Bone Healing

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Principles of Fracture Treatment

1. Reduce:

Can be anatomical reduction (as original anatomy, e.g. for intra-articular fractures to minimize secondary osteoarthrosis) or functional (restoring acceptable length, alignment, and rotation of bone, e.g. shaft fractures. The acceptable amount of deviation from original anatomy depends on fracture site and age of the patient).

Principles of Fracture Treatment

2. Hold:

Stabilize your reduction by a brace, cast, metal, etc. This can result in either absolute stability (does not allow any movement at the fracture site), or relative stability (allows minimal movement at the fracture site).

Principles of Fracture Treatment

3. Mobilize

Start moving or rehabilitating the injured site. The timing to start mobilization depends on the stability of the fixation.

The aim is to start as early as the fracture stability and healing allow in order to avoid possible complications such as joint stiffness.

Fracture Healing

- Fracture healing is a normal biological process.
- For a fracture to heal properly it needs:

1. Good blood supply.
2. Stability of the fracture site (either absolute or relative).
3. Good bony opposition (no interposed soft tissue between the fracture pieces).

Types of Fracture Healing

1) Secondary bone healing (also called indirect bone healing or bone healing through the generation of a fracture callus).
2) Primary bone healing (also called direct bone healing).

- These types of bone healing are observed in cortical and in cancellous bone .

Types of Fracture Healing

- Secondary bone healing is seen with fractures held by a method resulting in relative stability (e.g. cast, sling, k-wires, intramedullary nails, etc.).

- Primary bone healing is only possible with:
  1. Fracture gap of less than 2 mm
  2. Motion at the fracture site of less than 1 mm or possibly only a few micrometers (absolute stability).

Secondary Bone Healing

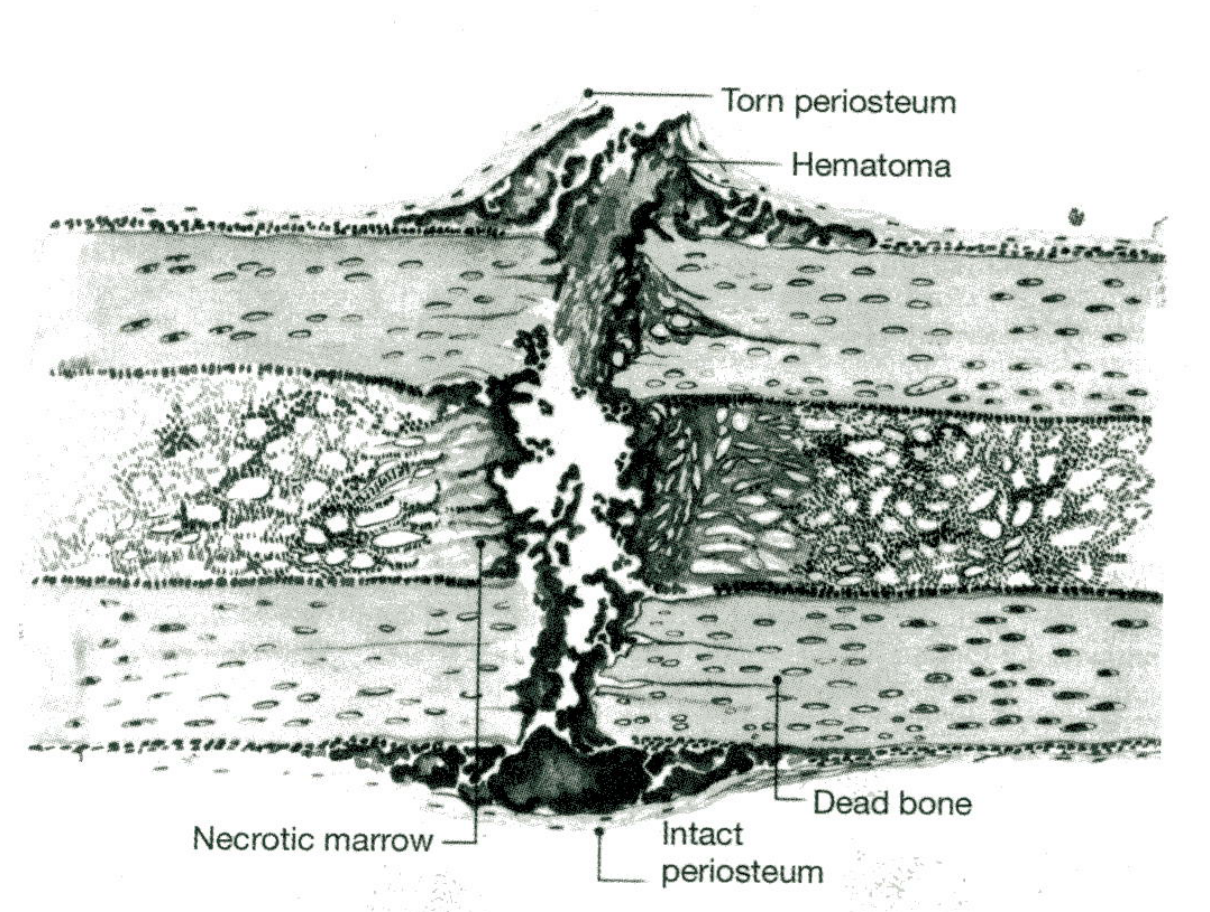
This type of healing occurs in fractures treated by methods resulting in relative stability (most of long bone shaft fractures).

It has 4 stages:

1. Hematoma formation and inflammation
2. Soft callus
3. Hard callus
4. Remodeling

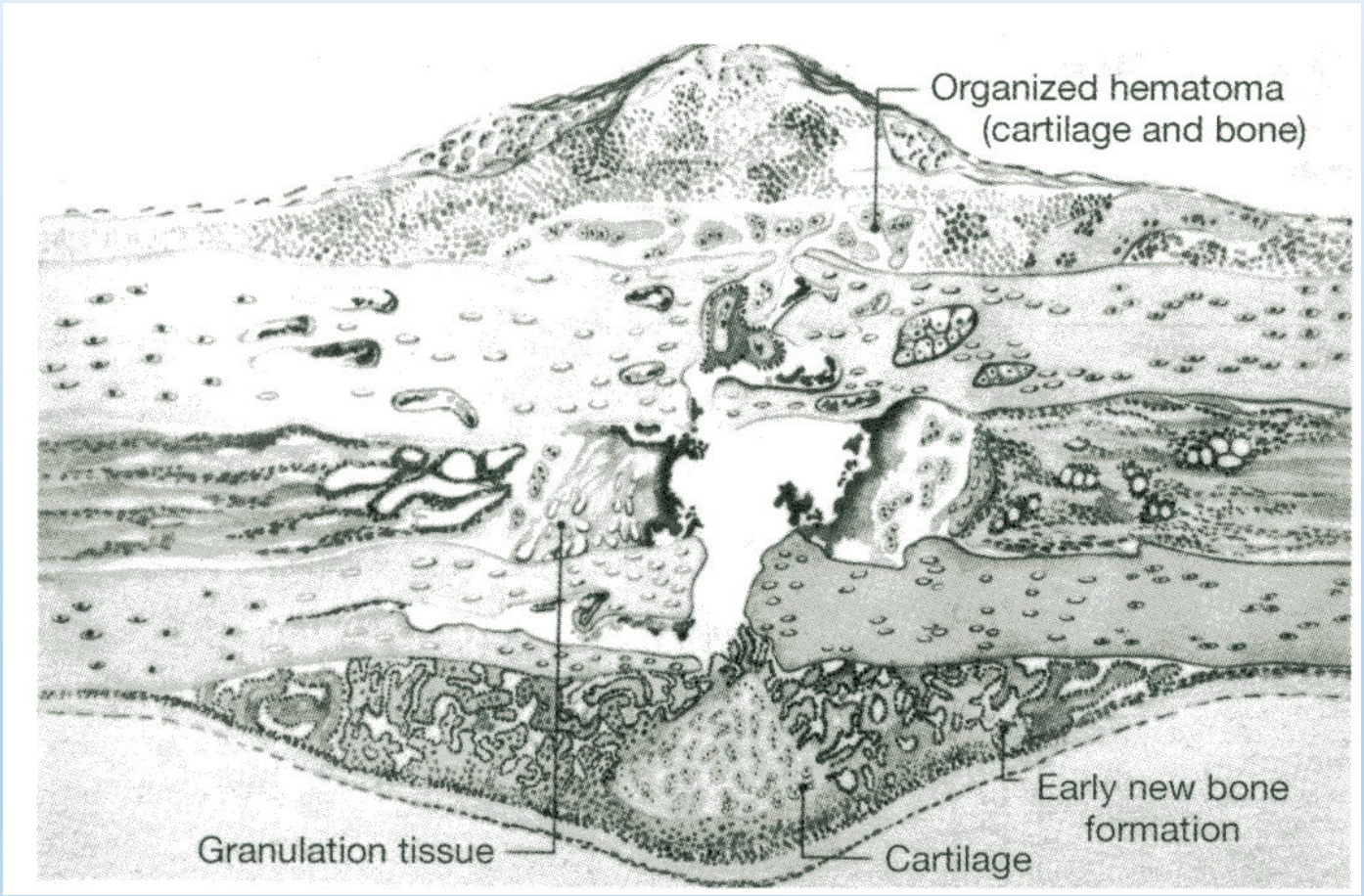
Hematoma formation and inflammation

- Hematoma with necrosis of bone ends from ischemia.
- Necrotic material releases cytokines:
  - attracts macrophages.
  - Promotes neovascularization
- Granulation tissue produced.


Torn periosteum
Hematoma
Dead bone
Necrotic marrow
Intact
periosteum

Formation of the fracture callus

- Fibroblasts, chondroblasts, and osteoblasts invade granulation tissue.
- Fibrous tissue is **replaced** by cartilage (soft callus, fracture becomes sticky) then **replaced** by bone (hard callus/ woven bone).
- Bone healing between fracture ends resembles endochondral ossification.


Organized hematoma
(cartilage and bone)
Granulation tissue
Cartilage
Early new bone
formation

Remodeling:
Restoration of normal structure and pattern

- Progressive mineralization of the woven callus and its protuberant shape facilitates early load and weightbearing .

- But still suboptimal:
  - High cellularity and water content.
  - Amorphous arrangement of collagen fibers.
  - Patchy pattern of matrix mineralization.

Remodeling:
Restoration of normal structure and pattern

- The callus is replaced gradually with *lamellar bone* (according to stresses applied upon it).

- Osteoclastic resorption, removes extraneous peripheral bone that is not necessary for optimal mechanical function.

Primary Bone Healing

This type of healing occurs in fractures treated by methods resulting in absolute stability (most intra-articular fractures where stability is required to start early mobilization in order to avoid stiffness).

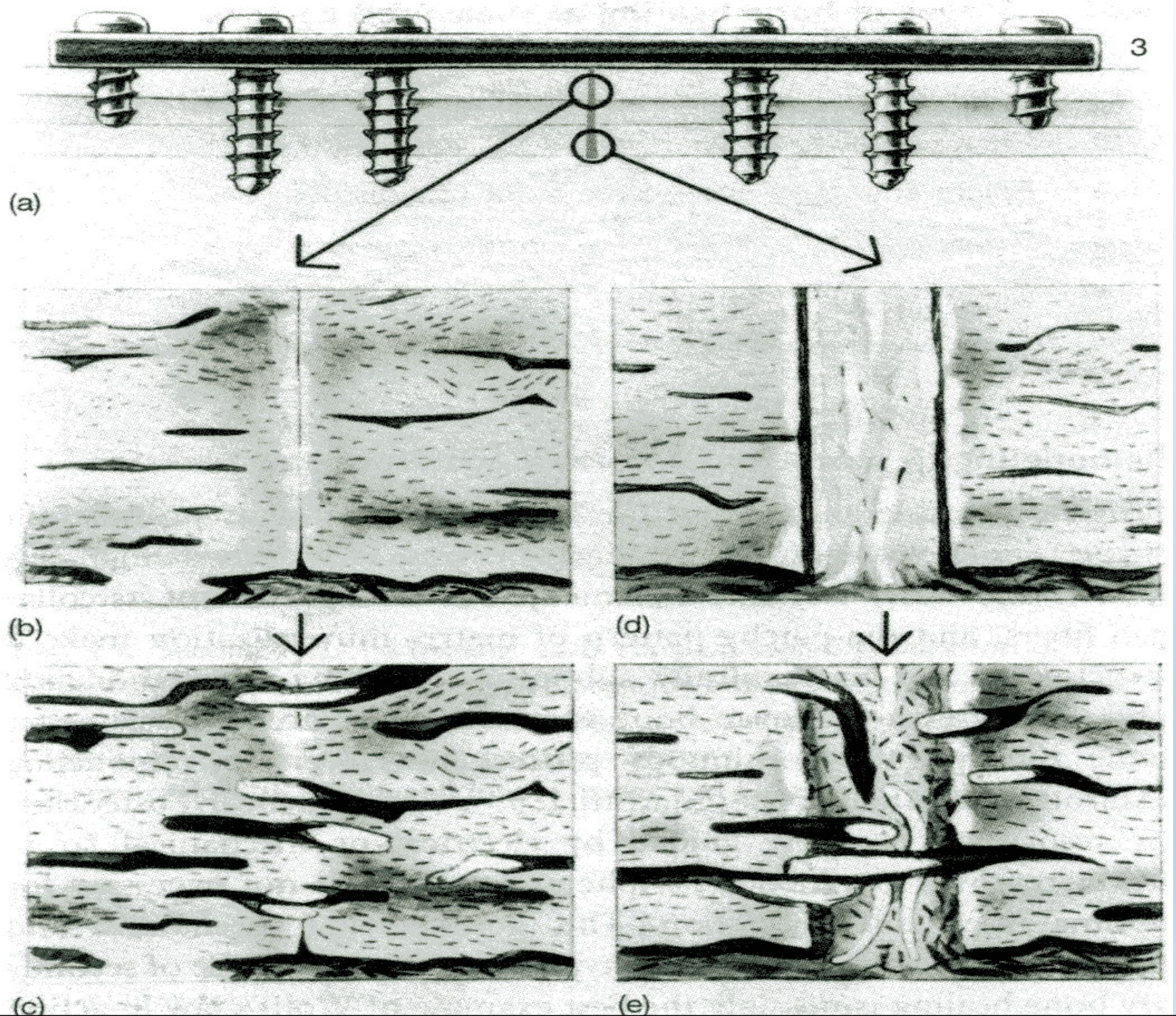
- The immediate stability gained by surgical fixation, facilitates early motion at adjacent joints.
- The massive callus formation is **absent**.
- Gradual disappearance of the small fracture lines.

Primary Bone Healing

- A temporary acceleration of the Haversian remodeling.
  - ➢ Responsible for the perpetual turnover of the skeleton.
  - ➢ Continuous process of coupled bone resorption and bone formation.
  - ➢ Carried out by bone metabolizing units.

Primary Bone Healing

- Bone metabolizing units, at the frontal end, contain **cutting cones**
  - Lined by multicelluar osteoclasts.
  - Linear rate of bone resorption 50ųm/ day.
- Behind them, walls of osteons are lined by osteoblasts
  - Oppose new osteoid at 1ųm/day


(a)
(b)
(d)
(c)
(e)

Primary Bone Healing

- Seen in:

Absolutely stable fractures

e.g. lag screws

compression plates

tension band wiring

N.B. all other fracture fixation methods result in relative stability, and thus indirect (secondary bone healing).

Complications of fracture healing

1. Malunion:

Good healing but in an inappropriate position thus compromising function.

Treatment: osteotomy (surgically breaking the bone) and fixation in the correct position.

Complications of fracture healing

2. Nonunion:

2 types; hypertrophic where the problem lies in inadequate stability of the fracture site (gross mobility so the callus is formed but cannot hold the ends together),

And atrophic where the problem lies in inadequate vascularity at the fracture site causing necrosis at the fracture ends and minimal capacity fo r the fracture to heal.

Hypertrophic Nonunion

Hepertrophic fracture ends on the radiographs (elephant foot or horse hoof appearance).

Treatment: surgical stabilization of the fracture.

Atrophic Nonunion

No callus formation is seen, in long standing cases pencil like appearance of the fracture ends on the radiograhps could be seen.

Treatment: debridement of the necrotic bone ends, bone grafting, and fixation.