

Surgical wound and wound healing

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Wound definition and classification

A wound is a break in the integrity of skin or tissue, which may be associated with disruption of the structure and function.

There are many classifications for wounds:

1-(Rank & Wakefield)

A- tidy

B- untidy

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 |



Figure 3.2 (a) Tidy incised wound on the finger. (b) Untidy avulsed wound on the hand.

Other classifications:

2- A-Closed Wounds:-

Bruise, Contusion, Hematoma

B-Open Wounds:

Abrasion, Incised wound, Lacerated wound, Punctured wound, Penetrating wound, Bite wound.



Ecchymosis or Contusions

Abrasions



Incised Wound



Lacerated wound



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Human bite

3-Classification based on the thickness of the wound:

Superficial wound.

partial thickness.

Full thickness.

4- Classification based on the cleanliness of the wound :

a-clean wound.

b-clean contaminated wound.

c-contaminated wound.

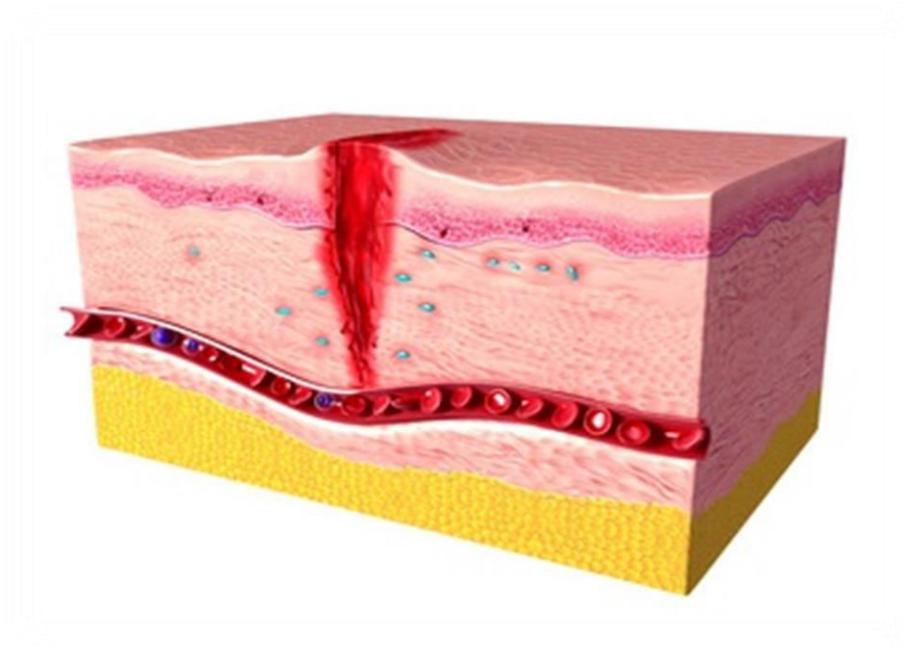
d-dirty infected wound.

| Class | Contamination potential of the operation | Characteristics | Example | Estimate of occurrence from SSI |
|-------|--|--|---|---------------------------------|
| I | Clean | No signs of inflammation, no opening of the respiratory tracts, food, genital or urinary | Inguinal herniorrhaphy | <2% |
| II | Potentially contaminated | Opening of the respiratory tracts, food, genital or urinary with no significant contamination | Cholecystectomy (without overflow bile) | <10% |
| III | Contaminated | Inflammatory process or opening of the respiratory tracts, food, genital or urinary with significant contamination | Appendectomy, colectomy | 20% |
| IV | Infected | Coarse contamination secondary to pus or drilling | Cholecystectomy by cholecystitis acute with empyema | > 40% |

Wound healing

Wound healing is defined as a mechanism where the body attempts to restore the integrity of the injured part.

Filling the gap that is caused by injury and tissue destruction followed by reconstruction of the tissue continuity.



Wound healing is mainly divided into three phases that can overlap;

1: the inflammatory phase

2: the proliferative phase

3: the remodeling phase

In addition some classifications include the haemostatic phase which occurs before the inflammatory phase

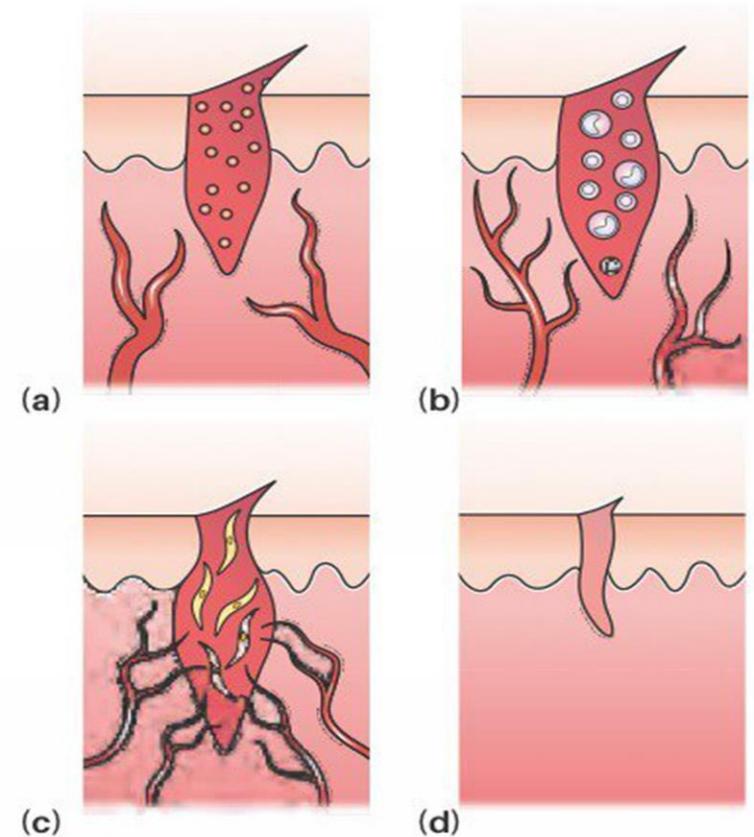


Figure 3.1 The phases of healing. **(a)** Early inflammatory phase with platelet-enriched blood clot and dilated vessels. **(b)** Late inflammatory phase with increased vascularity and increase in polymorphonuclear leukocytes and lymphocytes (round cells). **(c)** Proliferative phase with capillary buds and fibroblasts. **(d)** Mature contracted scar.

The inflammatory phase

The inflammatory phase begins immediately after wounding and lasts 2–3 days. Bleeding is followed by vasoconstriction and thrombus formation to limit blood loss.

Platelets stick to the damaged endothelial lining of vessels, releasing adenosine diphosphate (ADP), which causes thrombocytic aggregates to fill the wound. When bleeding stops, the platelets then release several cytokines from their alpha granules. These attract inflammatory cells such as polymorphonuclear lymphocytes (PMN) and macrophages (chemotaxis). Platelets and the local injured tissue release vasoactive amines, such as histamine, serotonin, and prostaglandins, which increase vascular permeability.

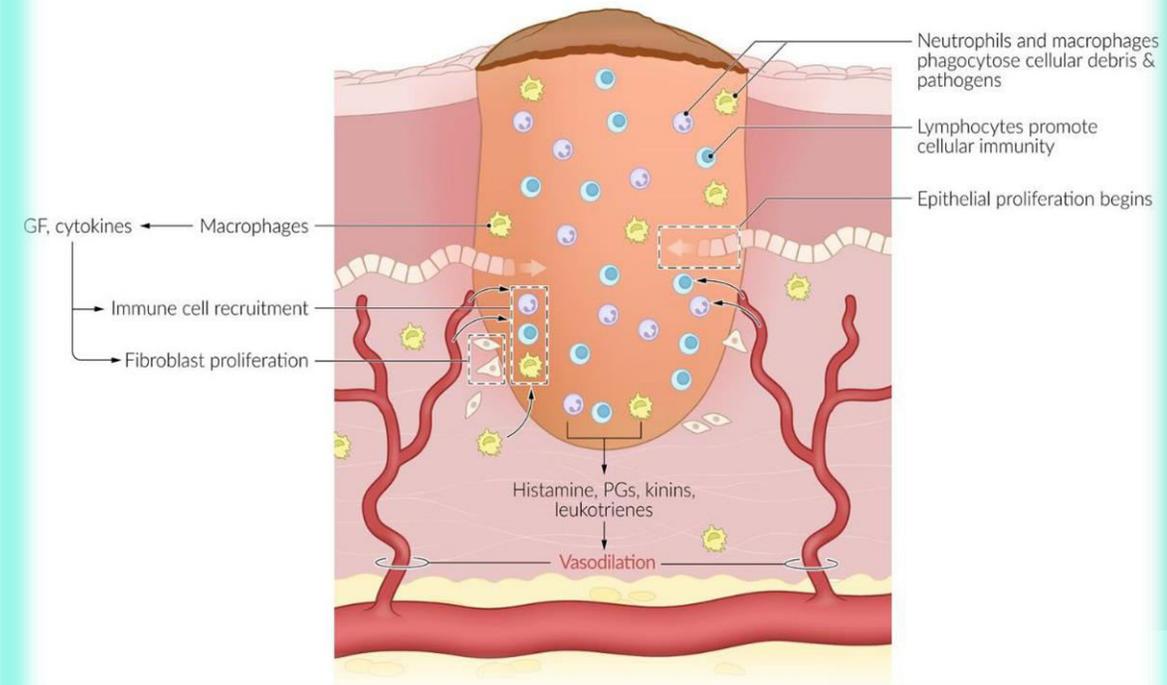
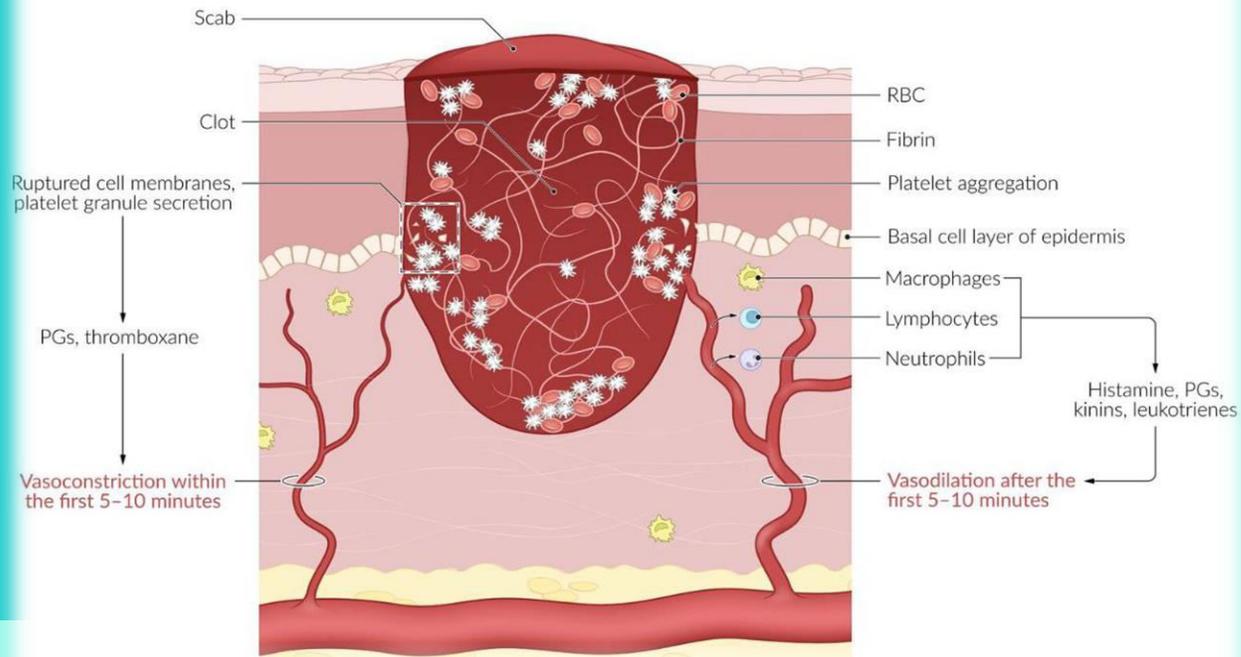
Macrophages remove devitalized tissue and microorganisms while regulating fibroblast activity in the proliferative phase of healing.

Cellular response in the inflammatory phase:

Neutrophils (24-48 hours)

Macrophages (48-96 hours)

Lymphocytes (5-7 days)



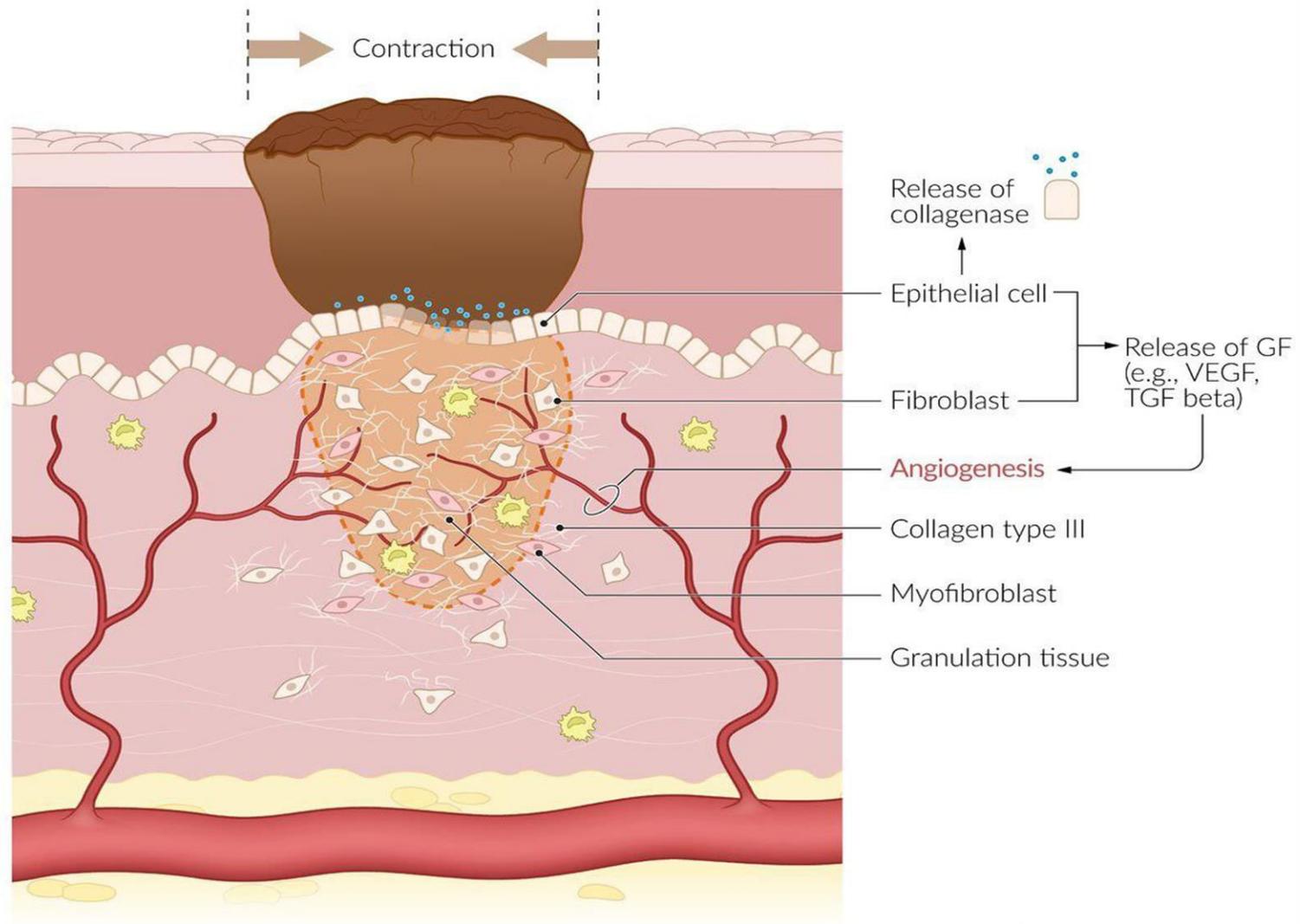
The fibroproliferative phase

The proliferative phase lasts from the third day to the third week.

It consists mainly of fibroblast activity with the production of collagen and ground substance (glycosaminoglycans and proteoglycans).

It also involves the growth of new blood vessels as capillary loops (angiogenesis), and the re-epithelialization of the wound surface.

The wound tissue formed in the early part of this phase is called granulation tissue. In the latter part of this phase, there is an increase in the tensile strength of the wound due to increased collagen synthesis, which was deposited in a random fashion and consists of type III collagen at first.



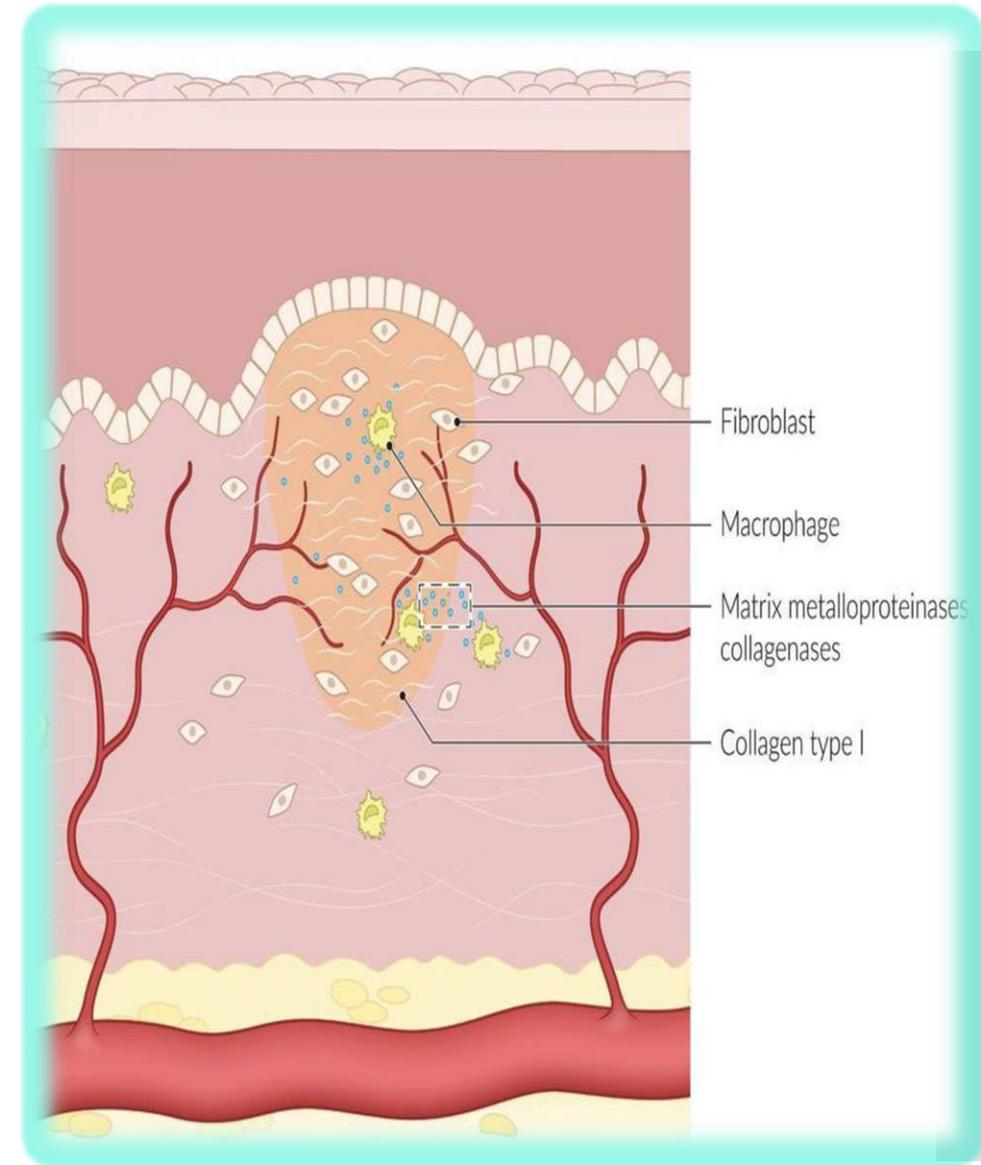
The proliferative phase

The Maturation/Remodeling phase

The remodeling phase lasts from Week 3 to 1 year.

The remodeling phase is characterized by the maturation of collagen (type I replacing type III until a ratio of 4:1 is achieved).

There is a realignment of collagen fibers along the lines of tension, decreased wound vascularity, and wound contraction due to fibroblast and myofibroblast activity.



Scar

- Maturation phase of wound healing leads to formation of scar.
- Immature scar (Pink, raised, hard & itchy) → As the collagen matures & becomes denser, scar becomes almost acellular, as fibroblast & blood vessels reduce → Scar becomes (paler, flattens, softer & itching diminishes) → Tensile strength of scar increases; maximum at week 12 (after 3 months) post-injury; represent approx. 80% of uninjured skin strength.
- Types of scar: Atrophic scar, hypertrophic scar & keloid

| Feature | Hypertrophic Scar | Keloid |
|-----------------|--|--|
| Genetic | Not familial ^Q | May be familial ^Q |
| Race | Not race related ^Q | Black^Q >white |
| Sex | Female = male | Female^Q >male |
| Age | Children ^Q | 10-30 years ^Q |
| Border | Remains within wound ^Q | Outgrows wound area |
| Natural history | Subsides with time | Rarely subsides |
| Site | Flexor surfaces ^Q | Sternum (MC^Q) , shoulder, face |
| Etiology | Related to tension ^Q | Unknown |
| Develop | Within 4 weeks | 3 months to year after trauma |
| Symptoms | Raised , some pruritus Respect wound confines | Pain, pruritus, hyperesthesia Growth beyond wound margins |
| Histology | Parallel orientation of collagen fibers | Thick wavy collagen fibers in random orientation |

Healing process

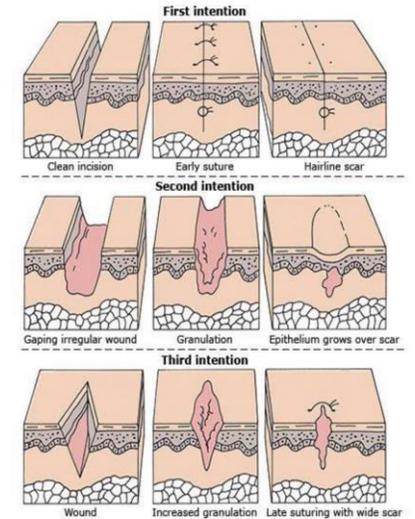
- The process of healing involves two distinct processes which are Regeneration and Repairing.
- Regeneration is when healing takes place by re-epithelization resulting in complete restoration of the original tissue (as structure and function). Which seen after having a minor laceration.
- Repair is the process of the generation of a scar or less functional tissue with a different form and /or composition than the original tissue. (Doesn't restore complete functionality).

TYPES OF WOUND HEALING

Wound closure and healing are classified into:

1. Healing by primary intention (wounds with opposed edges)
2. Healing by secondary intention (wounds with separated edges)
3. Healing by tertiary intention.(delayed primary intention).

**The aim of treatment is to achieve healing by primary intention and so reduce the inflammatory and proliferative responses.



Classification of wound closure and healing

- Primary intention
 - Wound edges opposed
 - Normal healing
 - Minimal scar
- Secondary intention
 - Wound left open
 - Heals by granulation, contraction and epithelialisation
 - Increased inflammation and proliferation
 - Poor scar
- Tertiary intention (also called delayed primary intention)
 - Wound initially left open
 - Edges later opposed when healing conditions favourable

PRIMARY INTENTION

Healing by primary intention or healing by first intention. This occurs when there is apposition of the wound edges and minimal surrounding tissue trauma.

This type causes the least inflammation and leaves the best scar.

Healing of wound with the following characteristics:

- ❑ Clean and uninfected.
- ❑ Surgically incised.
- ❑ Without much loss of cells and tissue.
- ❑ Wounds with opposed edges.
- ❑ Edges of wounds are approximated by surgical sutures.
- ❑ Primary union.

PRIMARY INTENTION

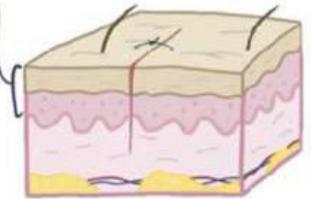
WOUND EDGES COME TOGETHER



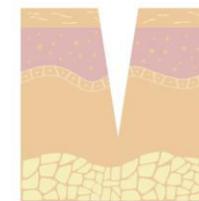
EPIDERMIS

REGENERATE DAMAGED TISSUE NEAR SURFACE

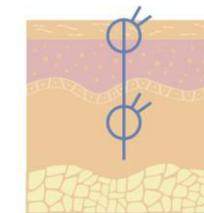
MINIMAL SCAR



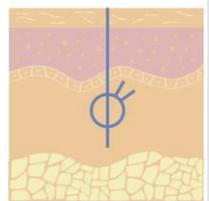
Primary intention



Clean incision



Early suture



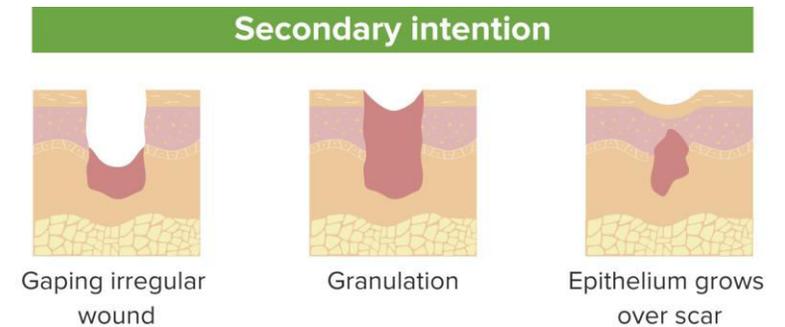
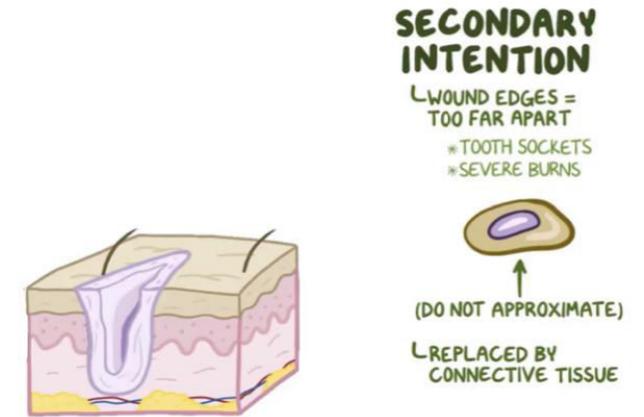
Hairline scar

Secondary intention

- Healing by secondary intention has increased inflammation and proliferation, and it leaves a poor scar.
- In this type wounds are left open and allowed to heal by granulation, contraction, and epithelialisation.

Healing of wound with the following characteristics:

1. Wounds with separated edges.
2. Secondary union
3. When there is a more extensive loss of cells
4. tissue Regeneration of parenchymal cells can't completely reconstitute the original architecture.
5. Abundant granulation tissue grows from the margin to complete the repair.



DEFERENCE BETWEEN HEALING BY PRIMARY AND SECONDARY INTENTION

Healing by Secondary intention differs from healing by primary intention in :

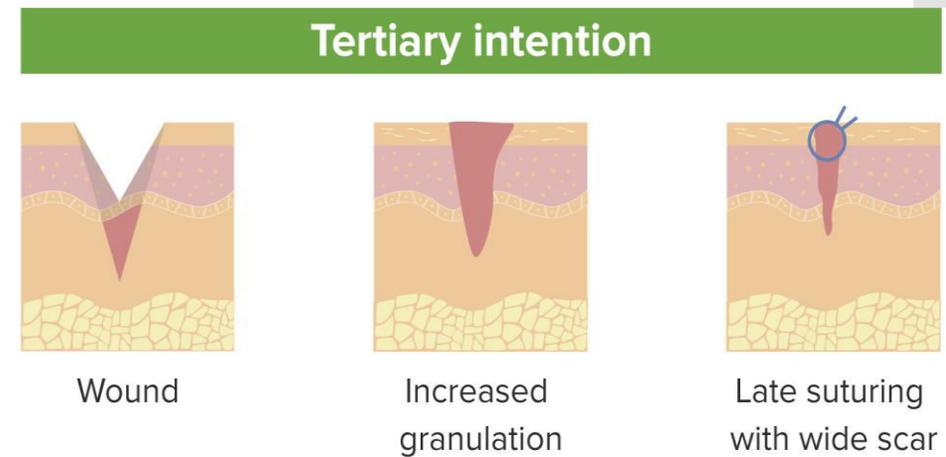
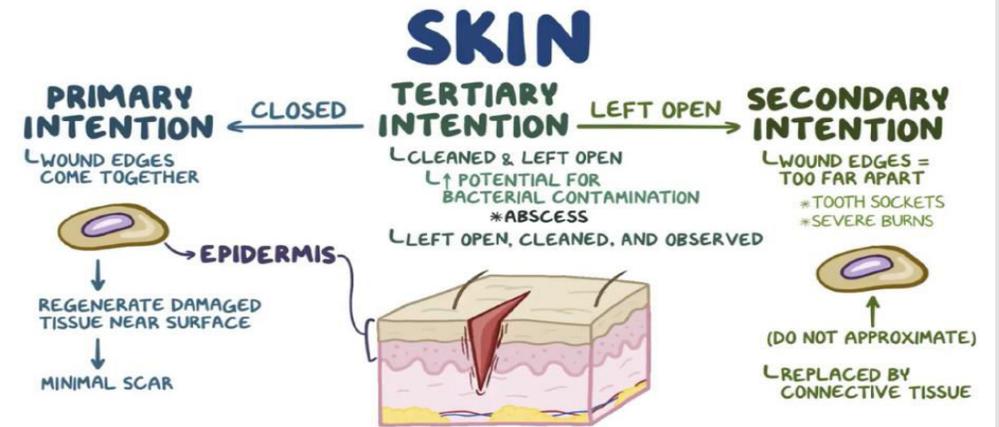
1. Inflammatory reaction is more intense.
2. Much larger amounts of granulation tissue are formed.
3. Wound contraction occurs on a large surface.
4. Substantial scar formation and thinning of the epidermis occurs.

Difference between 1° & 2° union of wound

| FEATURES | PRIMARY | SECONDARY |
|--------------|--------------------------|--------------------------|
| CLEANLINESS | CLEAN | NOT CLEAN |
| INFECTION | NOT INFECTED | INFECTED |
| MARGINS | SURGICALLY CLEAN | IRREGULAR |
| SUTURES | USED | NOT USED |
| HEALING | SMALL GRANULATION TISSUE | LARGE GRANULATION TISSUE |
| OUT COME | LINEAR SCAR | IRREGULAR WOUND |
| COMPLICATION | NOT FREQUENT | FREQUENT |

TERTIARY INTENTION

- Also called delayed primary intention, the wound is initially left open and the edges are not opposed immediately.
- can be necessary for contaminated wounds.
- Result in a scar that is less satisfactory than scars that result from primary intention.



FACTORS AFFECTING WOUND HEALING

Several factors may influence healing. lead to impaired wound healing. In general terms, the factors that influence repair can be categorized into **local** and **systemic**.

Local factors are those that directly influence the characteristics of the wound itself, while systemic factors are the overall health or disease state of the individual that affect his or her ability to heal.

Factors influencing healing of a wound

- Site of the wound
- Structures involved
- Mechanism of wounding
 - Incision
 - Crush
 - Crush avulsion
- Contamination (foreign bodies/bacteria)^a
- Loss of tissue
- Other local factors
 - Vascular insufficiency (arterial or venous)
 - Previous radiation
 - Pressure
- Systemic factors
 - Malnutrition or vitamin and mineral deficiencies
 - Disease (e.g. diabetes mellitus)
 - Medications (e.g. steroids)
 - Immune deficiencies (e.g. chemotherapy, acquired immunodeficiency syndrome [AIDS])
 - Smoking

^a In explosions, the contamination may consist of tissue such as bone from another individual.

- Local factors that affect wound healing

- Site of the wound.
- Structures involved.
- Mechanism of wound injury:

1-Incision

2-Crush

3-Crush avulsion

- Vascularity:** A good blood supply (e.g. face & scalp) → rapid healing while poor supply (e.g. below knee) → delayed healing.

- Good vascularity of the edge (without tension or infection)→ proper wound healing & is the most important factor that affects wound healing

- Increase tension in the wound due to suture under tension, hematoma & infection → ischemia & impaired healing.

- Poor venous drainage e.g. post-phlebitis limb → delays wound healing.

-Infection:

- Bacteria compete with for fibroblast O₂ & nutrition.
- Bacteria secrete enzymes that destroy collagen.

-F.B. & necrotic tissue → prevent wound healing.

-Immobilization: Movement & shearing forces → damage of granulation tissues. Immobilization of the wound help healing.

-Adhesions of the wound to the bony surface (e.g. venous ulcer) → delay healing

SYSTEMIC FACTORS

1-Age of the patient

Increased age is a major risk factor for impaired wound healing due to a reduced rate of protein formation in addition to multiple existing comorbidities, there is a decrease in the body's inflammatory response.

2- Sex Hormones in Aged Individuals

Compared with aged females, aged males have been shown to have delayed healing of acute wounds. Studies indicate that estrogen can improve the age-related impairment in healing in both men and women, while androgens regulate cutaneous wound healing negatively

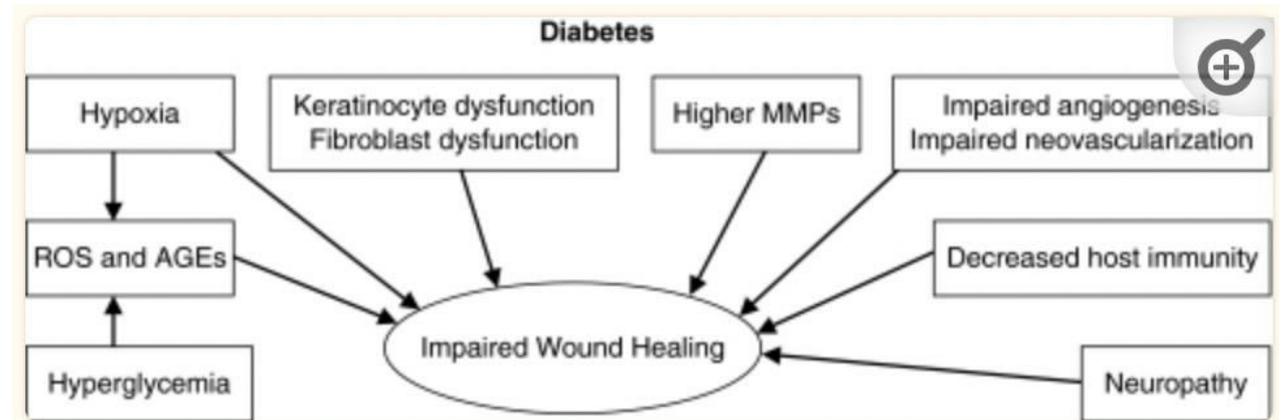
SYSTEMIC FACTORS

3- Nutritional factors

- Hypoproteinaemia → diminish formation of collagen & ground substance.
- Vitamin C deficiency → Lack of maturation of procollagen.
- Vitamin A deficiency → deficiency of epithelialisation.
- Deficiency of Ca, zinc, copper & manganese also affects wound healing.

4- Debilitating diseases such as: Renal failure, jaundice, cirrhosis, DM, malignancy and Atherosclerosis delay wound healing.

In Diabetic patients >> hypoxia, dysfunction in fibroblasts and epidermal cells, impaired angiogenesis and neovascularization, Also the neuropathy that occurs in diabetic individuals probably also contribute to impaired wound healing.



SYSTEMIC FACTORS

5-Medications such as Corticosteroids, cancer chemotherapy, radiation, and immunosuppressive drugs inhibit wound healing.

6-Immunocompromised conditions: cancer, radiation therapy, AIDS.

7-Alcohol Consumption: leads to impaired wound healing by impairing the early inflammatory response, inhibiting wound closure, angiogenesis, and collagen production, and altering the protease balance at the wound site.

8- Smoking: patients who smoke show a delay in wound healing and an increase in a variety of complications such as infection, wound rupture, anastomotic leakage, wound and flap necrosis, epidermolysis, and a decrease in the tensile strength of wounds

SYSTEMIC FACTORS

9- obesity

Obesity is well-known to increase the risk of many diseases and health conditions, which include coronary heart disease, type 2 diabetes, cancer, hypertension, dyslipidemia, stroke, sleep apnea, respiratory problems, and impaired wound healing. Obese individuals frequently face wound complications, including skin wound infection, dehiscence, hematoma and seroma formation, pressure ulcers, and venous ulcers.

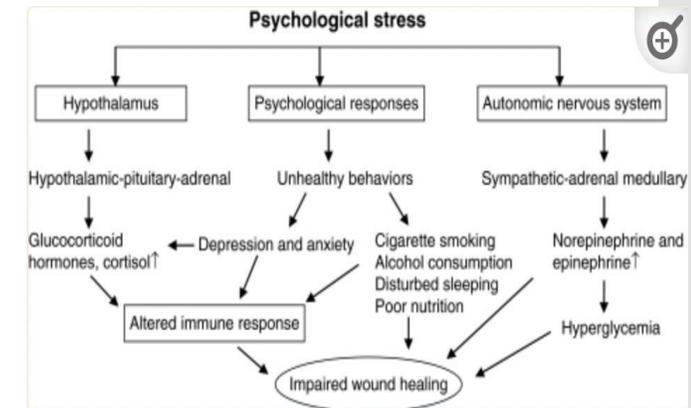
Summary of Factors Related to Wound Impairment in Obesity

| Local Wound Conditions | Associated Diseases and Conditions |
|--|------------------------------------|
| 1. decreased vascularity in adipose tissue | 1. hard to reposition |
| 2. skin folds harbor micro-organisms | 2. coronary heart disease |
| 3. friction caused by skin on skin | 3. atherosclerosis |
| 4. increased wound tension | 4. type 2 diabetes |
| 5. increased tissue pressure | 5. cancer |
| 6. hematoma and seroma formation | 6. hypertension |
| 7. venous hypertension | 7. dyslipidemia |
| | 8. stroke |
| | 9. respiratory problems |

10- stress

The pathophysiology of stress results in the deregulation of the immune system, mediated primarily through the hypothalamic-pituitary-adrenal and sympathetic-adrenal medullary axes or sympathetic nervous system

stressed individuals are more likely to have unhealthy habits, which include poor sleep patterns, inadequate nutrition, less exercise, and a greater propensity for abuse of alcohol, cigarettes, and other drugs.



Wound evaluation

- Before evaluating the wound itself, mainly when there are multiple injuries, remember to examine the whole patient according to acute trauma life support (ATLS) principles.
- According to that start with:
 - ** Primary survey and resuscitation → ABCDE
 - **Secondary survey → starts after resuscitation and stabilization through complete history and examination of the patient from head to toe.

Evaluation of the wound:

Identify the wound location.

Determine the cause of the wound

Evaluate foreign bodies or neoplastic processes.

Consider bacterial colonization versus acute/chronic infection.

Determine the stage of the wound.

Evaluate and measure the depth, length, and width of the wound.

Evaluate the wound bed for exposed bone, vessels, or subcutaneous fat.

Survey for presence, type, and amount of exudate.

Careful examination to detect any nerves, tendons, vessels, or bone injuries.

Observe pain

For all wounds on extremities, a careful neurovascular examination of the entire limb is mandatory.

Document findings and report unexpected results to the healthcare team.

**Tetanus prophylaxis and adequate analgesia.

Investigations that may help in wound management:

****Laboratory studies**

CBC (e.g., Hb, MCV, WBCs)

CRP, ESR

Specific test according to patient's medical condition and diseases (e.g., glucose and HbA_{1c} in diabetic patients).

Serum pre-albumin/albumin may be valuable in determining nutritional status.

****Imaging modalities**

Plain X-ray (evidence of fracture), Ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI).

****Wound biopsies**





Wound management

Clean the wound by saline irrigation, and sterile the skin around the wound with antiseptic

Tourniquet should be avoided (except in the hand).

Reduce tissue resistance to infection.

Exploration and diagnosis of injured structures.

Further management depends on the degree of Contamination, type of the wound, its depth, and injured Structures as follows:

1) Tidy Clean incised wound:

Primary suture (i.e., immediate suture in the same session of wound repair) of all layers including tendons and nerves.

If there is skin loss → primary grafting.



- 2) Untidy lacerated or crushed wounds:

- **a) Debridement of the wound:**

- Definition: Removal of foreign material and unhealthy ischemic or dead tissues which predispose to infection.
- Aim: is to convert a lacerated wound into one that approximates an incised wound.
- Rules of Debridement of a Wound:
 - Washing of the wound with saline.
 - Remove any foreign body.
 - Excise any devitalized skin. Don't excise too much skin.
 - If large important vessel: Suture or arterial graft according to the degree of injury.
 - If small vessel: Ligation or diathermy (e.g. one of the arteries of the forearm as radial or ulnar.)
 - Excise any devitalized muscles (dark, does not bleed, and does not contract on pinching) to guard against gas gangrene.



Nerves and tendons are examined, arranged, and approximated by black silk sutures to help their identification during secondary suture (after 3-6 weeks).

- Bone is often viable and any fragment should be replaced in position. Any fracture is treated by closed reduction & external fixation or external skeletal fixator, but open reduction & internal fixation is contraindicated due to the high risk of infection.
- In any contaminated wound or extensive tissue damage, the deep fascia is incised & left open to decompress the underlying structures (to prevent compartment syndrome).

b) The wound is left open with general antibiotic and local antibiotic powder and daily dressing with splinting of the part for 5 days.

c) After 5 days the wound is re-examined to determine further management:

➤ If the wound is clean:

If edema subsides and allows suturing without tension → delay primary suture is done.

If edema is severe → delayed primary graft even if there is no skin loss to avoid infections & suture under tension. After healing, tissue returns to normal, and the graft can be excised with suturing of normal skin.

➤ **If the wound is infected:**

Give general antibiotics according to culture and sensitivity.

After subsidence of inflammation → secondary suture is done and if there is skin loss → secondary graft can be done.

VACUUM ASSISTED CLOSURE/ NEGATIVE PRESSURE WOUND THERAPY

VACUUM ASSISTED CLOSURE/NEGATIVE PRESSURE WOUND THERAPY (NPWT)

- NPWT promotes wound healing by **applying a vacuum through a special sealed dressing**.
- Continued **vacuum draws out the fluid** from wound & **increases blood flow** to the area.
- **Vacuum** may be **applied continuously or intermittently**, depending upon the types of wound being treated & clinical objectives.
- **Negative pressure** of **-125 mm Hg^Q** is used.
- **Dressing** should be **changed 2-3 times/week^Q**

| Primary Effects of NPWT on Wound Healing | |
|---|--|
| Macrodeformation^Q | Drawing the wound edges together leading to contraction |
| Stabilization of wound environment^Q | Wound protected from outside micro-organisms in a warm & moist environment |
| Reduced edema^Q | With removal of soft tissue exudates |
| Microdeformation^Q | Leading to cellular proliferation on the wound surface |

| Contraindications for NPWT Use | |
|---|--|
| <ul style="list-style-type: none">• Malignancy in the wound^Q• Untreated osteomyelitis^Q | <ul style="list-style-type: none">• Non-enteric & unexplored fistula^Q• Necrotic tissue with eschar^Q |

Managing the acute wound

- Cleansing
- Exploration and diagnosis
- Debridement
- Repair of structures
- Replacement of lost tissues where indicated
- Skin cover if required
- Skin closure without tension
- All of the above with careful tissue handling and meticulous technique

The resources

Bailey&love's, short practice of surgery, 27th edition

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2903966/>

<https://www.ncbi.nlm.nih.gov/books/NBK482198/>

https://youtu.be/ydRr_YRo2gA

<https://www.lecturio.com/concepts/wound-healing/>