and patient features.

Some of the important wound features are-

1. wound should have adequate supply of blood
2. wound should not have established deep infection
3. debridement of the wound should have been done
4. size of the wound should be more than 2cms in diameter

Some of the important patient factors which help in identifying patients who respond well with vac therapy are-

1. patient must be well nourished with general wellbeing
2. patient should not have other comorbidities like diabetes, hypertension, coagulation disorders etc.
3. patient should not be in pain due to other conditions like cancer etc
4. patient should be well educated and encouraged to follow treatment instructions

Before applying vac therapy the wound should be thoroughly debrided and all the dead and infectious material should be removed.

MATERIALS AND METHODS

In our institution seventeen patients with Gustilo Anderson compound grade IIIB patients were selected for this prospective study. The study period is from November 2012 to September 2014

All patients were selected based on our inclusion and exclusion criteria. Only Gustilo Anderson compound grade IIIB fractures were included in the study.

Inclusion criteria

1. Gustilo Anderson Compound Grade III B Fractures
2. Fractures with superficial infection

Exclusion criteria

1. Fractures with sequestrum
2. Pathological fractures
3. Chronic osteomyelitis

Mode of injury:

1. Road traffic accidents : 14
2. Train traffic accidents: 2
3. Accidental fall : 1

AGE AND SEX DISTRIBUTION

17 patients were treated with VAC therapy of age between 21yrs to 60 yrs

Among the 17 patients 15 were male and 2 were female

Assessment of wound before applying VAC therapy

1. Pus C/S
2. Size of wound
3. Area of the bone exposed
4. Area of tendons exposed
5. Any implants exposed
6. ESR
7. CRP

Initially the wound is thoroughly debrided and all the infected and foreign materials like mud etc are removed and through wound wash is given. Antibiotics are given as soon as the patient is received in the emergency ward. Initially broadspectrum antibiotics are given and later specific antibiotics are given according to sensitivity profile.

Protocol after each dressing

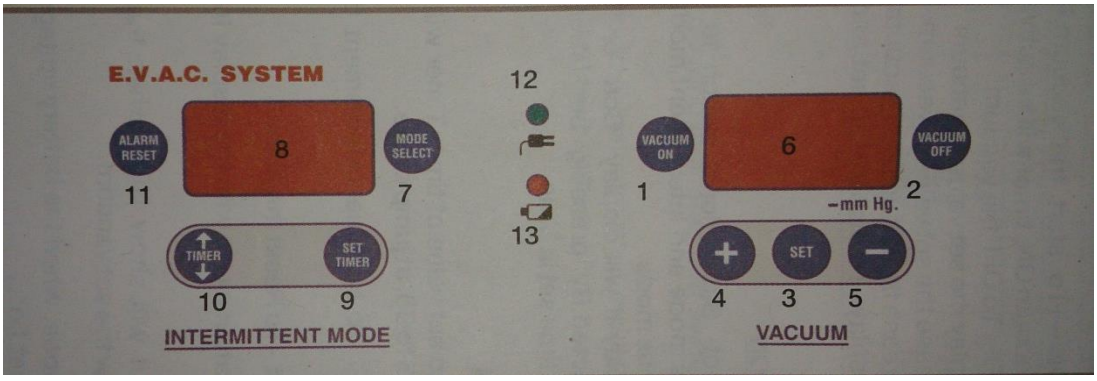
1. Pus culture/sensitivity
2. Size of the wound
3. Area of bone exposed
4. Area of tendons exposed
5. Amount of drain collection
6. Duration taken to get healthy granulation bed
7. Skin covering procedures (needed or not)
8. ESR
9. CRP

MATERIALS

ELECTRONIC VACUUM ASSISTED CLOSURE SYSTEM

Specification:

1. Machine operated on battery as well as mains.
2. Continuous as well as intermittent mode.
3. Vacuum range -10 to -200mmHg
4. Visual and audio alarm, for leakage in system.
5. Safety one way valve to ensure patient mobility.



1-vacuum on switch

2-vacuum off switch

3-set-to display set value of vacuum

4-(+)(plus button) to increase value of vacuum

5-(-)(minus button) to decrease value of vacuum

6- vacuum display

7-mode select button-to select continuous or intermittent mode

8-mode display-here type of mode selected will be displayed

9-set timer

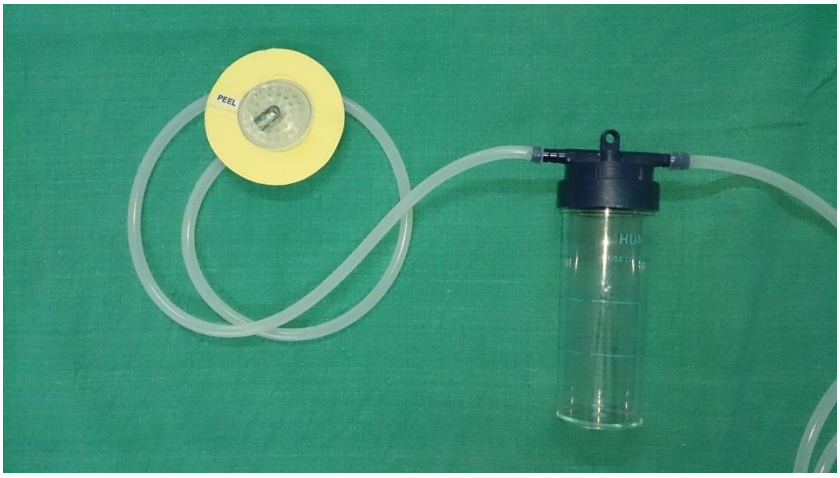
10- timer increments/decrement button

11- alarm reset button- alarm starts once the vacuum goes 25mm below set value & on battery mode when battery voltage reaches 9V.

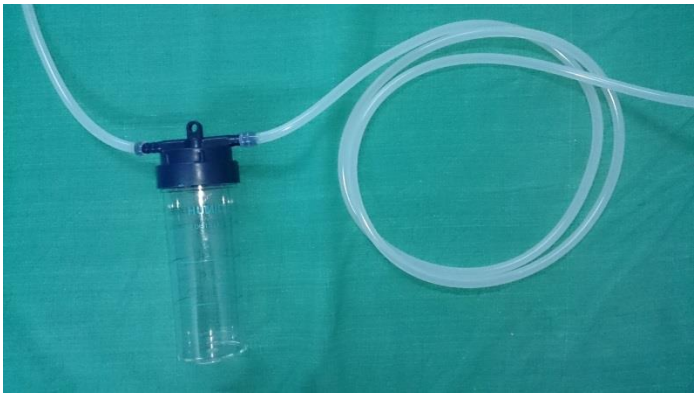
12-green LED glowing indicates that system is workin on mains

13-red LED glowing indicates that system is working on internal rechargeable battery.

12-open cell porous black foam



13-suction canister along with silicon tubing,single sided foam tape,suction cap all these are towards the wound from canister.



14 suction canister along with silicon tubing which is connected to the vacuum system.

Intermittent mode timer options

Set timer(mins)	Vacuum ON	Vacuum OFF
5	5mins	2mins
10	10mins	4mins
15	15mins	6mins
20	20mins	8mins
25	25mins	10mins
30	30mins	12mins

TIMING OF APPLICATION OF VAC THERAPY

Among the 17 patients for 14 patients VAC dressing was applied within 24 hrs of admission in our hospital and for 3 patients who had already developed superficial infection, the wound was thoroughly debrided and then VAC dressing was applied

ANESTHESIA

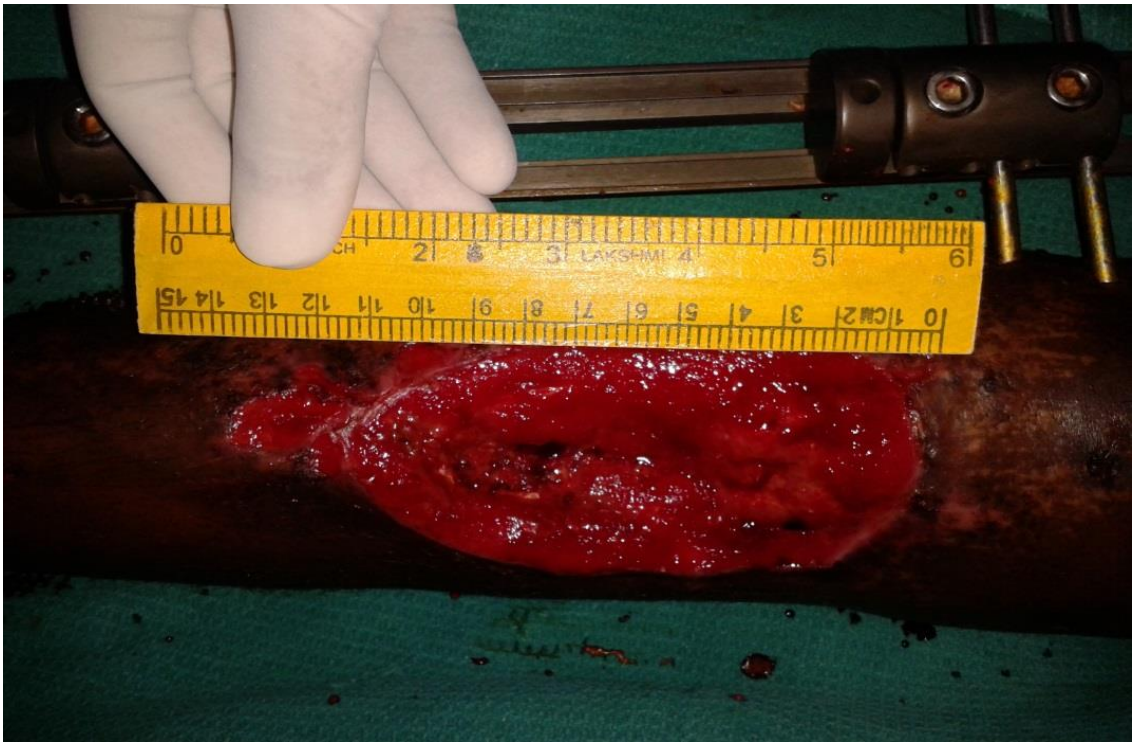
Spinal anesthesia was used in patients having injury in lower limbs and supraclavicular block was used in patients having injury in upper limbs only for debridement purpose and repeat dressings were applied without any anesthesia.

TECHNIQUE FOR APPLICATION OF VAC DRESSING

1. Debride the wound thoroughly and remove the necrosed tissue and foreign materials

2. Thorough wound wash is given and then a swab is taken for microbiological study(pus culture and sensitivity)

3. The wound size is measured and then the foam is cut according to size and shape of the wound. And then it is kept over the wound.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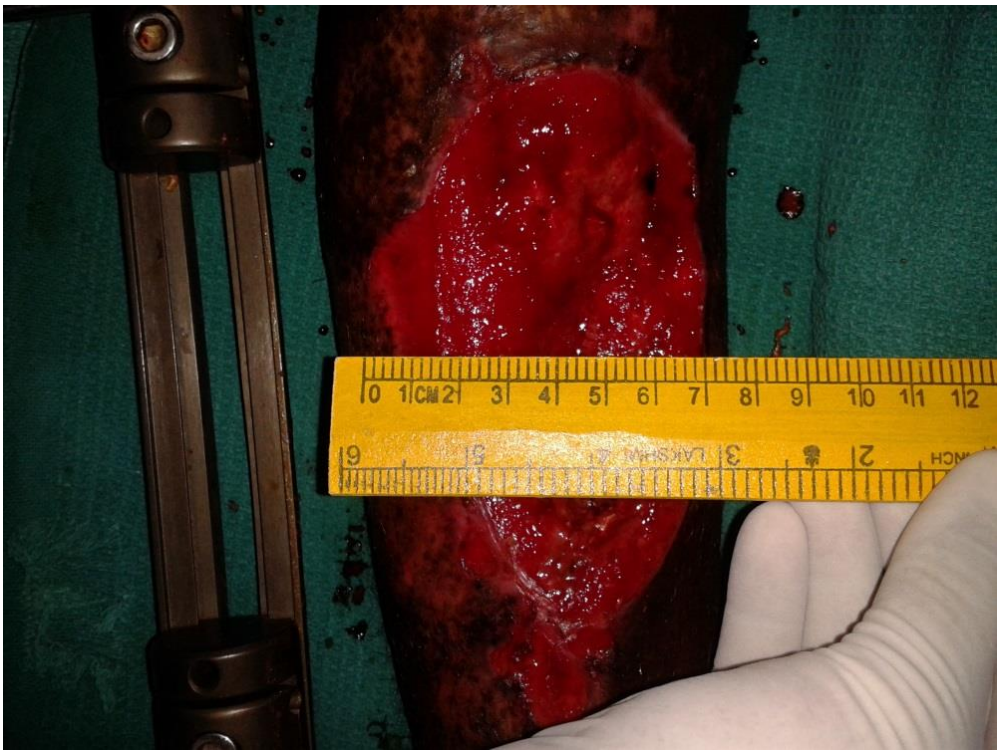
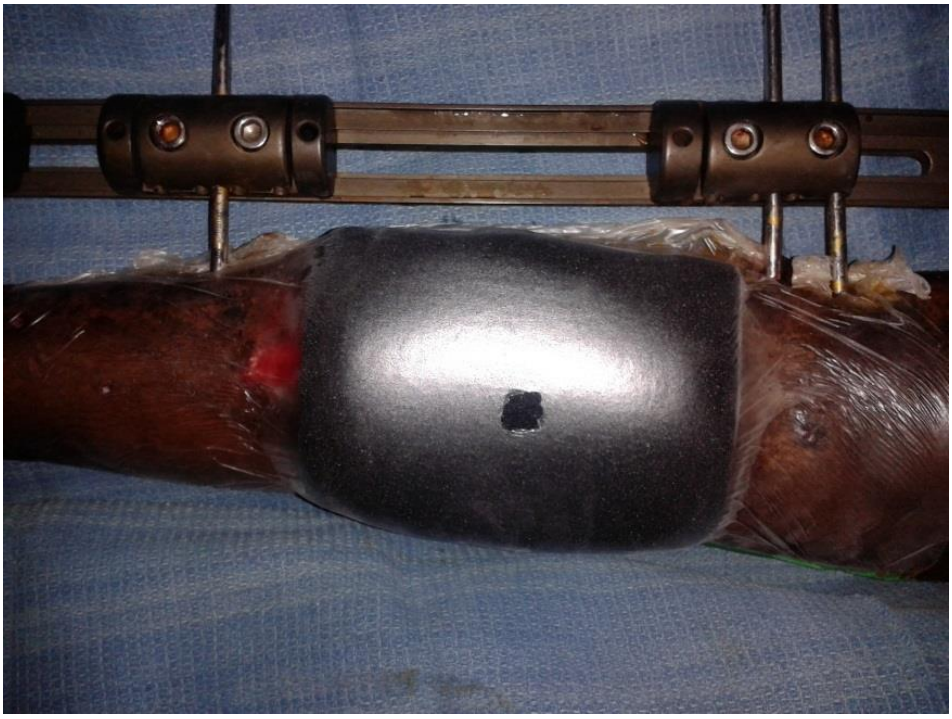
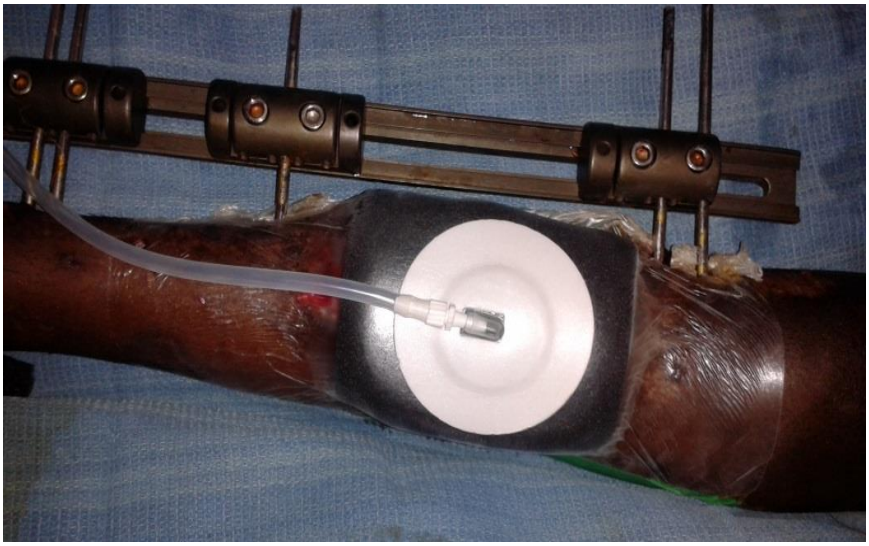
0 1CM 2 3 4 5





4. Then wound is completely covered using a sterile transparent opsite and a small hole is made in the centre of the sponge for the connecting tube.

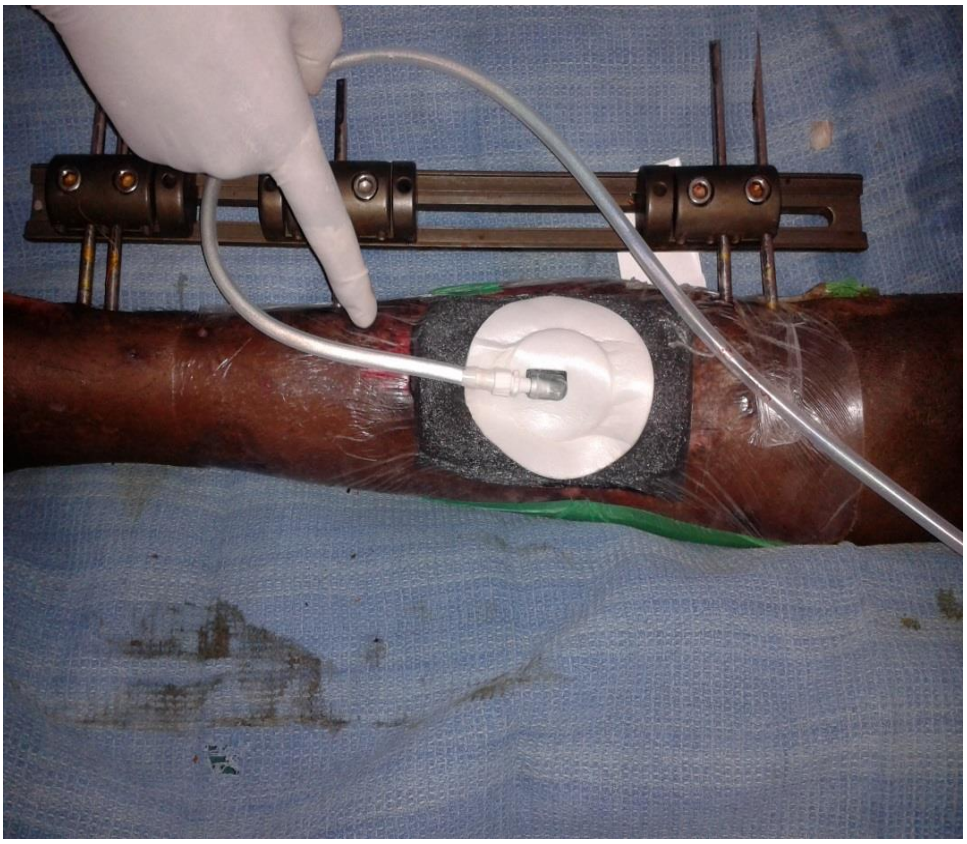
5. Insert the evacuation tube over the dressing and the other end of the tube is connected to a container which collects the edema fluid.



8. Connecting tube to the suction machine.

Connect the draining tube from the edema collecting container to to the suction machine.

9. Then Start up the VAC machine and watch it compress, The sponge will start contracting as the suction pressure is started.



10. The dressing was removed after 72 hrs and dressing was done again if necessary

Skin cover procedures

1. Split skin graft.
2. Flap cover.

Follow up of patients were done till definitive skin cover procedures.

RESULTS

Our study includes seventeen patients treated with VAC therapy. Mean age of the group is 40.5 years. The age group 30-50 dominates the series accounting for 44% among the cases. Gustilo Anderson compound grade III B fractures caused by road traffic accidents includes 14 cases (82.35%), train traffic accident 2 cases(11.76%) and accidental fall 1 case(5.88%).

The average duration of treatment was 10.5 days (9–12 days), and on an average the dressing change was 3.3 times. Infection rate. Among the non infected cases (14 cases) only one case showed infection and among the infected cases(3 cases) one case showed infection at the end of treatment for which additional wound debridement and appropriate antibiotics were given and later wound cover was done.

Duration of wound healing -Mean wound size reduction at treatment completion 15mm (10-20mm), . 15 patients among the 17 achieved good wound healing and the tendons which were exposed were adequately covered by granulation tissue. The mean duration required for formation of healthy uniform granulation bed was 10.5 days(9-12 days)

After VAC therapy, SSG was done to cover the healthy granulation tissue in 13 patients and flap cover was done for 4 patients.

In two patients infection was reduced and these wounds were thoroughly debrided and flap cover was done to cover exposed bone. Duration of hospital stay- as the patient load is very high in our institute the definitive management of the fractures was delayed and the average duration of hospital stay one and a half month(range 1month -2 months)

There were no complications in our study like bleeding overgrowth of granulation tissue over the foam or deep infections

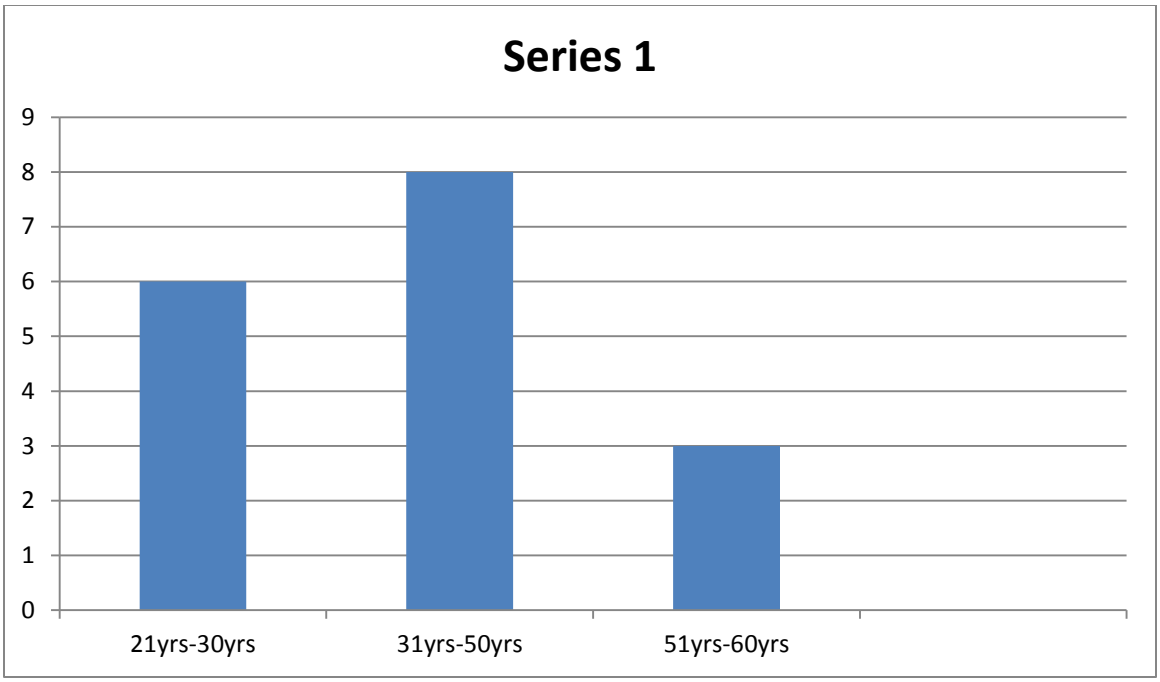
STATISTICAL ANALYSIS

DISTRIBUTION OF CASES BASED ON AGE

Table -1

SL.NO.	AGE in Years	Number of patients	%
1	21-30	6	35.29
2	31-50	8	47.05
3	51-60	3	17.64
	Total	17	100

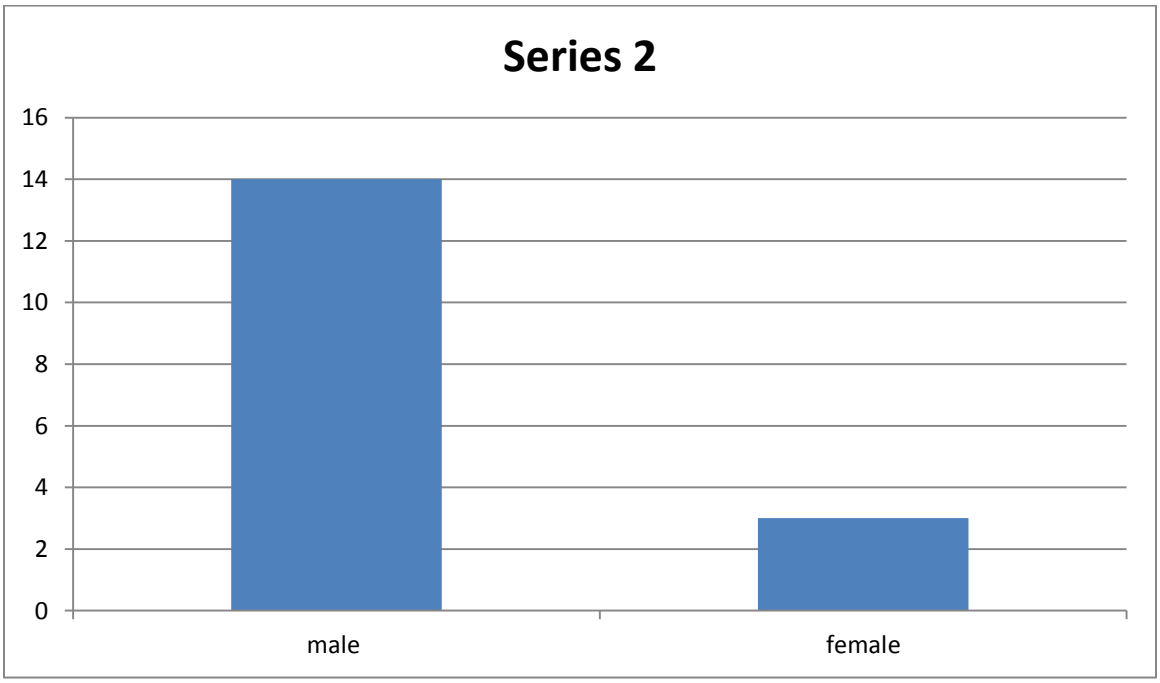
From the above table it is very clear that majority of cases occurred in 31-50 years age group correlating with common occurrence of RTA in that age.


Series 1
9
8
7
6
5
4
3
2
1
0
21yrs-30yrs
31yrs-50yrs
51yrs-60yrs

DISTRIBUTION BASED ON SEX

Table -2

Sl.no			
1	Male cases	14	82.35%
2	Female cases	3	17.64%
	Total	17	100%

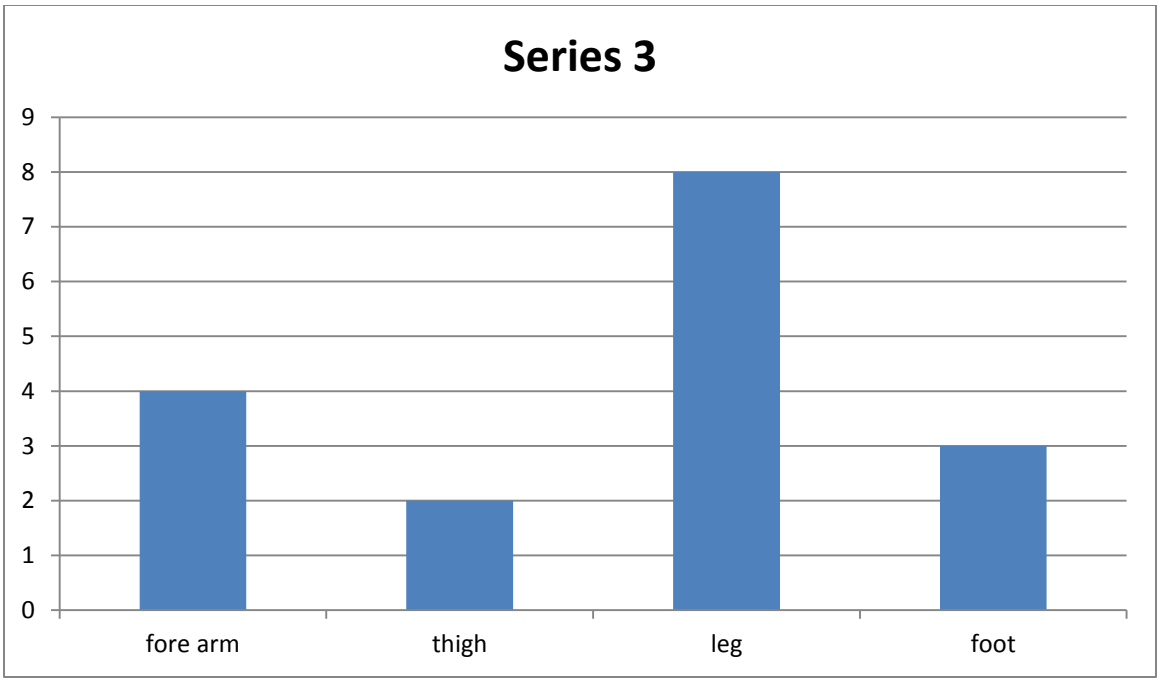


DISTRIBUTION BASED ON LOCATION OF INJURY

Table -3

Sl.no	Site	No. of cases	% of cases
1	Fore arm	4	23.52
2	Thigh	2	11.76
3	leg	8	47.05
4	foot	3	17.64
	Total	17	100

This table shows that gustilo Anderson compound grade IIIB fractures occurred in leg in 47.05% of patients.

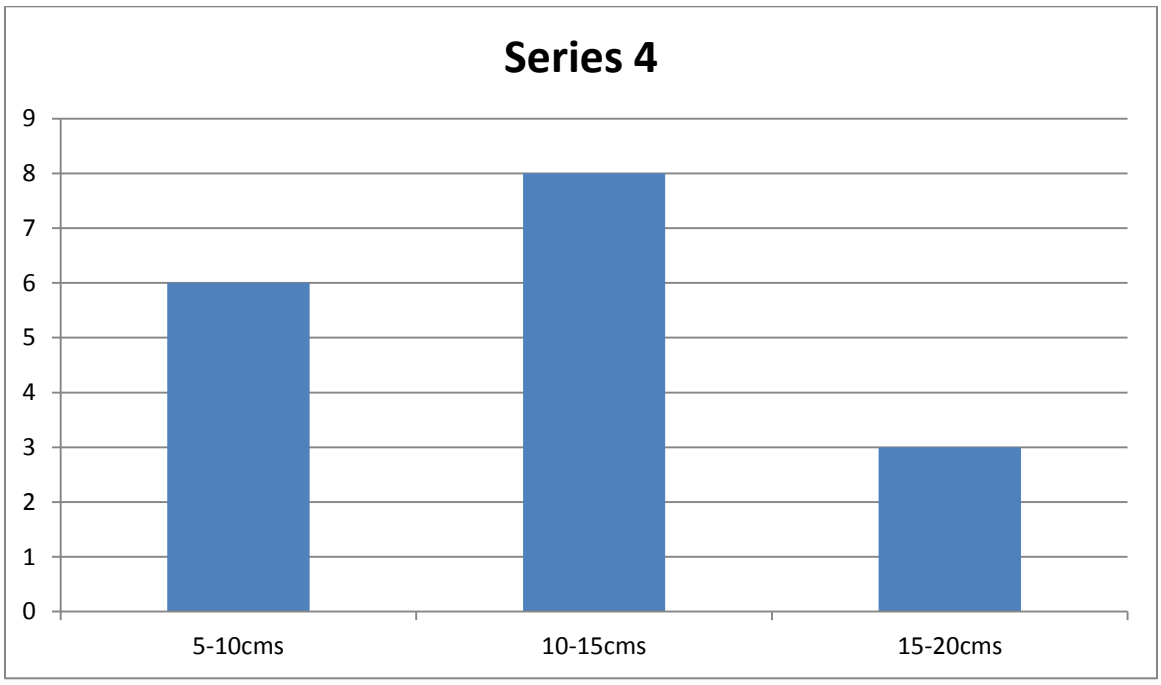

Series 3
9
8
7
6
5
4
3
2
1
0
fore arm
thigh
leg
foot

DISTRIBUTION BASED ON SIZE OF THE WOUND

Table -4

Sl.no	Size of the wound in cm	No. of cases	% of cases
1	5-10cms	6	35.29%
2	10-15cms	8	47.05%
3	15-20cms	3	17.64%
	total	17	100%

This table shows distribution of wounds based on the size of the wound



Open wound score (journal of orthopaedic surgery and research 2009 4:14)

Score 0 – skin and soft tissue intact

Score 1 – defect in the skin is present

Score 2 – one of the following is exposed in the wound bed

a-Bone,

b-tendon,or

c-implant

Score 3 – a combination of any two of the above are exposed

Score 4 – presence of deep infection

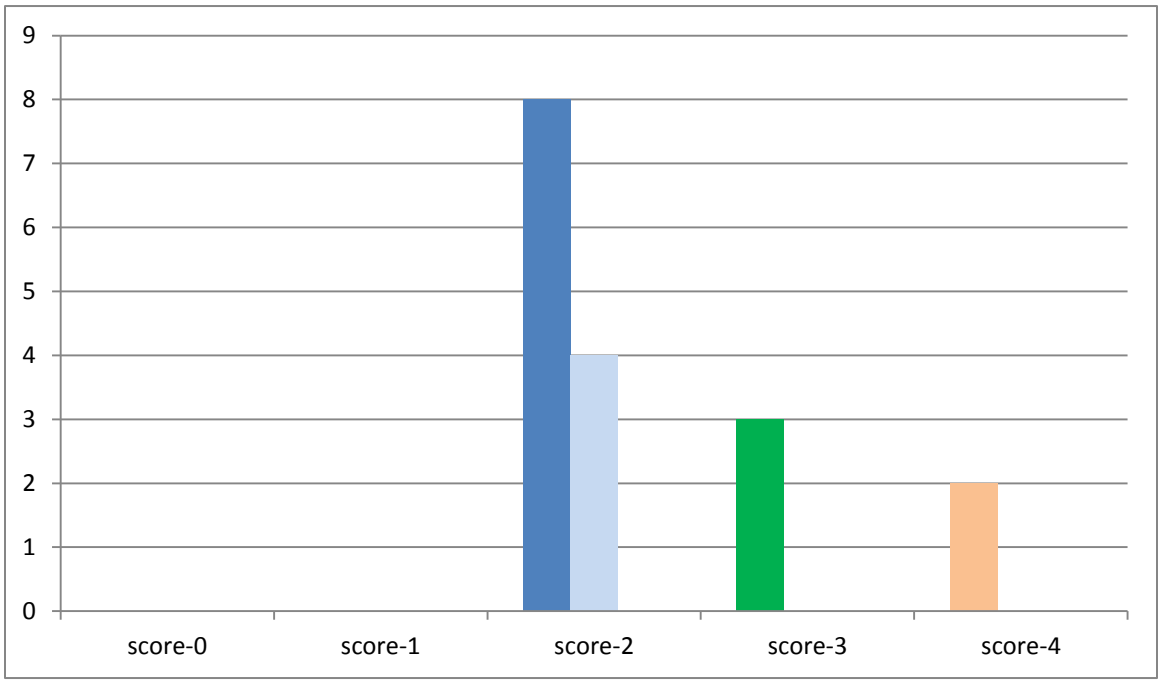
DISTRIBUTION BASED ON SCORING OF THE WOUND PRIOR TO VAC THERAPY

Table -5

Sl.no	Score of the wound	No. of cases	%
1	Score-0	0	0%
2	Score-1	0	0%
3	Score-2 Bone exposed Tendon exposed Implant exposed	 8 4 0	 47.05% 23.52 0%
4	Score-3 Bone+tendon exposed	 3	 17.64%
5	Score-4	2	11.76%
	Total	17	100%

Gustilo Anderson compound grade IIIB fractures are associated with bone exposure and tendons are also exposed in few cases depending on the site of the defect. Tendons are more commonly exposed in forearm.

Series-5



DISTRIBUTION BASED ON NUMBER OF DRESSINGS APPLIED

Sl.no	Score of the wound	No.of cases	No.of dressings
1	Score-0	0	0
2	Score-1	0	0
3	Score-2 Bone exposed Tendon exposed	 5+3 4	 3+4 3
4	Score-3 Bone+tendon	 3	 4
5	Score-4	2	4

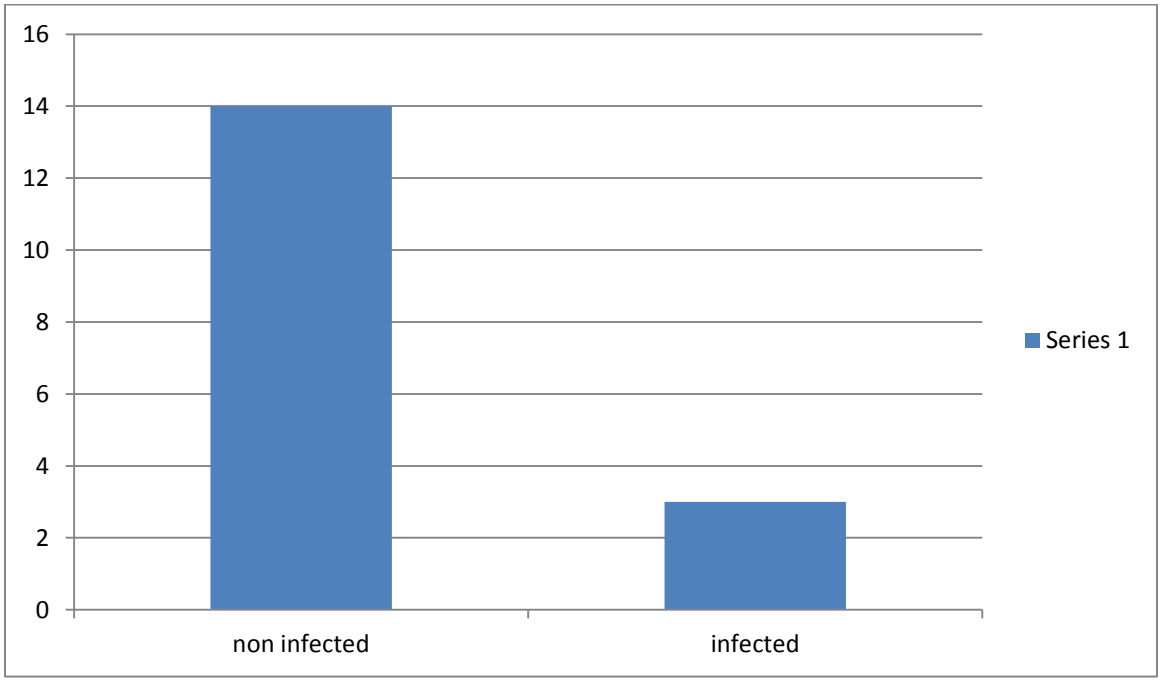
Five cases of bone exposed wounds required 3 dressing changes, three cases of bone exposed wounds required 4 dressing changes, four cases of tendon exposed wounds required 3 dressing changes, three cases of bone & tendon exposed wounds required 4 dressing changes, two cases with bone exposed and with superficial infection cases required 4 dressing changes.

DISTRIBUTION OF CASES BASED SUPERFICIAL INFECTION

Table-7

Sl.no		No. of cases	%
1	Non-Infected cases	14	82.35%
2	Infected cases	3	17.65%

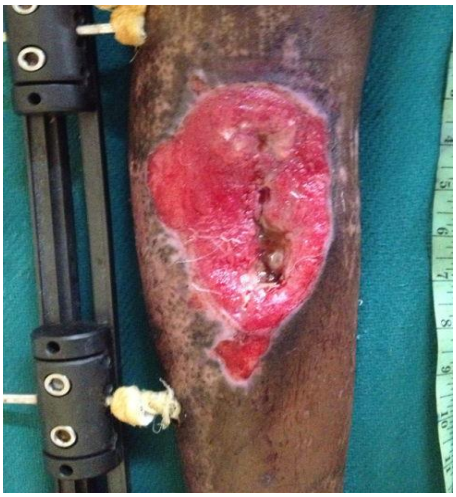
Series -7



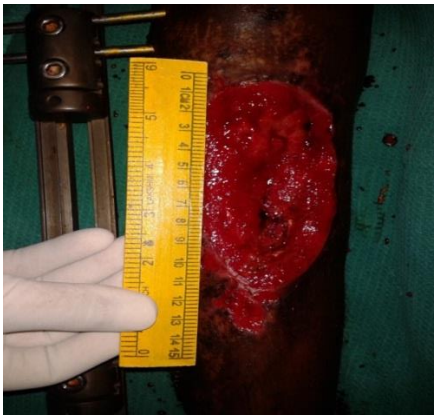
CASE ILLUSTRATIONS

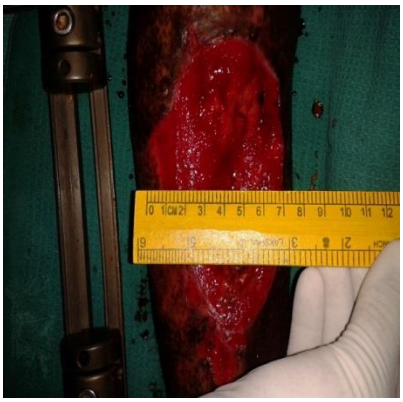
1.Mr Jagadeeshwaran , 25/M, Fracture both bones left leg compound grade IIIB

PREVAC STATUS

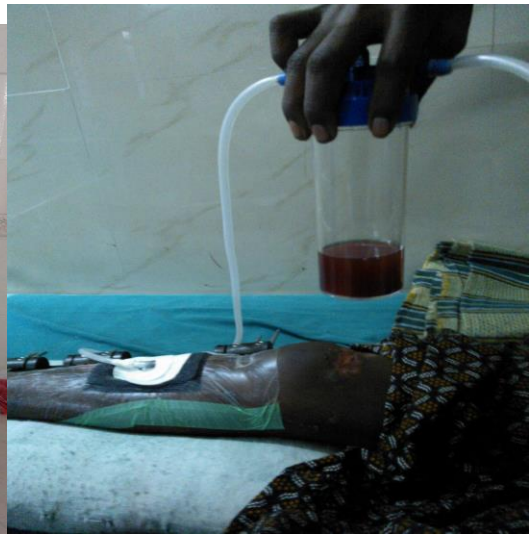


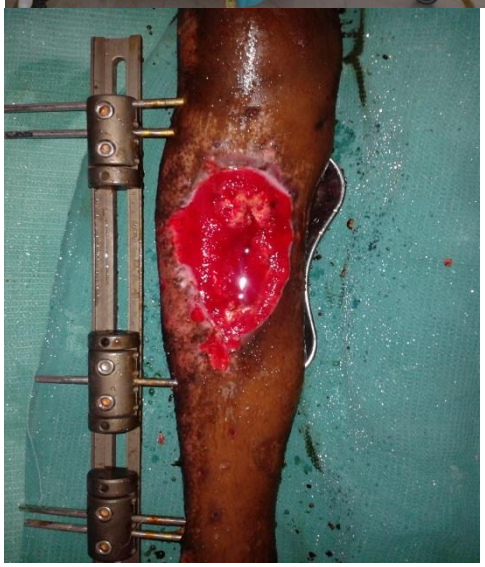
1ST DRESSING



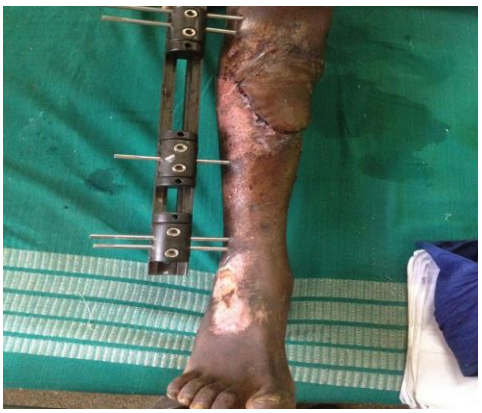


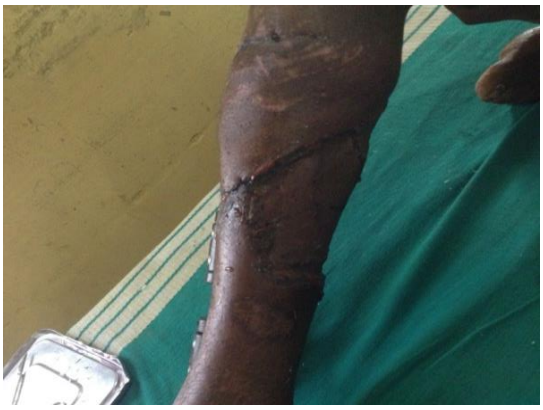
AFTER 2ND DRESSING

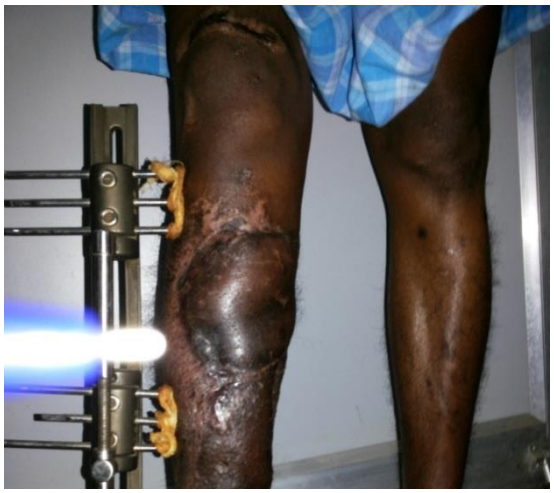




AFTER FLAP COVER

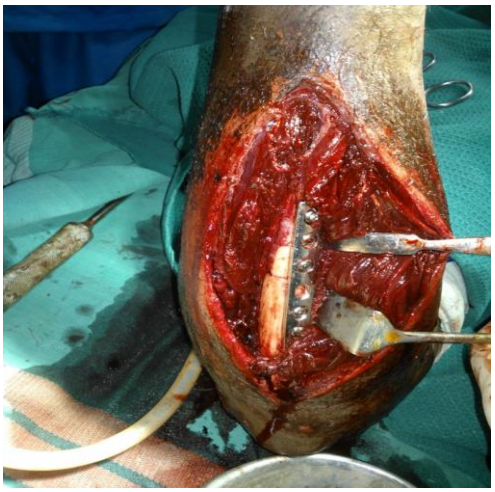


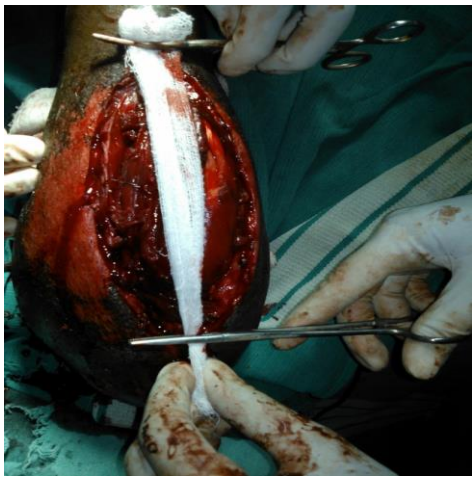


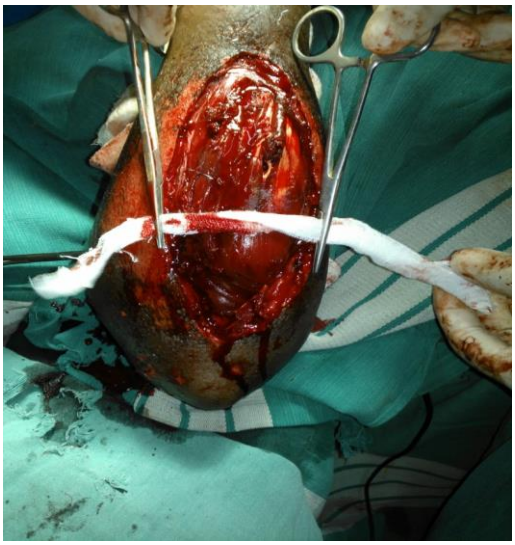


Case 2-Mr.Muneeswaran, 55/M, Fracture both bones right fore arm compound grade IIIB

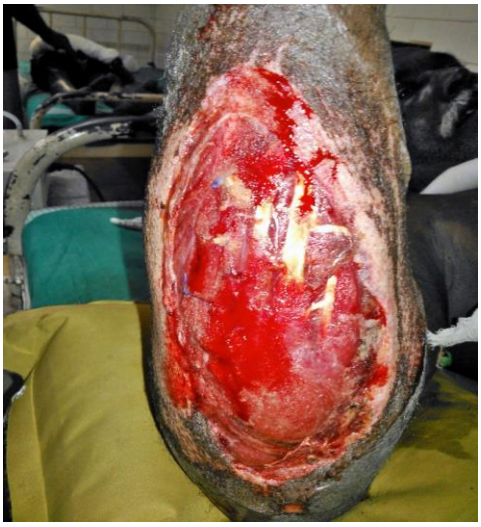
PRE VAC



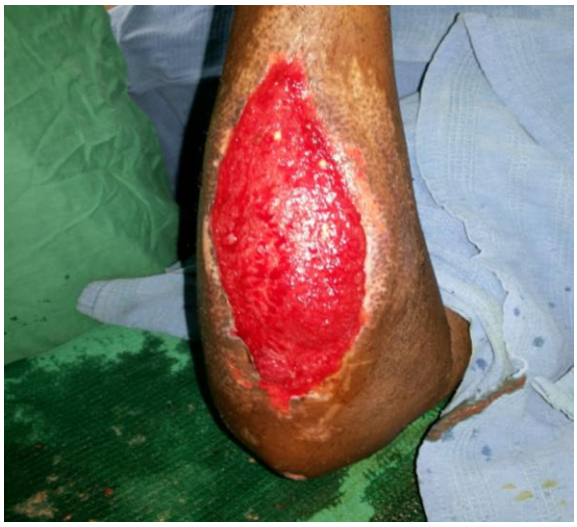




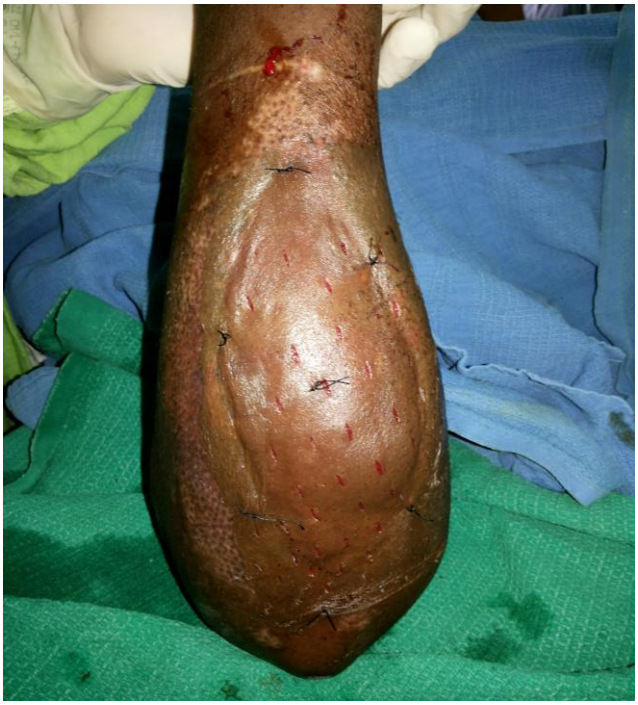
1ST DRESSING

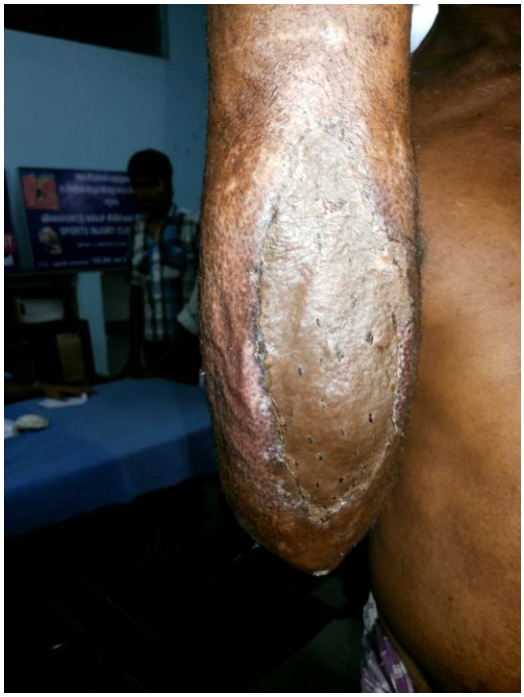


AFTER 3RD DRESSING



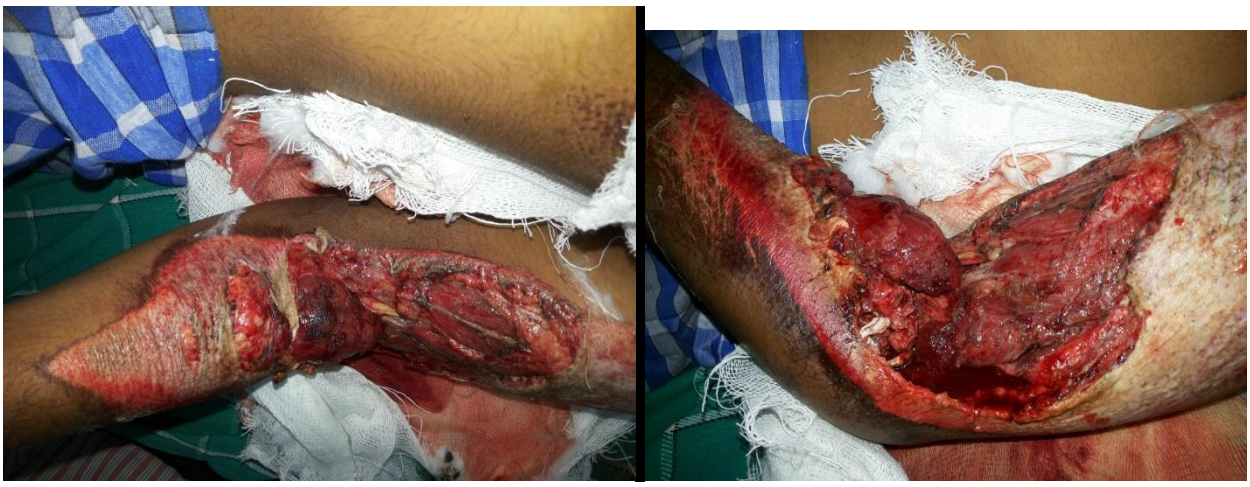
SPLIT SKIN COVER



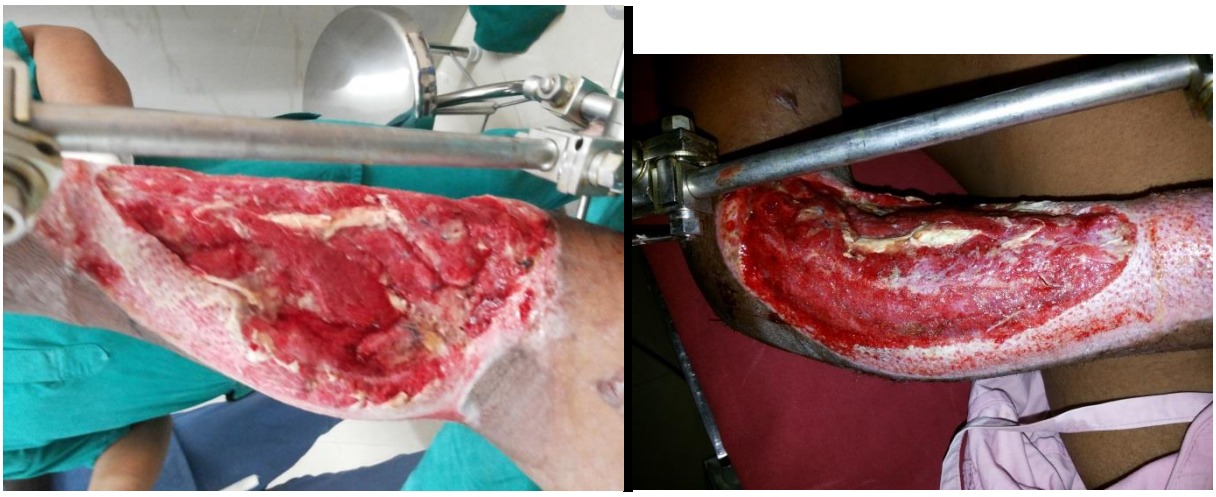


CASE 3,-Mr. Murugan 36/M, Galeazzi fracture dislocation compound grade IIIB

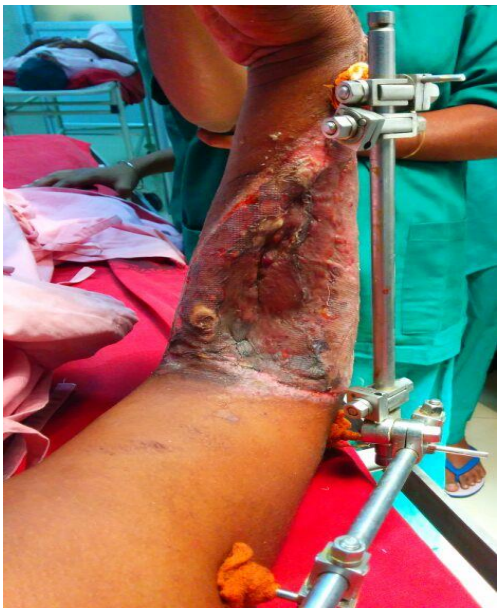
PRE VAC



AFTER 2ND DRESSING

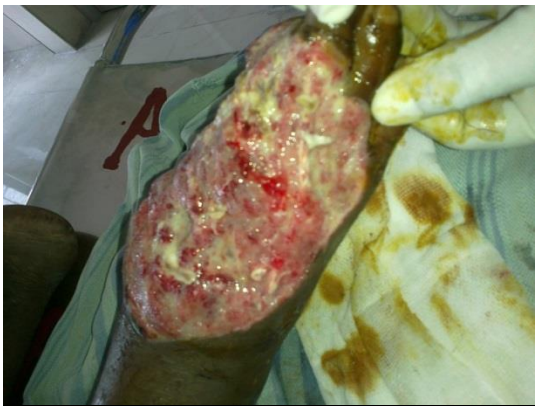


AFTER SPLIT SKIN GRAFT

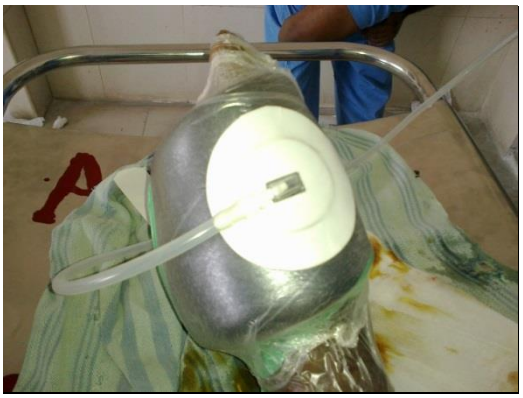


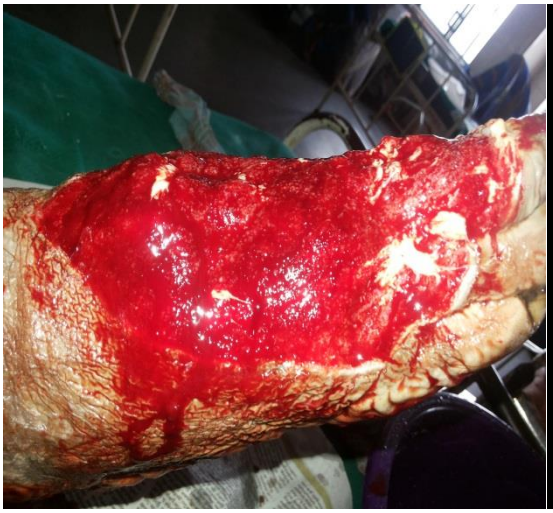
CASE-4, Mr.Mookan, 57/M Crush Injury Foot Left side

PRE VAC

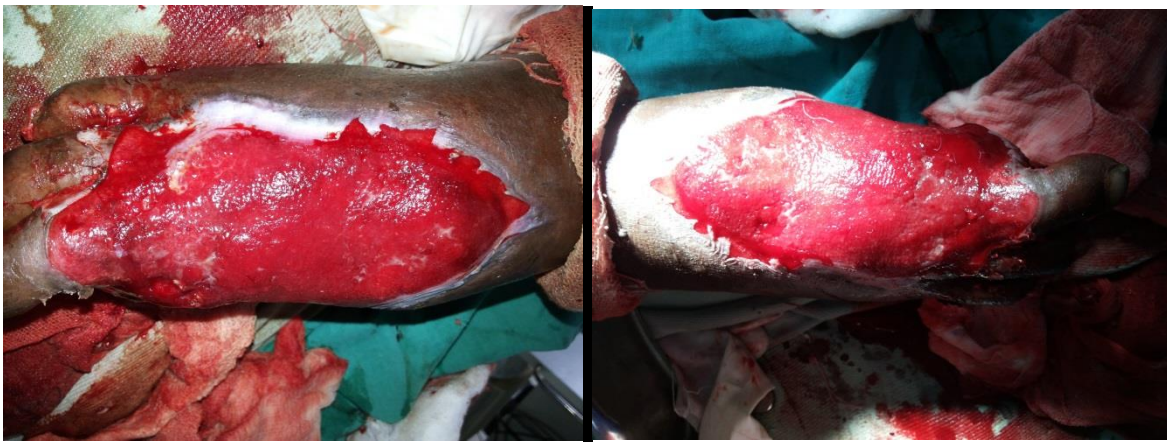


1ST DRESSING

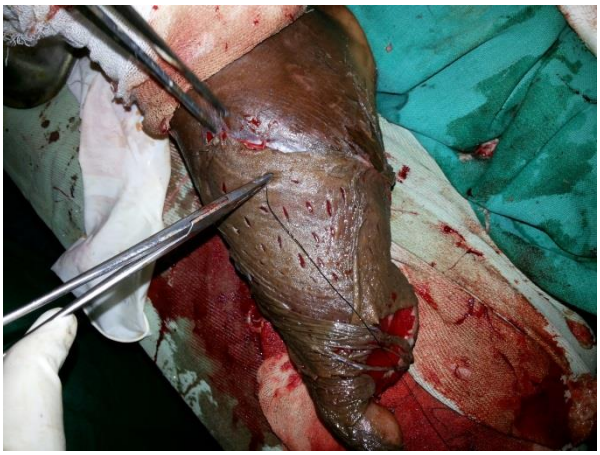


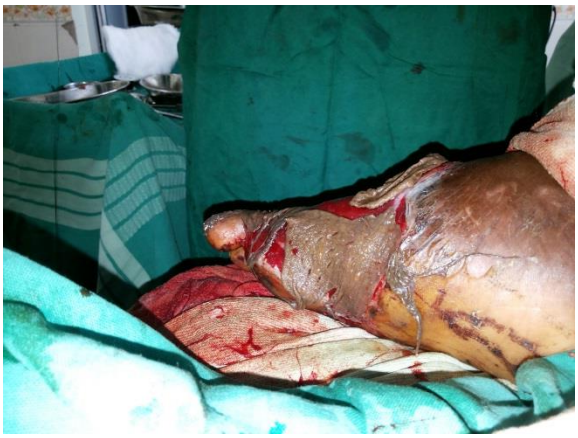


AFTER 4TH DRESSING



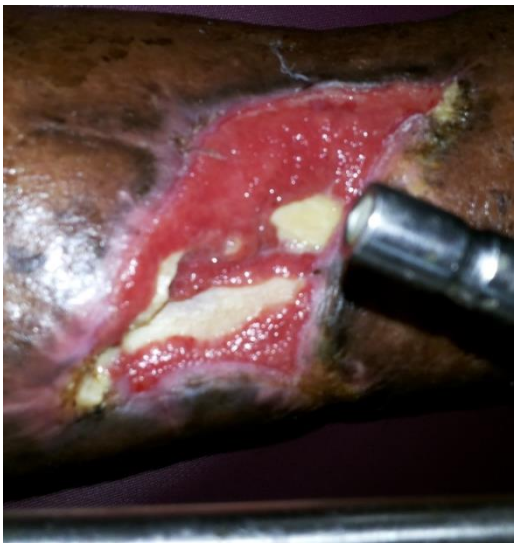
AFTER SPLIT SKIN GRAFT



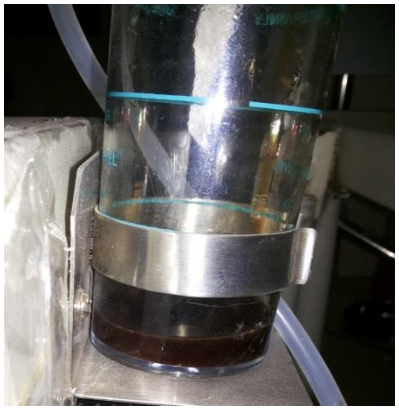


CASE 5-Mr. Senthil Pandi, 60/M, Fracture tibial plateau schatzkar type VI compound grade IIIB

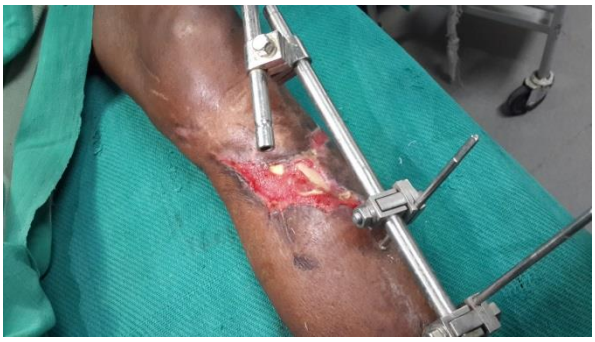
PRE VAC



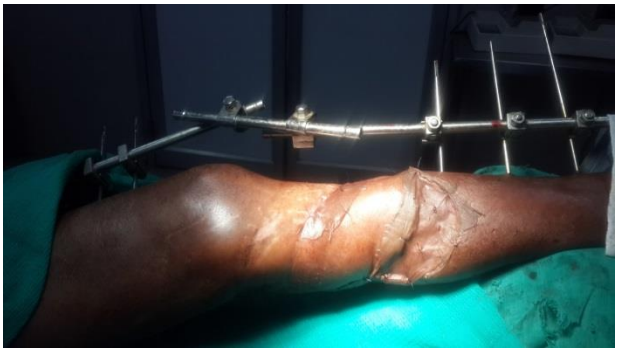
1ST DRESSING

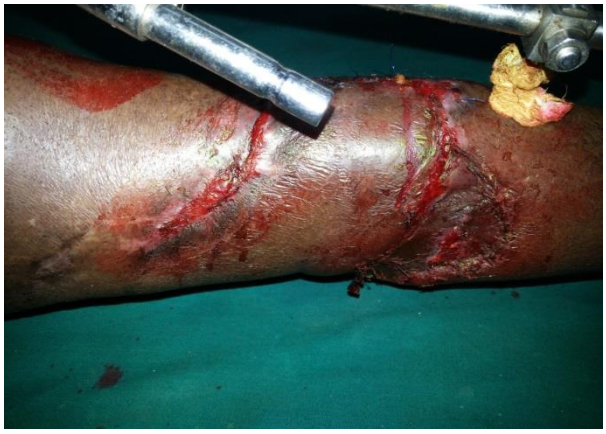


AFTER 2ND DRESSING



AFTER FLAP COVER





DISCUSSION

Management of soft tissue plays a very important role in Gustilo Anderson compound fractures[26]. Many factors play a coordinated role in wound healing like the wound environment the composition of the wound which includes physical characters of the wound, chemical composition of the wound, biological structure of the the wound[35] etc. all these play a important role in the healing.

The goals of soft tissue management are

1. Controlling bleeding.
2. New granulation tissue should replace the soft tissue defects.
3. The soft tissue defect should be covered by SSG or flap cover as soon as possible.

Many factors affect the wound healing like[7]

1. Defect in vascular supply.
2. Defect in angiogenesis.
3. Defect in laying matrix proteins.
4. Defect in locally acting growth factors.
5. Defects in clearing the dead and necrotic cells.
6. Defect in migration of macrophages and their composition.

7. Defect in enzymes which lyse the defective cells.
8. Defect in production of new proteins for the wound.

Any of these factors or a combination of these factors affect the wound healing and the wound goes into a stage of chronic non healing. After applying VAC therapy the negative force causes more blood circulation to the wound, reduces the burden of bacterial infection and supplies more oxygen to the affected soft tissue.

Rate of infection- In our study rate of infection was 11.76% and we compared our result with the following literature study where the soft tissue injuries were managed by saline dressings[36]- Henley et al, JOT 1998- 34.7%[27]., Charalambous et al, Injury 2005-27%[28]., Gopal et al JBJS-B 2004-27.4%[29]

Duration required for forming new healthy granulation bed.

In our study an average of 10.5 days was taken for formation of a uniform healthy granulation bed of the wound. Similar studies were conducted by Argenta et al., Morykwas et al[14]., & Joseph et al[30],.& these studies also showed that VAC

proved effective in shrinking of the diameter of the wound size and formation of healthy granulation tissue when compared to normal saline dressing methods.

Microscopically application of VAC therapy also showed increase in formation of new blood vessels and formation matrix tissue but the wounds treated by saline dressing showed inflammatory tissue & fibrous tissues as compared by above studies.

The uniform negative pressure delivered by the VAC therapy to the wound bed plays a significant role in formation of new healthy granulation tissue.

In normal saline dressings the gauze pad sticks to the dead tissue and while changing the dressings the dead tissue along with the new and delicate tissue formed underneath is also removed along with the gauze pad and this causes mechanical damage to the formation of new granulation tissue in the wound bed.

Duration of hospital stay- As the patient load was very high and availability of OT is limited in our institution the definitive management like split skin grafting, flap cover and fixation of the fractures was delayed and hence the duration of hospital stay was prolonged inn our study.

Studies on application of VAC therapy on compound fractures is very less. And these compound fractures have high chances of going in for non union and secondary infection if they are not adequately treated. These wounds should be

thoroughly debrided and skin cover should be given as soon as possible as the exposed bones, tendons & neurovascular structures should be covered as soon as possible to save these structures from infection.

The high cost of vacuum system and the cost of vacuum dressing has discouraged many doctors from its application but when compared with saline dressings which take longer duration for wound healing, more number of debridement & more number of days of absence from work when all these factors are compared with expense of VAC the treatment expense of VAC is lesser with also lesser morbidity to the patient. And lesser hospital stay and the hospital beds can be used for other patients[31,37].

VAC therapy has wide range of benefits it can be applied to most of the wounds but all wounds cannot be treated by VAC therapy. VAC causes bone exposed wound to be covered by granulation tissue which requires a simple split skin graft to cover the granulation tissue where as the bone exposed area needs a more time consuming and more expertized flap cover for covering the wound.

Limitations –

-The study is non randomized.

-Our sample size is small and the mean follow up period is short.

-Definitive management of the wound like SSG and flap cover is done by different surgeons.

CONCLUSION

The following conclusion were drawn from our study

1. The rate of wound infection was significantly reduced.
2. The time duration taken for formation of healthy granulation tissue was less.
3. The wound was fit for definitive skin cover procedures like SSG & flap cover at a faster rate.
4. The number of debridement of the wound were reduced.
5. The granulation tissue formed was healthy and uniform.
6. Soft tissue defects which lead to ugly and irregular surface was avoided by forming uniform granulation tissue and the defects were covered.
7. Technical difficulties are present in applying vac dressing in presence of external fixator but it was overcome by realignment of fixator.

ANNEXURE-I

PROFORMA

BASIC DETAILS ABOUT PATIENTS

Name	
Age/Sex	
Unit/IP No.	
DOA	
DOS	
DOD	
Address/ phone number	

Specific details about injury

Site of wound	
Size of wound	
Infection status	
Bone exposed or not	
Tendons exposed or not	

Neurovascular structures exposed or not	
Grading of the wound before application of vac	
Number of dressings done	
Number of days required for growth of healthy granulation tissue	
Grading of the wound after application of vac therapy	
Number of days of hospital stay	
Definitive skin cover procedures	
Any complications	

ANNEXURE II- ETHICAL COMMITTEE APPROVAL

COPY

ANNEXURE III- ANTI PLIAGARISM CERTIFICATE

ANNEXURE IV- COLLABORATION DEPARTMENT APPROVAL

CERTIFICATE

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MASTER CHART

No	Age	Sex	Injury	Site	Wound grade (before)	Wound grade (after)	Size Reduction in mm	Duration in days	Additional procedures	Compli cations
1	43	M	RTA	Leg	2	1	11	9	SSG	-
2	35	M	RTA	Foot	2	1	13	9	SSG	-
3	42	M	RTA	Leg	2	1	12	9	SSG	-
4	29	M	RTA	Thigh	2	1	14	9	SSG	-
5	25	F	TTA	Leg	2	1	11	9	SSG	-
6	47	M	Fall	Fore arm	2	1	19	9	SSG	-
7	51	M	RTA	Leg	4	2	18	12	Flap cover	-
8	24	F	RTA	Leg	2	1	13	9	SSG	-
9	46	M	RTA	Foot	3	2	19	9	Flap coveer	-
10	57	M	RTA	Fore arm	2	1	18	9	SSG	-
11	28	M	TTA	Thigh	2	1	14	9	SSG	-
12	39	M	RTA	Leg	3	2	12	9	SSG	-
13	44	F	RTA	Leg	2	1	10	9	SSG	-
14	25	M	RTA	Fore arm	4	1	18	12	SSG	-
15	35	M	RTA	Leg	2	1	10	9	SSG	-
16	21	M	RTA	Fore arm	3	2	17	9	SSG	-
17	52	M	RTA	Foot	2	1	10	9	SSG	-