University of Mosul
Lecture No.: 6
College of Veterinary Medicine
Date:
Unit of Scientific Affairs
Website:

Lecture title: Orthopedics & Fractures
Second Semester of Academic year 2024-2025

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Fracture Healing

- Bone is one of the few tissues that can heal through its original tissue.

Types of fracture healing:

1. Direct Fracture Healing

- ❖ Direct fracture healing requires proper anatomical alignment of the fracture ends, with no gap present, as well as rigid and stable fixation of the fracture ends. When these conditions are met, direct healing of the fractured bone can occur through the direct remodeling of Haversian canals and blood vessels.
- ❖ New bone cells form via intramembranous ossification, without the formation of an external callus.
- ❖ Therefore, the primary objective of open anatomical reduction and internal fixation of the fracture ends is to achieve direct fracture healing. As such, direct healing typically does not occur in the natural healing process of most types of fractures.

2. Indirect Fracture Healing

- ❖ Indirect fracture healing (secondary healing) is the most common form of fracture healing. New bone formation occurs through both intramembranous and endochondral ossification.
- ❖ As a result, indirect healing does not require open anatomical alignment or rigid fixation, and the fracture ends are typically separated by a small gap with slight movement and load-bearing stress. However, excessive movement or weight-bearing can delay or prevent healing.

Secondary or Indirect Fracture Healing consists of the following stages:

1. Reactive phase (1-14 days)

a) Inflammatory and hematoma formation stage

- Immediately following the injury, blood vessels are disrupted at the fracture site, leading to hematoma formation.

b) Granulation tissue formation stage.

- The hematoma formed at the fracture site is rapidly infiltrated by fibroblasts and capillary buds originating from the surrounding soft tissues, the medullary cavity, and the endosteum. This process results in the progressive transformation of the hematoma into a mass of granulation tissue, which serves as a precursor to subsequent callus formation.

2. Reparative phase (2-6 weeks)

a) Soft callus formation

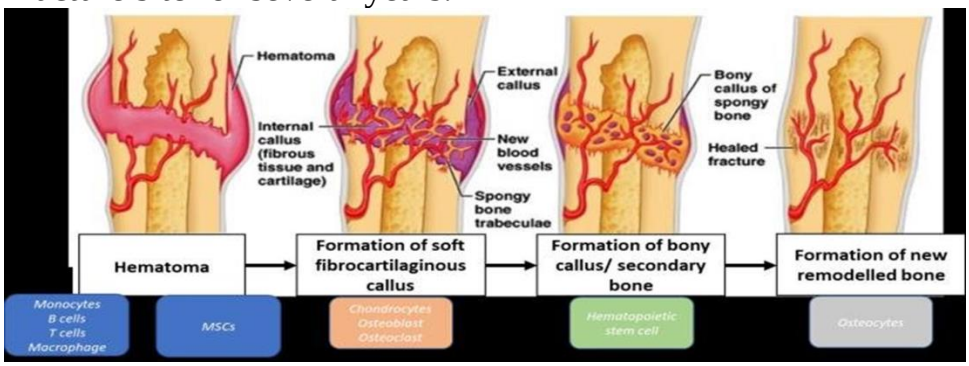
- Mesenchymal or undifferentiated cells which is originated from the endothelial cells of blood vessels, periosteum and adjacent external soft tissues converted either to chondroblast to form cartilage or osteoblast to form bone (woven bone) this depend on vascularity. This region of woven bone and new cartilage is referred to as the soft callus.

b) Hard callus formation

- The cartilage is gradually replaced by woven bone through the process of endochondral ossification. During this stage, mineralization occurs, with the deposition of mineral salts within the osteoid matrix, and rigidity to the newly formed bone.

3. Remodeling phase

- The remodeling phase represents the final stage of fracture healing, characterized by the replacement of woven bone with lamellar bone. This process involves the resorption of excess callus by osteoclasts and gradual reforming the fractured bone to the normal shape. This phase can persist at the fracture site for several years.



Factors affecting bone healing

1) Age: Fractures heal faster in young animals.
2) Type of bone: Faster healing in flat an cancellous bone.
3) Pattern of fracture: Oblique fracture heal faster than transverse.
4) Type of reduction: Accurate and good reduction results in faster healing.
5) Type of fracture: Open fracture often go into delayed healing or non union.

6) Type of immobilization: The surgeon must choose fixation method depends on the fracture site and type.

Complications of Fracture Healing

1) **Delayed Union**
2) **Non-union**
3) **Malunion**
4) **Osteomyelitis.**

Complications Not related to the bone union:

1) **Myositis ossificans**
2) **Avascular necrosis**
3) **Joint stiffness**
4) **Osteoarthritis**

Delayed union

- Delayed union occurs when a fracture takes longer time than expected to heal but still shows some progression.

Causes of delayed union:

1) Inadequate reduction.
2) Inadequate immobilization.
3) Lack of blood supply.
4) Infection.
5) Loss of fragment bone.
6) Systemic or local disease.

Clinical signs of delayed union include:

1) Little pain at the fracture site.
2) No bony crepitus.
3) The bone may show abnormal shape.

Radiological signs of delayed union:

1) The fracture line is evident with some feature of healing (The fracture site has irregular appearance)
2) Callus formation is minimal.
3) Medullary canal is opened
4) Absence of sclerosis. (Sclerosis: Refers to the hardening or increased density of bone)

Treatment of delayed union

- Before treatment, it's crucial to identify factors delaying healing, such as: Poor blood supply; Infection (osteomyelitis); Inadequate stabilization; Poor nutrition (calcium, phosphorus, vitamin D deficiency) or Systemic diseases (e.g., Cushing's disease, diabetes).

Treatment Strategies

- Improve Fracture Stability by External Fixation use external skeletal fixator (ESF). or by Internal Fixation – Plate and screw fixation or intramedullary pins may be needed to Bone Grafting
- Stimulate Bone Healing by using Low-intensity pulsed ultrasound (LIPUS) or electrical stimulation can enhance osteogenesis or uses a Platelets-Rich Plasma (PRP), Platelets Rich Fibrin (PRF) Growth factors, may promote bone repair.