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VAC – Prospective Study of Management of Open Wounds in Compound Fractures

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Abstract: *A wound is defined as an injury creating a disruption in the normal anatomical structure and function of the skin. There are two different types of wounds: vulnus that is an acute wound, which heals according to the normal wound healing process, and ulcus that is defined as hard-to-heal wounds (previously labeled chronic wounds) such as leg ulcers, pressure ulcers and diabetic foot ulcer. These wounds have duration of more than six weeks and often show a disturbed wound healing process due to underlying causes other than direct trauma.*

MATERIALS AND METHODS

This is a prospective study. Source of study were the 40 Cases satisfying the inclusion criteria admitted in KIMS, Hubli during the study period of November 2016 to October 2018.

RESULTS

40 patients visiting KIMS hospital with open fractures of Guistilo Anderson grade 3B.Wounds were initially debrided and vacuum assisted dressing applied. Wounds were assessed depending on wound size and score before and after the application of VAC and the number of VAC settings required for uniform healthy granulation tissue formation was noted. VAC Increases the local blood flow to the wound. It considerably decreases the bacterial load of the wound and thus wound infection. VAC maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis. Negative pressure wound therapy Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing. VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the 'reconstructive ladder' when applied as a temporary dressing to acute open fractures.

CONCLUSION

The conclusions drawn from our study, Guistilo Anderson type 3 B open fractures were most commonly caused by road traffic accidents. Males were more prone than females. The most common bone involved, Vacuum assisted closure therapy appears to be a viable adjunct for the treatment of open musculoskeletal injuries, Application of sub atmospheric pressure after the initial debridement to the wounds results in an increase in local functional blood perfusion, an accelerated rate of granulation tissue formation, and decrease in tissue bacterial levels. The granulation tissue formed was healthy and uniform.

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I. Introduction / Back Ground

A wound is defined as an injury creating a disruption in the normal anatomical structure and function of the skin. There are two different types of wounds: vulnus that is an acute wound, which heals according to the normal wound healing process, and ulcus that is defined as hard-to-heal wounds (previously labeled chronic wounds) such as leg ulcers, pressure ulcers and diabetic foot ulcer. These wounds have duration of more than six weeks and often show a disturbed wound healing process due to underlying causes other than direct trauma.

The classic model of normal wound healing is divided into three sequential, yet overlapping, phases: inflammatory, proliferative and remodeling. However, this process can easily be interrupted due to several inhibiting factors such as smoking, ischemia in the tissue, diabetes and infections, leading to the formation of a hard-to- heal wound, by definition wounds that have failed to heal within six weeks.

Wounds may heal by three principles: primary, secondary or tertiary healing. Primary healing occurs when the wound edges are put together, often with sutures, and healing occurs with minimal tissue defects. Secondary healing occurs in open wounds, when the wound edges are not put together and healing occurs with formation of granulation tissue. Tertiary healing is delayed primary healing and occurs when a wound is allowed to heal openly for a few days and then is closed with secondary sutures as if primarily.

BRIEF HISTORY OF WOUND HEALING

The concept of recorded wound care goes back to circa 2200 BC, when "three healing gestures" were chiselled into the famous Sumerian clay tablet: washing the wound with beer and hot water, making plasters (mixtures of herbs, ointments, and oils), and bandaging the wound.

Ancient Egyptian treatment for open wounds using a paste of grease, honey and lint, is documented in papyruses dating back to 1400 BC. Hippocrates (*circa* 400 BC) detailed the importance of draining pus from the wound, and Galen described the principle of first and second intention healing.

The earliest accounts of wound healing date back to about 2000 B.C., when the Sumerians employed two modes of treatment: a spiritual method consisting of incantations and a physical method of applying poultice like materials to the wound. The Egyptians were the first to differentiate between infected and diseased wounds compared to non infected wounds. The 1650 B.C. Edwin Smith Surgical Papyrus, a copy of a much older document, describes at least 48 different types of wounds. Ebers Papyrus, (fig 1) 1550 B.C., relates the use of concoctions containing honey (antibacterial properties), lint (absorbent properties), and grease (barrier) for treating wounds.

The Greeks, classified wounds as acute or chronic in nature. Galen of Pergamum (120 – 201 A.D.,), appointed as the doctors to the Roman gladiators, emphasized the importance of maintaining a moist environment to adequate healing. It was shown later that epithelialization rate increases by 50 % in a moist wound environment when compared to a dry wound environment.

Antisepsis was championed by Ignaz Semmelweiss (1818 - 1865) who noticed that the incidence of puerperal fever was much lower if medical students, after cadaver-dissection class and before attending childbirth, washed their hands with soap and hypochlorite. Louis Pasteur (1822 – 1895) was instrumental in dispelling the theory of spontaneous generation of germs and proving that germs were always introduced into the wound from the environment.

Joseph Lister (1827-1912) probably made one of the most significant contribution to wound healing. He is credited as developing the first antiseptic dressing in 1867 by soaking lint and gauze in carbolic acid.[7] Lister noted that water from pipes that were dumping waste containing carbolic acid (phenol) was clear. In 1865, Lister began soaking his instruments in phenol and spraying the operative rooms, reducing the mortality rates from 50 to 15%. After attending an impressive lecture by Lister in 1876, Robert Wood Johnson (American industrialist and co-founder of company Johnson & Johnson)began 10 years of research that ultimately resulted in the mass production of an antiseptic dressing in the form of cotton gauze impregnated with iodoform.

Polymeric dressings were developed in the 1960s and 1970s.[3] The discovery of cytokines and growth factors in the 1950s opened a new age in wound healing research. The original description of negative pressure-assisted wound therapy (NPWT) was presented by Argenta and associates in 1997.

PHASES OF WOUND HEALING

Wound healing (fig 2) has traditionally been divided into three distinct phases:

- Phase of Preparation or Phase of Inflammation : *Hemostasis And Inflammation (Immediately upon injury through Day 4 to Day 6)* Wounding by definition disrupts tissue integrity, leading to division of blood vessels and direct exposure of extracellular matrix to platelets.[8]
- Phase of Proliferation: *Angiogenesis Provisional and Matrix Formation. Epithelization (Day 4 Through Day 14)*Fibroblasts and Endothelial cells are the predominant cells proliferating during this phase. Fibroblasts migrate into the wound site from the surrounding tissue become activated and begin to proliferate. The fibroblast is the surgeon's cell arriving in the scene to synthesize the collagen and ground substance of wound repair.
- Phase of Maturation or Phase of Re modeling:

- **<u>Vacuum-assisted closure (VAC):</u>**
- Vacuum-assisted closure (VAC) is a simple but effective method to promote rapid wound-healing. In recent years it has been shown to be an effective therapy for the management of large, complex, acute wounds as well as chronic wounds that have failed to heal by conventional methods (Joseph et al, 2000).

- Vacuum-assisted closure is an active wound therapy rather than a wound dressing. First described by Morykwas and Argenta (1997), the VAC system applies a sub atmospheric, or negative, pressure to the wound bed via an open-cell polyurethane foam dressing.
- The foam acts as the wound contact material and fills the wound. It is then connected via a suction tube to a canister, which fits on the side of the vacuum pump unit. The whole system is reliant on there being an effective seal around the dressing and this is achieved using the VAC semi-permeable film drape.

Once the seal has been obtained, the pump can be set to deliver continuous or intermittent pressures, ranging from 50mmHg to 200mmHg. The normal therapeutic level is 125mmHg, but this may be reduced if the wound is particularly painful. An intermittent regime normally follows a seven-minute cycle of two minutes off and fThe foam dressing is usually changed between days two and five, depending on the speed of tissue growth. If granulation is rapid the length of time between changes should be reduced to prevent adherence to the wound bed. The open-cell polyurethane foam dressing enables equal distribution of the negative pressure over the whole wound bed. It also allows exudate to flow freely for collection and removal in the canister. The foam can be used to pack open cavity wounds and can also be cut to size to fill undermining areas. The pore size of the VAC foam dressings differs from other foam dressings in that the pores are larger to maximise tissue growth (Morykwas et al, 1997). Therefore, it is important to use only the VAC foam dressing with the VAC pump.

Objectives of VAC

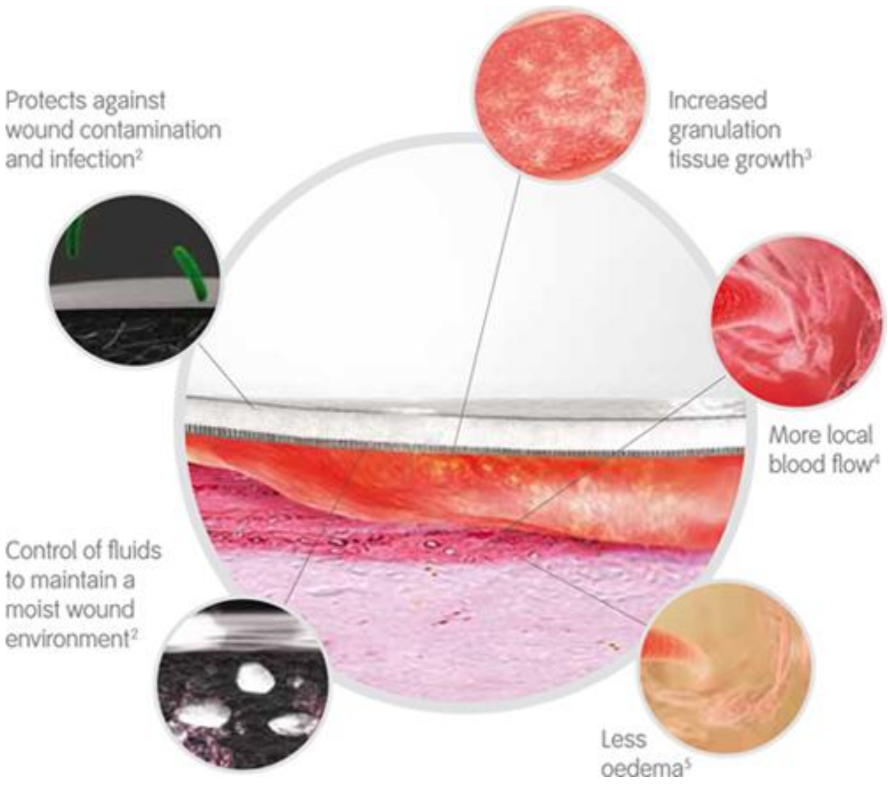
Applying negative pressure to the wound bed via the VAC pump achieves three main objectives:

- It removes excess exudate and promotes a moist, rather than wet, wound-healing environment. It also reduces oedema in the surrounding tissues that, if left, can impair wound-healing by reducing localised blood flow (Joseph et al, 2000);

- It promotes granulation tissue through increased angiogenesis (Morykwas et al, 1997);

- It reduces bacterial count at the wound bed.

In animal studies, blood flow level to the wound bed increased four-fold when 125mmHg subatmospheric pressure was applied (Morykwas et al, 1997). Granulation tissue formation was increased by approximately 64% on 125mmHg continuous pressure, and 103% on 125mmHg intermittent pressure when compared to standard wound management (Morykwas et al, 1997).



Mechanism of VAC

INDICATIONS

Almost any type of wound can be treated with VAC, provided that a seal can be obtained and maintained during therapy. VAC can be used successfully on the following wound types:

- Pressure ulcers;
- Diabetic foot ulcers;
- Acute/trauma wounds;
- Burns;
- Leg ulcers;
- Dehisced surgical wounds;
- Postoperative mediastinitis (Catarino et al, 2000).

Contraindications and precautions

Because VAC therapy increases cell generation and applies suction to the wound bed, it is contraindicated in known or suspected malignant wounds, in wounds with a fistula present or in untreated osteomyelitis. Similarly, the exposure of large blood vessels at the wound site would negate its use owing to the increased risk of bleeding (KCI, 1999).

Presence of a thick, necrotic eschar is a contraindication for VAC therapy, as the wound ideally needs to be clean before application. The VAC system is not able to debride large amounts of devitalised tissue, although it can cope adequately with small amounts of soft slough at the wound base (KCI, 1999).

Although not a contraindication for VAC therapy, extra care should be taken with patients who are likely to experience bleeding problems. These include patients on long-term anticoagulant therapy or those with haemophilia or haemoglobinopathies, such as sickle cell disease. These patients require more careful observation and may require lower pressure settings.

Gustilo Anderson classification[42]

• 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

II. Materials And Methods

This is a prospective study. Source of study were the 40 Cases satisfying the inclusion criteria admitted in KIMS, Hubli during the study period of November 2016 to October 2018.

- **Inclusion criteria:**

1) Patients with Gustilo Andersontype 3B Open fractures, where primary closure is not possible.

- **Exclusion criteria:**

1) Pathological fractures with untreated osteomyelitis.
2) Presence of a thick, necrotic eschar in wound.
3) Patients with hemophilia or haemoglobinopathies.
4) Open fractures that could be primarily closed in initial surgery without requiring flap or split skin grafting.

Method of applying VAC dressing:
SEQUENCE OF PROCEDURE:

1. Wound Preparation:

Any dressings from the wound are removed and discarded. A culture swab for microbiology should be taken before wound irrigation with normal saline. Surface slough or necrotic tissue are surgically debrided and adequate hemostasis achieved. Prior to application of the drape, the peri-wound skin is prepared and ensured that it is dry. Sharp edges or bone fragments eliminated from wound area or covered.

2. Placement of Foam. fig 17:

Sterile, open-cell foam dressing is gently placed into the wound cavity. Fenestrated evacuation tube is embedded in the foam which is connected to a computer-controlled vacuum pump that contains a fluid collection canister.

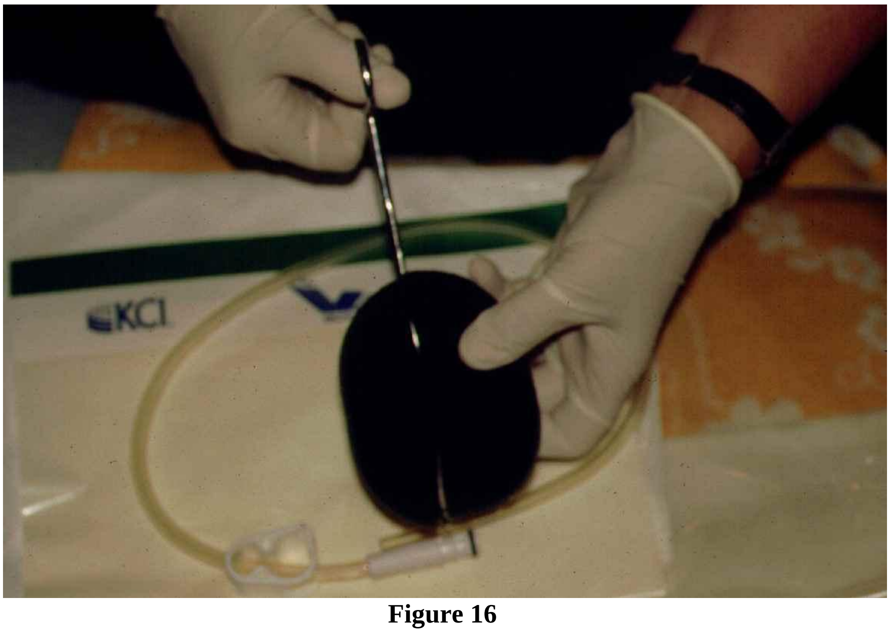


Figure 16

Figure 17

3. Sealing with Drapes. Fig 18:

The site is then sealed with an adhesive drape. (Opsite). Drapes cover the foam and tubing and at least three to five centimeters of surrounding healthy tissue to ensure a seal.

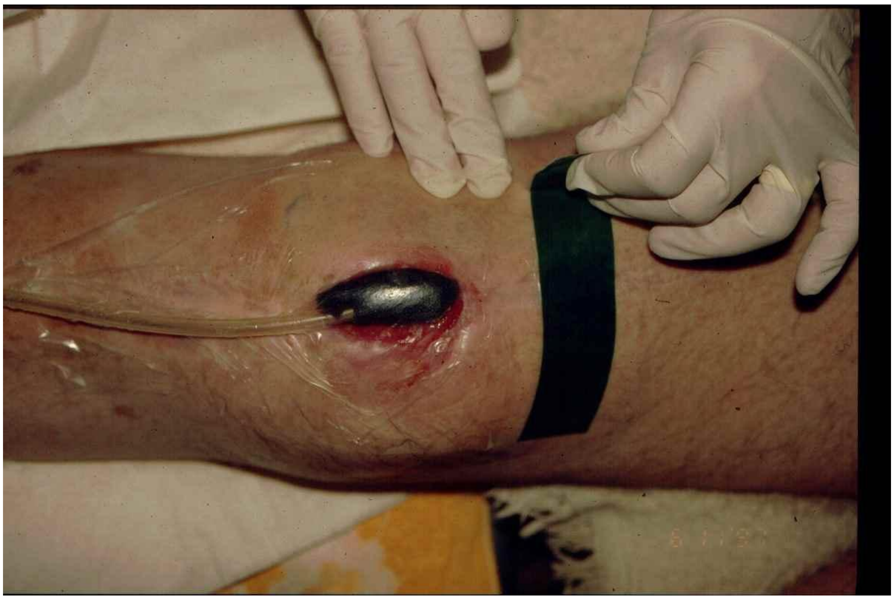


Figure 18

ORTHOPEDIC HARDWARE:

The V.A.C. Dressing can be placed on wounds with orthopedic hardware, such as pin sites.

- Appropriate V.A.C. Dressing is placed on the wound.
- Moldable hydrocolloid strip around pin approximately is applied 1/2 inch above the level of wound, wrapping it around the pin, ensuring snug fit.
- V.A.C. Drape is cut to appropriate size and applied to wound. Strips VAC of drape are cut and applied vertically over the pin and onto main V.A.C. Drape surrounding the pin. This is done from both sides of the pin. Drapes are pinched together to form airtight seal.

4. The Application of Negative Pressure. Fig 19:

Controlled pressure is uniformly applied to all tissues on the surface of the wound . The foam dressing is compressed in response to the negative pressure. The pump can deliver either continuous or intermittent pressures, ranging from 50 to 200 mmHg. Intermittent delivery consists of a seven-minute cycle of two minutes off and five minutes on, while the negative pressure is maintained throughout. Higher pressures of 180-200 mmHg are used for large cavity wounds such as acute traumatic wounds, as they produce copious amounts of exudate . The pressure is set to continuous for the first 48 hours and the pressure is changed into intermittent mode thereafter.

Figure 19

Procedure after the VAC treatment:

Size of the wound is measured, wound score is assessed. Time taken and the number of VAC settings required for the formation of healthy granulation tissue is noted. Second debridement is considered if there is presence of infection and VAC applied after the debridement with the inspection of wound every 24 hours. If the tendons or bone is exposed a secondary procedure of appropriate flap is done. If there is uniform healthy granulation tissue without the exposure of bone or tendon, split skin grafting was done as a secondary procedure.

III. Results

The present study was undertaken to assess the Clinical outcome of wound healing of open fractures with the use of vacuum assisted closure dressing. More important advances in wound management have occurred recently as a result of expansion of knowledge regarding healing process at the molecular level. NPWT is a novel technique for a managing an open wound by submitting the wound to either intermittent or continuous sub-atmospheric pressure.

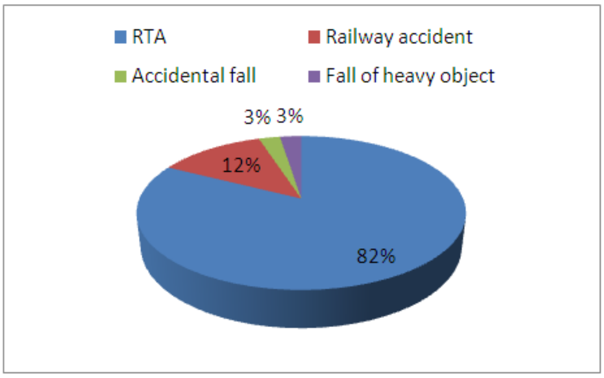
This a prospective studyof 40 patients visiting KIMS hospital with open fractures of Guistilo Anderson grade 3B.Wounds were initially debrided and vacuum assisted dressing applied. Wounds were assessed depending on wound size and score before and after the application of VAC and the number of VAC settings required for uniform healthy granulation tissue formation was noted.

In 40 patients, location of open fracture was 72% in leg, 20% in foot and 8% of wounds were with forearm fractures. 30% of patients had initial wound score of 2a, 12.5%had score 2b, and 57.5% had score of 3. Patients with initial wound score 2 showed average reduction of 12.2 mm with appearance of healthy granulation tissue by average of 9 days and patients with initial wound score 3 showed average reduction of 10.3 mm at the end of VAC treatment with appearance of healthy granulation tissue by mean 10.4 days. The mean reduction in size of the wound overall is 11.25mm. 20 patients required flap as a definitive closure procedure where as in 19 patients, wound was closed by split skin grafting. One wound was contracted with VAC treatment. More important advances in wound management have occurred recently as a result of expansion of knowledge regarding healing process at the molecular level. There are several advantages of applying a Primary VAC to an open fracture and these include Vacuum assisted dressing Protects the wound from external environment and further bacterial contamination. It absorbs the exudate from the wound and decreases local edema. It prevents loss of fluid from the wound and thus provides a moist environment at the wound which favors collagen synthesis and epithelial proliferation. VAC Increases the local blood flow to the wound. It considerably decreases the bacterial load of the wound and thus wound infection. VAC maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis. Negative pressure wound therapy Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing. VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the ‘reconstructive ladder’ when applied as a temporary dressing to acute open fractures.

So we conclude that with VAC, The time duration taken for formation of uniform healthy granulation tissue was less and the rate of wound infection was reduced with early improvement of wound score.

TABLE6: Distribution based on mode of injury

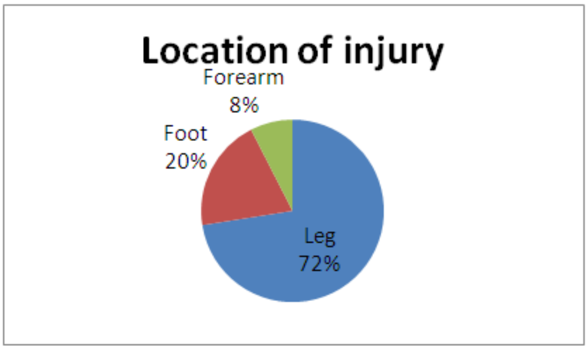
Sl no	Mode of injury	Number of patients	Percentage
1	RTA	33	82.5
2	Railway accident	5	12.5
3	Accidental fall	1	2.5
4	Fall of heavy object	1	2.5



Graph 3

TABLE 7: Distribution based on location of injury

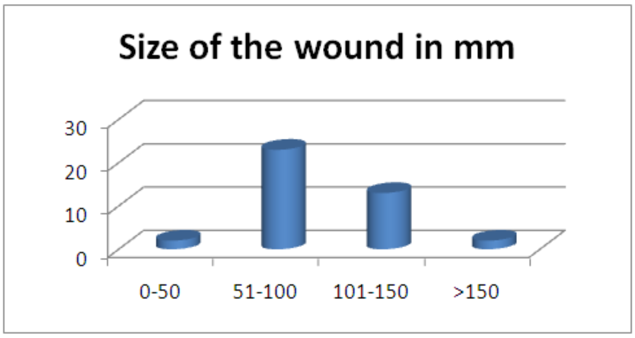
Sl no	Location of injury	Number of patients	Percentage
1	Leg	29	72.5
2	Foot	8	20
3	Forearm	3	7.5



Graph 4

TABLE 8 : Distribution based on initial size of wound

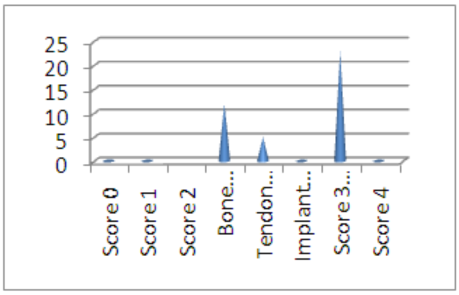
Sl no	Size of wound in mm	Number of patients	Percentage
1	0-50	2	5
2	51-100	23	57.5
3	101-150	13	32.5
4	>150	2	5



Graph 5

TABLE 9 : Distribution based on initial wound score

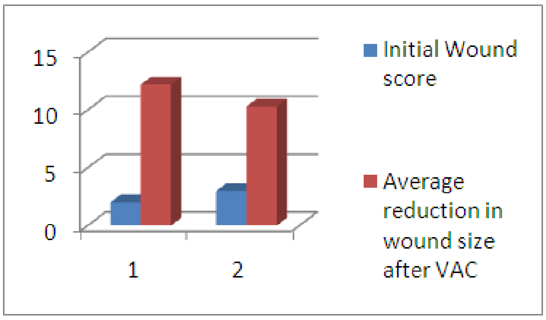
Sl no	Wound score	Number of patients	Percentage
1	Score 0	0	0
2	Score 1	0	0
3	Score 2		
	a. Bone exposed	12	30
	b. Tendon exposed	5	12.5
	c. Implant exposed	0	0
4	Score 3 (bone and tendon exposed)	23	57.5
5	Score 4	0	0



Graph 6

TABLE 10 : Initial wound score and average size reduction in mm after VAC treatment

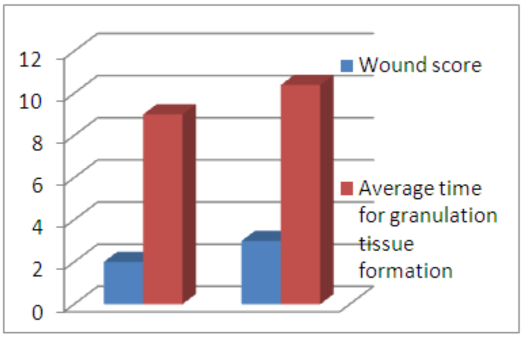
Sl no	Initial Wound score	Average reduction in wound size after VAC
1	2	12.2
2	3	10.3



Graph 7

TABLE 11. Wound score and time for formation of healthy granulation tissue with VAC

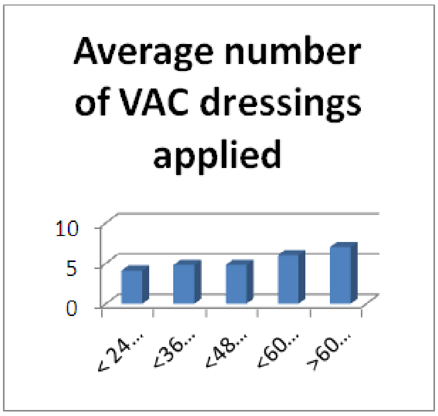
Sl no	Wound score	Average time for formation of healthy granulation tissue
1	3	10.4 days
2	2	9 days



Graph 8

TABLE 12 : Duration from time of injury to VAC dressing and number of VAC dressings applied

Sl no	Time from injury to first VAC	Average number of VAC dressings applied
1	< 24 hours	4.1
2	<36 hours	4.8
3	<48 hours	4.8
4	<60 hours	6
5	>60 hours	7



Graph 9

IV. Discussion

The use of negative pressure wound therapy in the form of vacuum-assisted closure has been established as a promising method in the field of wound healing in a variety of wounds including those that are difficult to heal.

There are two main factors considered to be responsible for the dramatic response seen in these wounds: removal of fluid and mechanical deformation[63]. Removal of fluid decreases edema which decreases the interstitial pressure resulting in increased blood flow. Mechanical deformation causes a wide variety of molecular responses, including changes in ion concentration, permeability of cell membrane, release of second messengers, and stimulation of molecular pathways increasing the mitotic rate of stretched cells. Recently, Scherer et al. have concluded that vascular response is related to the polyurethane foam, whereas tissue strain induced by vacuum assisted closure device stimulated cell proliferation.

Duration for change of dressing:

DeFranzo et al. advocated the changing at 2 days interval, while Banwell et al. recommend 4-5 days Singh SH et al. advocated change at 3-5 days interval. In our study, VAC dressing was changed every 2 days.

Rate of infection:

Stannard et al, studied the impact of NPWT on severely contaminated open fractures and observed significant difference between the 16 groups for total infections. With regular saline dressing,

Henley et al, reported 34.7% of infection 27., Charalambous et al, reported 27%28 and, Gopal et al reported 27.4%29 of infection. Comparatively our study showed overall 12.5% of infection

Time for healthy granulation tissue formation and final reduction in wound size:

Our study showed a mean reduction in size of the wound by 11.25 mm after VAC therapy. Study by Kushagra Sinha et al. showed a decrease in size of 1 to 4.9mm in 26.66% of patients in VAC group whereas 93.33% in control group from day 0 to day 8. A decrease in size of 10 to 19.9mm was seen in 46.66%of patients of VAC group and only 6.66% in control group. A decrease in size of more than 25mm was seen in 13.33% in VAC group. Similar studies were conducted by Argenta et al., Morykwas et al, & Joseph et al[58],.& these studies 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.

Russel et al advocates that primary wound closure should be avoided in treatment of open Tibia fractures, whereas Veliskakis described primary internal fixation and primary wound closure gives good results. Presently there is a tendency towards radical debridement immediate fracture stabilization and immediate definitive coverage.

There are several advantages of applying a Primary VAC to an open fracture and these include,

1) Protects the wound from external environment and further bacterial contamination.

2) Absorbs the exudate from the wound and decreases local edema.
3) Prevents loss of fluid from the wound and thus provides a moist environment at the wound
4) which favors collagen synthesis and epithelial proliferation.
5) Increases the local blood flow to the wound.
6) It considerably decreases the bacterial load of the wound and thus wound infection.
7) Maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis.
8) Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing.
9) VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the 'reconstructive ladder' when applied as a temporary dressing to acute open fractures.

Hence VAC can be applied after each debridement and irrigation until the wound is fit for a reconstructive procedure such as SSG or flap cover. VAC can be applied in a continuous or cyclical manner. The observation that intermittent cyclical treatment appears more effective than continuous therapy is interesting although the reasons for this are not fully understood. Two possible explanations were proposed by Philbeck et al. They suggested that intermittent cycling results in rhythmic perfusion of the tissue which is maintained because the process of capillary auto regulation is not activated. They also suggested that as cells which are undergoing mitosis must go through a cycle of rest, cellular component production and division, constant stimulation may cause the cells to 'ignore' the stimulus and thus become ineffective. Intermittent stimulation allows the cells time to rest and prepare for the next cycle. For this reason it is suggested that cyclical negative pressure should be used clinically.

The daily rental charges for a VAC machine and consumables are significant. This has discouraged many from using the system. However, there have been some reports showing that the increased healing times and downgrading of required operations correlate to decreased overall costs of care. The dressing should also enable larger wounds to be treated in the community with minimal nursing care impact. This would free up hospital beds permitting faster healing of operative patients and preventing waiting list buildup. VAC therapy is not the answer for all wounds; however, it can make a significant difference in many cases.

V. Conclusion

Following were the conclusions drawn from our study,

- Guistilo Anderson type 3 B open fractures were most commonly caused by road traffic accidents.
- Males were more prone for injury than females.
- The most common bone involved in this type of fracture is Tibia.
- Vacuum assisted closure therapy appears to be a viable adjunct for the treatment of open musculoskeletal injuries.
- Application of sub atmospheric pressure after the initial debridement to the wounds results in an increase in local functional blood perfusion, an accelerated rate of granulation tissue formation, and decrease in tissue bacterial levels.
- The granulation tissue formed was healthy and uniform.
- Soft tissue defects which lead to ugly and irregular surface was avoided by forming uniform granulation tissue and the defects were covered.
- Although traditional soft tissue reconstruction may still be required to obtain adequate coverage, the use of this device appears to decrease their need overall.

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