By the Name of ALLAH the Most Gracious the Most Merciful

Wounds, Tissue Repair and Scars Part I

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Bailey & Love's Short Practice of Surgery 28th Edition.

Wounds, healing and tissue repair Ch 3.

Learning objectives

To understand:

- Normal healing and how it can be adversely affected.
- How to manage wounds of different types, of different structures and at different sites.
- Aspects of disordered healing that lead to chronic wounds
- The variety of scars and their treatment.
- How to differentiate between acute and chronic wounds.

Wound definition

- (Break down / discontinuity in the integrity of cellular surface (i.e.an epithelial) with an extent to different depth down to deep structures.

- **Wounds can be : Open (exposed) / Closed (not exposed).**
- **Wounds can be : (Acute / Chronic).**
- **Wounds can be : (Tidy / Untidy).**
- **Trauma (Penetrating / Blunt).**
- **Trauma (force) Vs. (Injury = damage).**

Open Wound Types/Blunt trauma wounds:

- **Abrasions**: superficial wounds due to the top layer of skin being traumatically removed (e.g. fall or slide on a rough surface).
- **Lacerations**: wounds that are linear and regular in shape from sharp cuts, to irregularly shaped tears from trauma.
- **Skin tears**: can be chronic like a wound in the base of a skin fissure, or acute due to trauma and friction.

Open Wound Types /Penetrating wounds:

- **Puncture wounds**: caused by an object that punctures and penetrates the skin (e.g. knife, splinter, needle, nail)
- **Surgical wounds and Incisions**: wounds caused by clean, sharp objects such as a knife, razor, or piece of sharp glass
- **Bites and stings.**
- **Gunshot wounds or other high velocity projectile** which penetrates the body (this may have one wound at site of entry and another at site of exit)

Open Wound Types:

- **Thermal, chemical, or electrical burns**

Closed Wound Types

- **Contusions**: blunt trauma causing pressure damage to the skin and / or underlying tissues (includes bruises)
- **Blisters**: fluid filled pockets under the skin
- **Seroma**: a fluid filled area that develops under the skin or body tissue (commonly occur after blunt trauma or surgery)
- **Hematoma**: a blood filled area that develops under the skin or body tissue (occur due to internal blood vessel damage to an artery or vein)
- **Crush injuries**: can be caused by extreme forces, or lesser forces over a long period of time.

NORMAL WOUND HEALING IN SKIN

- Wound healing is a complex and dynamic biological process.
- In human adults, the normal response to injury across all organ systems typically results in fibrosis and scar formation. Fibrotic healing causes tissue dysfunction and its potential impact on patients is often underappreciated.
- This contrasts with early gestation when fetal tissues can remarkably heal without fibrosis. Regenerative medicine is therefore an exciting field of research.
- Classically, wound healing has been arbitrarily described in three overlapping but distinct stages, including inflammation, proliferation and remodelling
- An additional stage, haemostasis, is often described as the immediate phase occurring before inflammation.

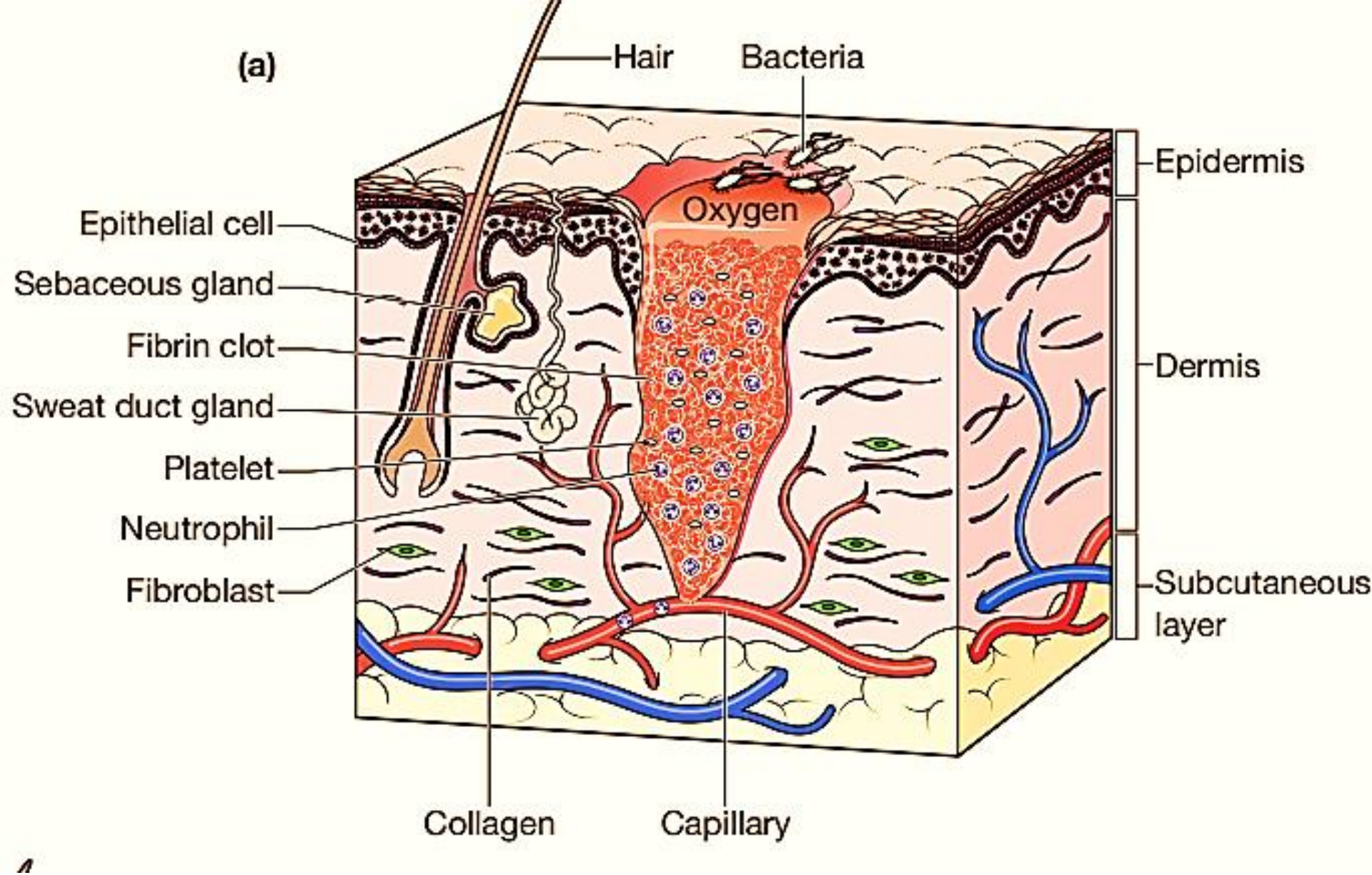
Haemostasis

- Disruption of the vascular endothelium following injury causes vasoconstriction and exposure of the subendothelial extracellular matrix. This encourages platelets to adhere, activate and aggregate, resulting in a platelet plug, which also helps limit further blood loss.
- Platelet adhesion results in their activation and release of granules. Alpha granules contain hundreds of proteins, including cytokines and growth factors; for example, transforming growth factor beta, platelet-derived growth factor, fibroblast growth factor, epidermal growth factor and vascular endothelial growth factor.

- These are involved in the deposition of extracellular matrix, chemotaxis, epithelialisation and the formation of new blood vessels (angiogenesis).
- Platelet aggregation occurs once platelets become activated. At the same time, tissue factor at the site of injury initiates the coagulation cascade , resulting in the formation of thrombin.
- Thrombin performs various functions, including fibrin generation, which helps to stabilise the platelet plug and form a scaffold for infiltrating cells.

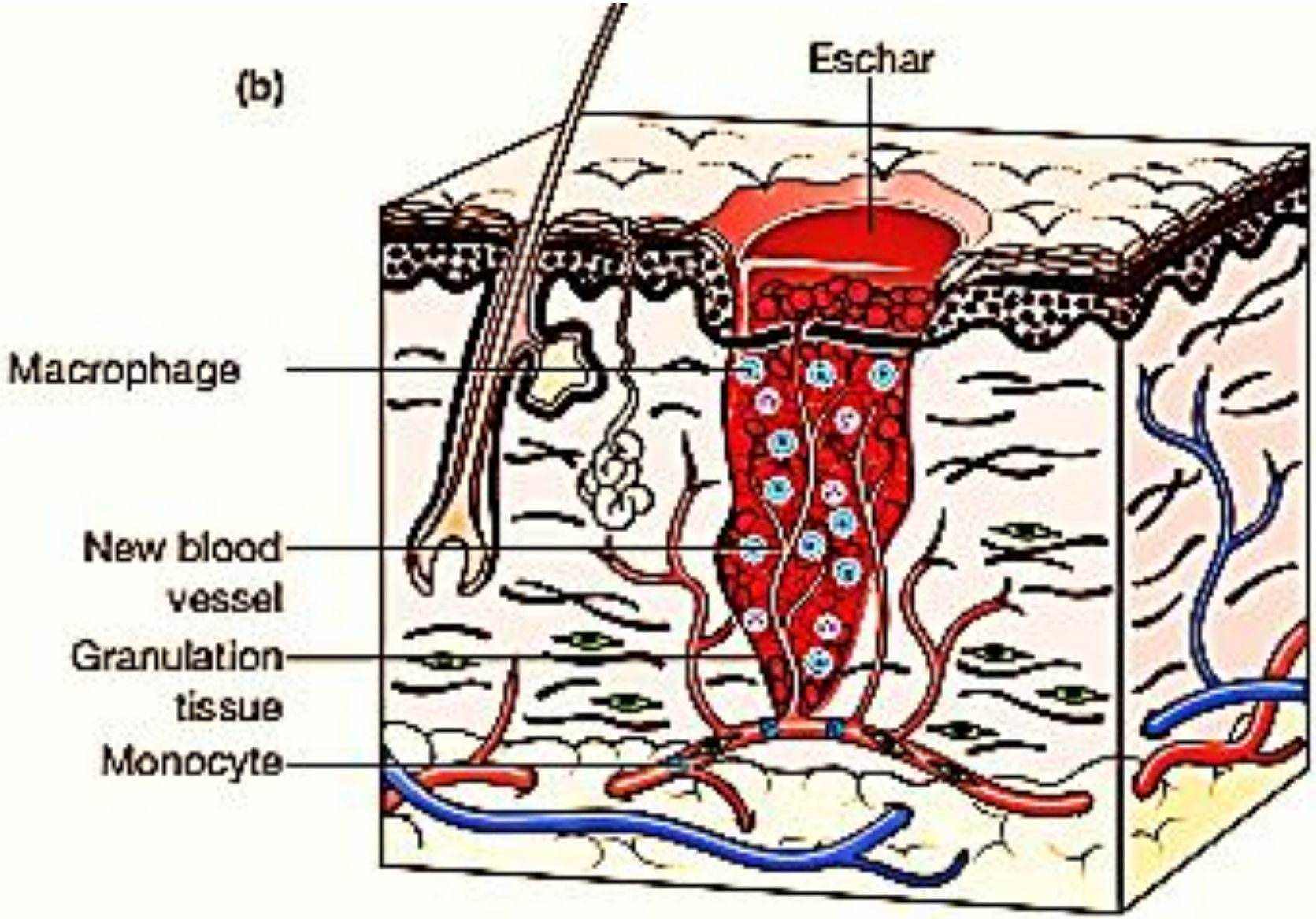
1- Inflammation

- **In the early inflammatory phase** (days 1–2), platelet activation causes an influx of inflammatory cells led by neutrophils to minimise bacterial contamination of the wound.
- Platelets and the local injured tissue also release vasoactive amines such as histamine and serotonin, which increase vascular permeability, thereby aiding infiltration of inflammatory cells.
- **During the late inflammatory phase** (days 2–3) monocytes appear in the wound and differentiate into macrophages. **Macrophages** play as phagocytic cells and release proteolytic enzymes to help debride the wound. They are also the primary producer of cytokines and growth factors promoting fibroblast proliferation and angiogenesis.
- Historically, this phase has been described by rubor (redness), tumor (swelling), calor (heat) and dolor (pain).


(a)
Hair
Bacteria
Epidermis
Oxygen
Epithelial cell
Sebaceous gland
Fibrin clot
Dermis
Sweat duct gland
Platelet
Neutrophil
Fibroblast
Subcutaneous layer
Collagen
Capillary

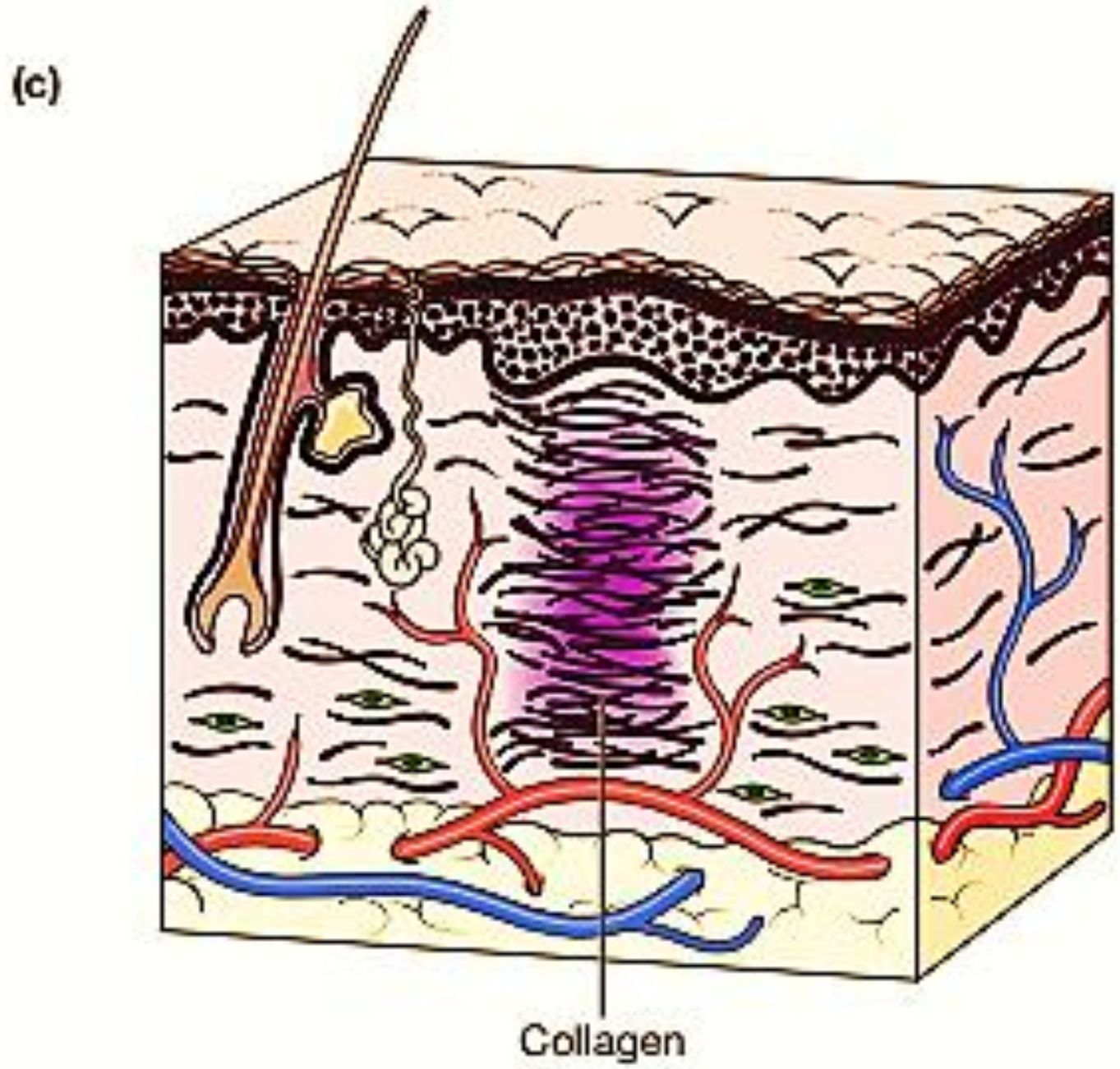
2- Proliferation

- The proliferative phase starts around day 3 and lasts for 2–4 weeks. It consists mainly of **fibroblast activity** with the production of ground substance (glycosaminoglycans and proteoglycans), collagen, angiogenesis and re-epithelialisation of the wound.
- The wound tissue formed in the early part of this phase is called **granulation tissue**. It has a pink and granular appearance.
- In the later part of this phase, there is an increase in the tensile strength of the wound as a result of increased collagen synthesised by fibroblasts. Some fibroblasts differentiate into myofibroblasts, which are contractile cells. These play an important role in contraction to bring the edges of the wound together.


(b)
Eschar
Macrophage
New blood vessel
Granulation tissue
Monocyte

3- Remodelling

- It begins 2–3 weeks after injury and lasts for a year or more. Which is characterized by maturation of collagen.
- Type III collagen, which is prevalent during proliferation, is replaced by stronger type I collagen until the normal skin ratio of 4:1 type I to type III collagen is re-established.
- The collagen becomes more cross-linked and uniformly aligned, leading to increased tensile strength in the wound, maximally 12 weeks post injury and represents approximately 80% of the uninjured skin strength.


(c)
Collagen

ABNORMAL WOUND HEALING

ABNORMAL WOUND HEALING

- Failure to heal in a timely and orderly manner, resulting in chronic non-healing wounds, significant morbidity and poor cosmoses.
- Aberrations of normal wound healing such as prolonged inflammation can result in excessive scar tissue, for example hypertrophic and keloid scars. (due to excess collagen, which is arranged in a disorganised pattern).

Local and systemic factors influencing wound healing

Local

- **Skin tension**
- **Hypoxia and ischaemia.**
  Vascular insufnciency.
- **Lymphoedema**
- **Contamination / Infection**
- **Presence of foreign bodies.**
  Radiotherapy

Systemic

- **Advancing age**
  Obesity
- **Malnutrition**
- **Smoking**
- **Diseases (e.g. diabetes mellitus, connective tissue diseases)**
- **Immunocompromised (e.g. acquired immunodenciency syndrome)**
  Medications (e.g. steroids, immunosuppressants, chemotherapy)
  Others :Uremia, Jaundice, Anemia..

TYPES OF WOUNDS
TIDY VERSUS UNTIDY

- The management of wounds based upon their classification into tidy and untidy.
- The surgeon's aim is to convert untidy to tidy by removing all contaminated and devitalised tissue.
- Primary repair of all structures may be possible in a tidy wound, but a contaminated wound with dead tissue requires debridement 'second look' .
- Injuries caused by explosions, bullets or other missiles, where the external wound itself may appear much smaller than the wider extent of the injured tissues deep to the surface.

TABLE 3.1 Tidy versus untidy wounds.

Tidy	Untidy
Incised	Crushed or avulsed
Clean	Contaminated
Healthy tissues	Devitalised tissues
Seldom tissue loss	Often tissue loss

Tidy Wound

Incised

Clean Healthy tissues

Seldom tissue loss

Untidy wound

Crushed or avulsed, Contaminated, Devitalised tissues, Often tissue loss

CLASSIFICATION OF WOUNDS

- The National Nosocomial Infections Surveillance (NNIS) score is commonly used to predict surgical site infections (SSIs)
- The NNIS score stratifies surgical wound infection rates by risk factors. This risk index score ranges from 0 (lowest SSI risk) to 3 (highest SSI risk) with a point allocated for the presence of each of the following risk factors:
- Contaminated or dirty wound .
- American Society of Anesthesiologists score ≥3;
- Operative time longer than the expected duration for similar procedures (>75th percentile).

US Centers for Disease Prevention and Control surgical wound classification.

- To describe the degree of bacterial load or contamination of surgical wounds at the time of surgery.

Surgical wound classification

- Class I surgical wound : Clean.
- Class II surgical wound : Clean-contaminated.
- Class III surgical wound : Contaminated.
- Class IV surgical wound : Dirty / Infected.

Class I Clean	Uninfected operative wounds .No inflammation is encountered .Respiratory, alimentary, genital or uninfected urinary tracts are not entered. Primarily closed and, if necessary, drained using a closed system
Class II Clean–contaminated	Respiratory, alimentary, genital or urinary tracts are entered under controlled conditions and without unusual contamination. No evidence of infection or major break in technique is encountered
Class III Contaminated	Open, fresh, accidental wounds Operations with major breaks in sterile technique (e.g. open cardiac massage) or gross spillage from the gastrointestinal tract Incisions in which acute, non-purulent inflammation is encountered
Class IV Dirty	Old traumatic wounds with retained devitalised tissue and those that involve existing clinical infection or perforated viscera

Classification of Wound Closure and Healing

- **Primary intention (first intention)**

  Wound edges opposed.

  Normal healing.

  Minimal scar.

- **Secondary intention (dirty wound)**

  Wound left open.

  Heals by granulation, contraction and epithelialisation.

  Increased inflammation and proliferation.

  Poor scar.

- **Tertiary intention (also called delayed primary intention)**

  (contaminated or untidy wounds)

  Wound initially left open .

  After debridement.

  Edges later opposed when healing conditions are favorable.

Synopsis of wound classification systems

Aetiology

- Clean, surgical
- Shearing or degloving
- Crush
- Blast
- Burn (thermal, electrical, chemical, radiation, mechanical)
- Cold injury
- Avulsion or traction
- Low or high energy
- Bite

Depth

- Epidermal
- Dermal (superficial or deep)
- Full thickness

Contamination

- Clean
- Clean–contaminated
- Contaminated
- Dirty
- Implant or non-implant

Complexity

- Simple
- Complex
- Signincant soft-tissue loss
- Open fracture or joint
- Visceral involvement

Complicated

Infection
Necrosis
Haematoma
Gas gangrene
Compartment syndrome

Chronic

Vascular ulcers (venous or arterial)
Pressure ulcers
Diabetic ulcers

ACUTE WOUNDS

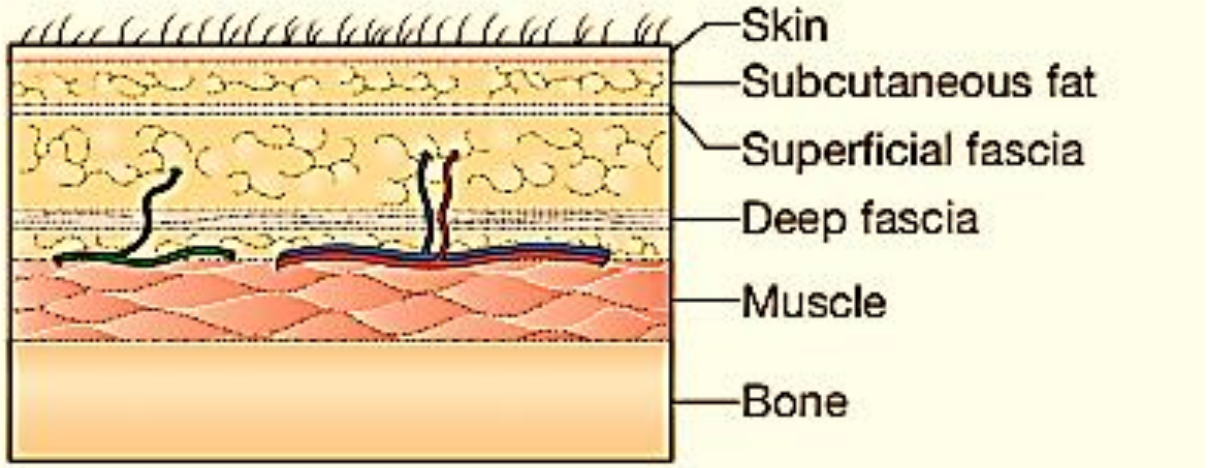
- Bites.
- Degloving

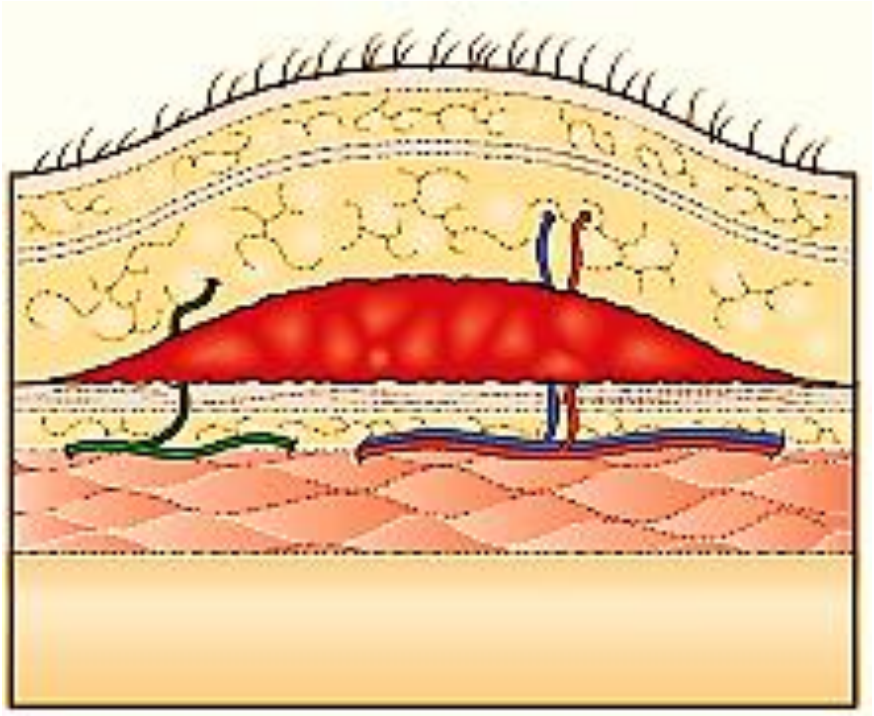
Bites

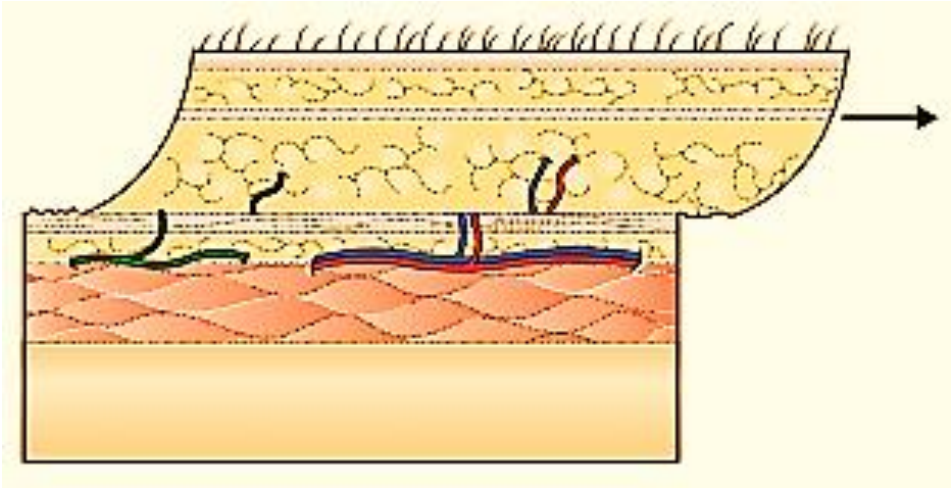
- Either puncture wounds or avulsions.
- Wounds over the metacarpophalangeal joint should be treated as a human bite following a punch to the mouth until proven otherwise.
- Joint infections are a surgical emergency as they can result in articular cartilage destruction.
- They present as hot, swollen and tender joints with a limited range of motion.

Degloving

- Degloving is the avulsion of skin and subcutaneous fat from the underlying fascia, muscle or bone.
- May be open degloving injuries (a finger avulsion injury with loss of skin).
- Or closed degloving injuries (shearing forces, which by motor vehicle collisions). The extent of these injuries is often underappreciated and much of the skin may be non-viable . Disruption of perforating vascular and lymphatic vessels may result in a characteristic haemolymphatic collection between the fascial planes called a **Morel-Lavallée** lesion
- Assessing the viability of degloved tissue can be dicult and may therefore require more than one surgical exploration and debridement before definitive reconstruction.


Skin
Subcutaneous fat
Superficial fascia
Deep fascia
Muscle
Bone





- Non-viable skin may show fixed staining and thrombosis of subcutaneous veins.
- Most surgeons serially excise the degloved skin until punctate dermal bleeding is seen from viable tissue.
- Intravenous fluorescein may also help delineate non-viable tissue, but it requires specialist equipment and there is a small risk of anaphylaxis. More recently, the use of indocyanine green fluorescence has been reported.

Classification of Degloving Injuries in Limb Trauma

- 1 Limited degloving with abrasion or avulsion
- 2 Non-circumferential degloving
- 3 Circumferential single plane degloving
- 4 Circumferential multiplanar degloving

Degloving hand injury

Degloving buttock injury

WOUND MANAGEMENT

- It is guided by the timing and mechanism of injury as well as factors affecting healing
- Assess the patient using Advanced Trauma Life Support principles to first identify and treat life- and then limb-threatening conditions.
- Some wounds require a multidisciplinary approach; for example, the involvement of orthopaedic surgeons and plastic surgeons in managing complex open lower

- Assess the site, size, geometry and nature of any wounds.
- Look for signs of contamination, infection, swelling and pulsatile bleeding.
- Deformities may suggest underlying fractures or dislocations. Has there been skin loss or degloving? What structures are visible?
- Wound irrigation for better visualisation.
- Correlate the clinical examination with the mechanism of injury as seemingly innocuous wounds can lead to underestimation of tissue damage. For example, high-pressure injection injuries of the hand can cause significant mechanical and chemical tissue damage with risk of amputation. The injected substances can track proximally into the forearm. Urgent surgical exploration and debridement is required.

- Before palpation, ensure that the patient has adequate analgesia or a local anaesthetic block.
- When possible, it is important to assess motor and sensory function before any local anaesthesia. Unless there are obvious muscle injuries, the purpose of testing specific muscle groups is to evaluate potential nerve or tendon injuries.
- Imaging is useful to exclude foreign bodies, fractures or dislocations where appropriate.

Principles of wound management

- Preparation
- Wound.
- Closure.
- Follow-up

Preparation	Antibiotic prophylaxis Tetanus prophylaxis Adequate analgesia/anaesthesia Wound irrigation

- Antibiotic prophylaxis is needed for clean–contaminated, contaminated and dirty wounds. It may also be used in clean wounds when there is a high risk of infection or when the sequelae of infection are potentially disastrous.
- Tetanus prophylaxis should be given based on the type of wound and immunisation status .

Tetanus-prone wounds	
Low-risk tetanus-prone wounds	High-risk tetanus-prone wounds
- Puncture-type injuries in a contaminated environment - Bites - Compound fractures - Containing foreign bodies - Wounds or burns with systemic sepsis	- Heavy contamination, e.g.soil or manure. - Wound requiring surgerywith >6-hour delay. - Extensive devitalised tissue

Wound	Early debridement and irrigation Exploration Repair structures Haemostasis

- Debridement is essential to remove any devitalised tissue and foreign material from the wound.
- Non-viable tissue must be excised until healthy bleeding occurs at the wound edges.
- The end points of surgical debridement can sometimes be difficult to determine. Healthy subcutaneous fat is yellow and soft.
- Muscle viability is judged by its colour, capacity to bleed and contractility. Contaminated, complex and complicated wounds often require more than one surgical debridement before definitive repair and closure; for example, blast injuries and necrotising fasciitis.

- All wounds should be irrigated at the first available opportunity to reduce bacterial contamination. This also allows better visualisation for wound assessment. Warm normal saline is typically used, although other irrigation fluids are available such as water and antiseptic solutions. Irrigation can also be performed with a soft brush or sponge to clear particulate matter prior to preoperative application of skin antiseptic preparation.
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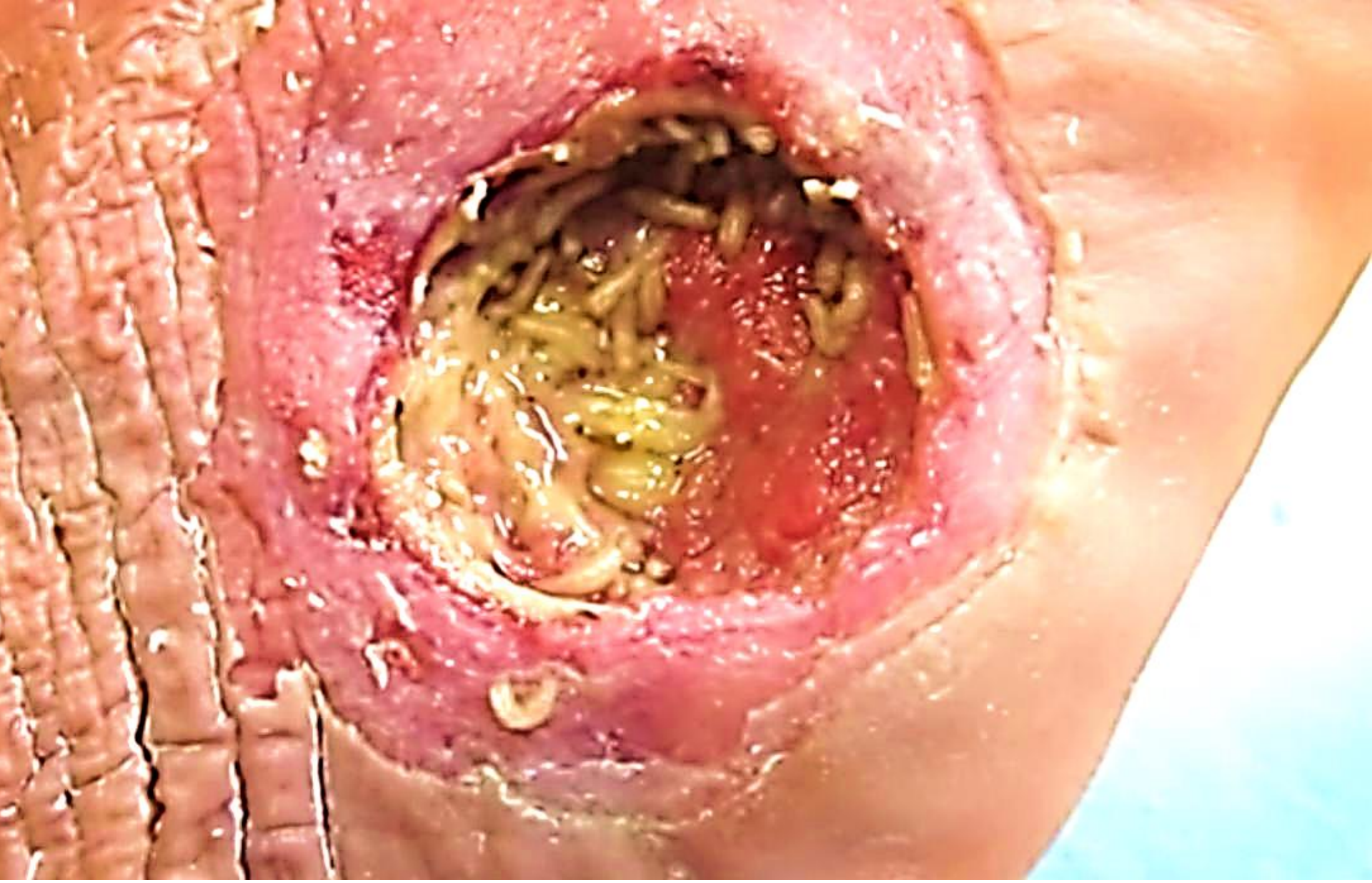
TABLE 3.4 Types of debridement.

Surgical	Excision of non-viable tissue using surgical instruments such as a scalpel, curette, scissors or rongeur until healthy bleeding occurs at the wound edges
Mechanical	Non-selective debridement such as using irrigation, wet-to-dry dressings and hydrotherapy. Both non-viable and viable tissue may be removed
Autolytic	Using dressings such as hydrocolloids or transparent films to retain moisture and allow wound enzymes to selectively liquefy non-viable tissue
Enzymatic	Chemically liquefy necrotic tissue with enzymes using topical agents such as collagenase or papain–urea
Biological	Medical-grade larvae of *Lucilia sericata* release proteolytic and antimicrobial substances to remove necrotic tissue. They also directly promote wound healing



Maggot Therapy

- Wounds should be **explored** to determine the extent of injury, including any damage to underlying neurovascular structures, tendons, joints and bones. Careful tissue handling and meticulous technique are important throughout. **Repair** of all damaged structures may be attempted once the wounds are clean. Repair of nerves and vessels should be performed under magnification using loupes or a microscope.

Closure	Skin closure without tension Consider reconstruction options Suture choice. Consider drains. Optimal dressings

- Skin closure should always be without tension.
- Direct closure is not always possible and other reconstruction methods should be considered.
- A skin graft has no inherent blood supply and is dependent on a well-vascularised recipient site for survival and wound healing. Split-thickness (epidermis and a small portion of dermis) whereas full-thickness (epidermis and the majority of the dermis).

- A skin flap contains tissue with its intrinsic blood supply that is transferred from one part of the body (donor) to another (recipient).
- A free flap contains tissue with its vascular pedicle that is transferred to a distant recipient site involving a microvascular to the recipient site.
- Negative-pressure wound therapy (NPWT) helps draw the wound edges together, remove exudate, reduce oedema and promote granulation tissue formation.
- It is not a replacement for definitive wound closure but is a useful adjunct and is not recommended in the setting of exposed vessels, malignancy, untreated osteomyelitis, necrotic tissue or non-enteric and unexplored fistulae.

Reconstruction options for wound closure

- Primary closure
- Secondary closure
- Tertiary (delayed primary) closure
- NPWT
- Split-thickness skin graft
- Full-thickness skin graft
- Dermal matrices
- Local, regional or pedicled flap
- Tissue expansion
- Free flap

Follow-up	Removal of sutures/splints. Physiotherapy. Monitoring for complications . Scar management

- Acute trauma life support (ATLS) principales (A,B,C,D,E,F).
- Hemostasis (pressure pad, clamping, tourniquet & ligation) .
- Swab (C + S).
- ATT vaccine.
- Body examination & wound assessment (ULA/GA).
- Cleansing (Irrigation with Normal saline) .
- Wound Toilet/Debridement/Exploration /Excision.
- Viability of the affected structure (Muscle :colour, bleeding pattern and contractility). .
- Repair / replacemet of (vascular, nerve, tendon, bone, muscle) .
- Skin closure w/- (skin graft/flap).
- Careful tissue handling and meticulous technique
- NOT under tension.
- Drainage.
- Dressing (Wet media).
- Broad spectrum antibiotics (Anaerobic and aerobic bacteria) .

PRAISE BE TO ALLAH