BONEHEALING PROCESS

TERMINOLOGIES

- Mesenchymal cells: Multipotent stromal cells that can differentiate into a variety of cell types.
- Fusiform: sphindle shaped
- Electronegativity: tendency to attract the shared pairs
- Cancellous bone: meshwork of spongy tissues(trabaculae)eg ,mandible, maxillae, flat bone of pelvis, end of long bones.

- Cortical bone: outer structure of bone.
- Medullary cavity: innermost cavity of bone
- PDGF: Platelet derived growth factor
- TGF-Beta: transforming growth factor
- FGF: Fibroblast growth factor

Introduction

- Fracture is a break in the structural continuity of bone.
- The healing of fracture is in many ways similiar to the healing in soft tissue wounds except that the end result is mineralised mesenchymal tissue i.e. BONE.
- Fracture healing starts as soon as bone breaks and continues modelling for many years

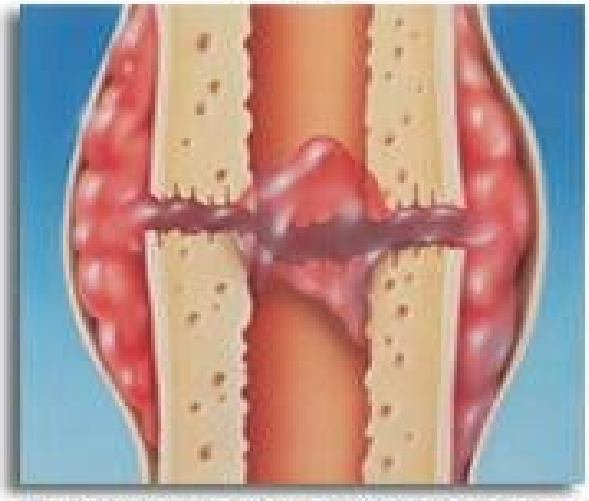
- Bone is unique in its ability to repair itself.,it can completely reconstitute itself by reactivating processes.
- Bone repair is a highly regulated process that can be seperated into overlapping histologic,bio-chemical & bio-mechanical stages.
- The completion of each stage initiates the next stage and this is accomplished by a series of interactions and communications among various cells and proteins located in healing zone.

Pathology & Staging

- The events in the process of fracture healing can be divided into 3 phases.
- 1.Inflammation Phase
- 2.Reparative Phase
- 3.Remodelling Phase

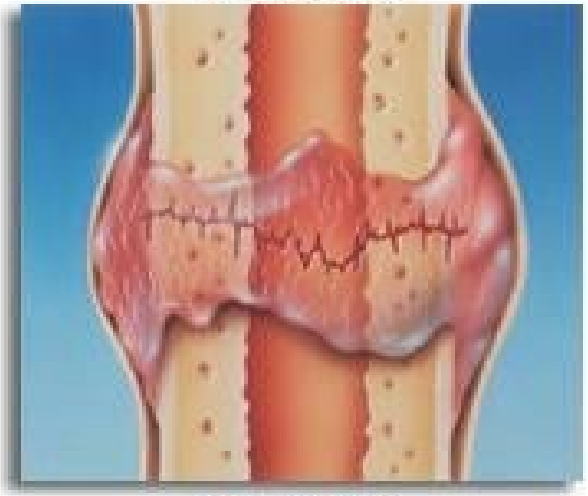
Fracture Healing Process

Week 1



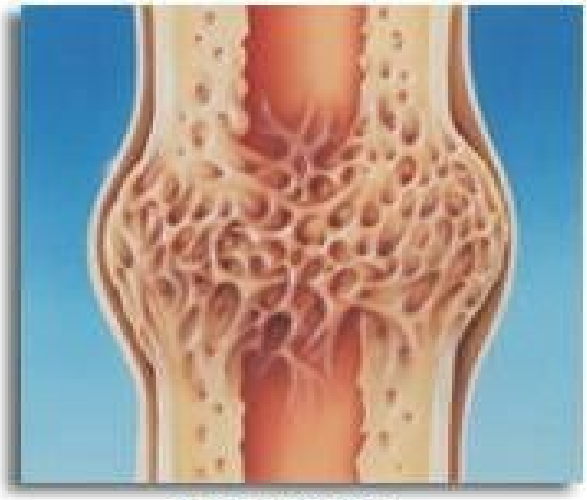
Hematoma (or Inflammation)

Weeks 2-3



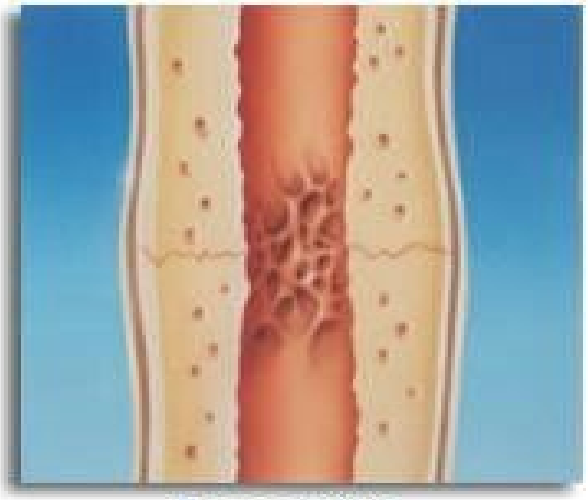
Soft Callus

Weeks 4-16



Hard Callus

Weeks 17 & Beyond



Remodeling

- Inflammation begins immediately after injury and is followed rapidly by repair.
- After repair has replaced the lost and damaged cells and matrix,a prolonged remodelling phase begins.

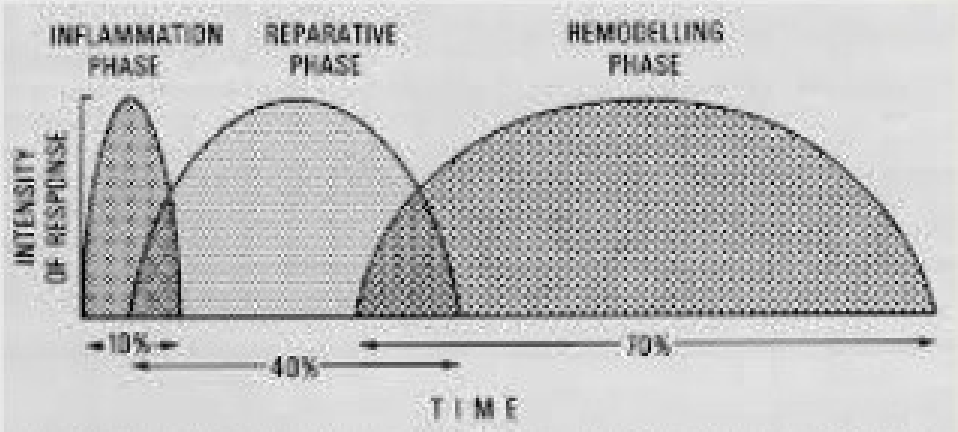
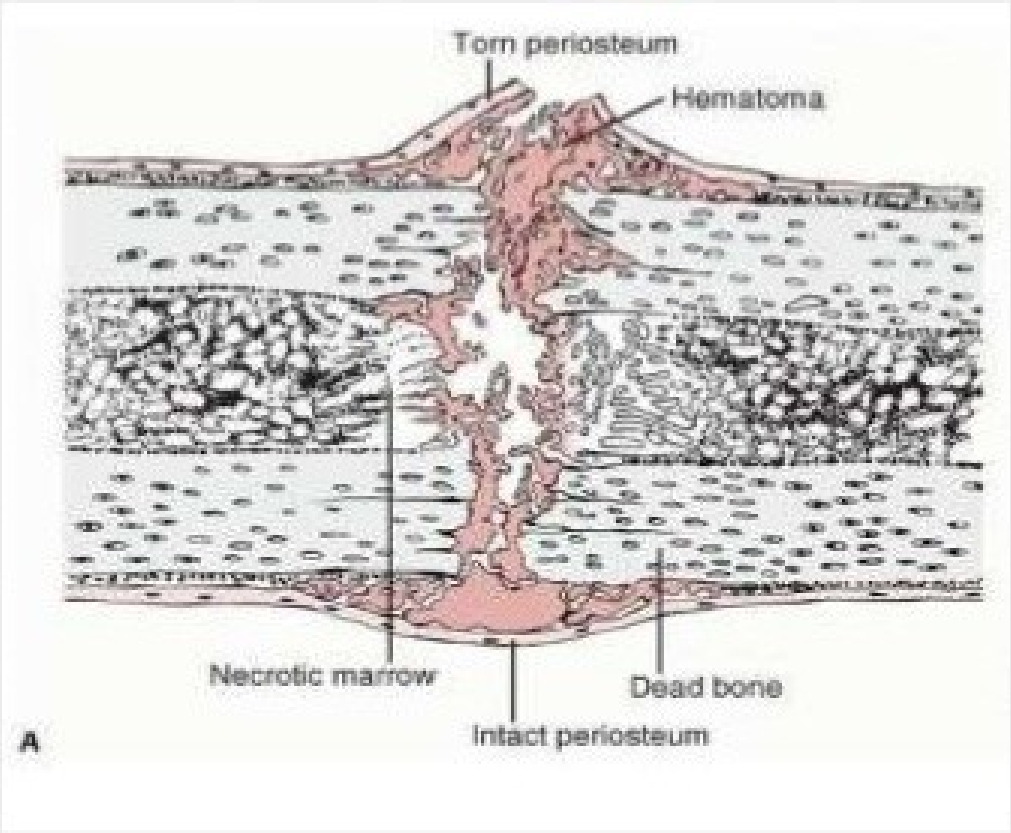


FIG. 3-1 An approximation of the relative amounts of time devoted to the inflammation, reparative, and remodeling phases in fracture healing. (Cruess RL, Dumont J: Healing of bone, tendon, and ligament. In Rockwood CA, Green DP (eds): Fractures, p 97. Philadelphia, JB Lippincott, 1975)

Inflammation Phase

- An injury that fractures bones damages not only the cells,blood vessels and bone matrix,but also the surrounding soft tissue including the periosteum and blood vessels.
- Immediately after fracture,rupture of blood vessels results in hematoma which fills the fracture gap and also the surrounding area.
- The clotted blood provides a fibrin mesh which helps seal off fracture site and allows the influx of inflammatory cells and ingrowth of fibroblasts & new capillary vessels.

Initial events following fracture of a long bone diaphysis

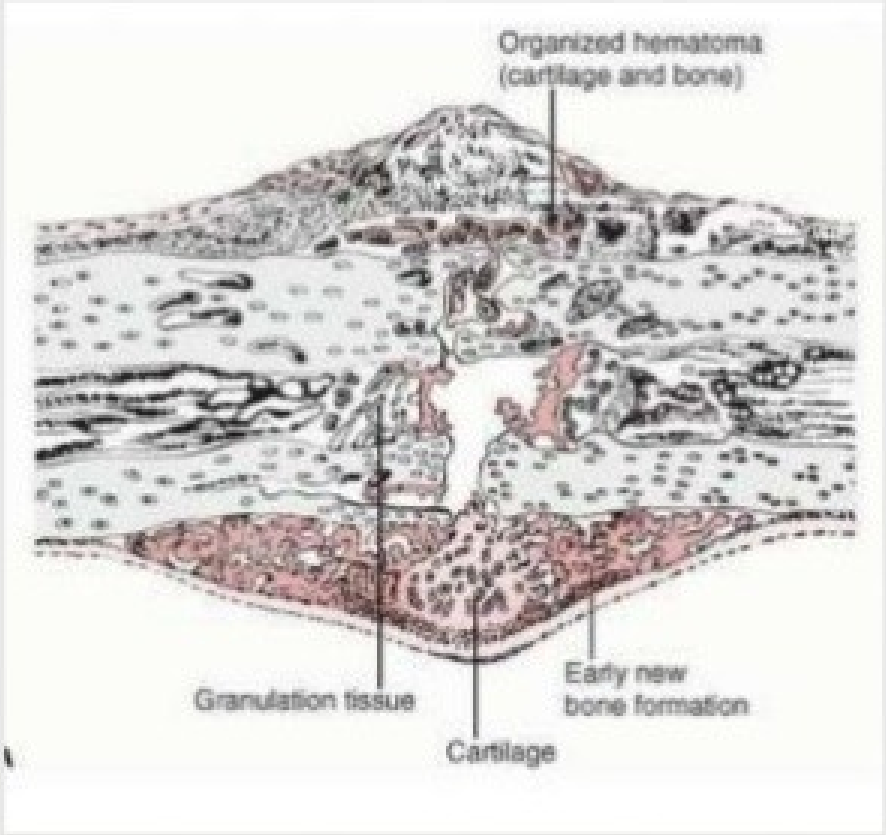


- The degranulated platelets and migrating inflammatory cells release PDGF, TGF-BETA, FGF and other cytokines,which activates the osteoprogenitor cells in the periosteum,medullary cavity,and surrounding soft tissues and stimulate the production of osteoclastic and osteoblastic activity.
- Thus by the end of first week,the hematoma is organizing,the adjacent soft tissue is being modulated for future matrix production.
- This fusiform & predominantly uncalcified tissue called ***soft tissue callus or procallus*** provides some anchorge between ends of fractured bones but offers no structural rigidity for weight bearing.

Reparative Phase

- The inflammatory cells releases the cytokines that stimulate angiogenesis.
- As the inflammatory response subsides,necrotic tissue and exudate are reabsorbed and fibroblasts and chondrocytes appear and start producing a new matrix,the fracture callus .
- Electronegativity found in the region of fresh fracture may also simulate the osteogenesis.

Early repair of a diaphyseal fracture of a long bone

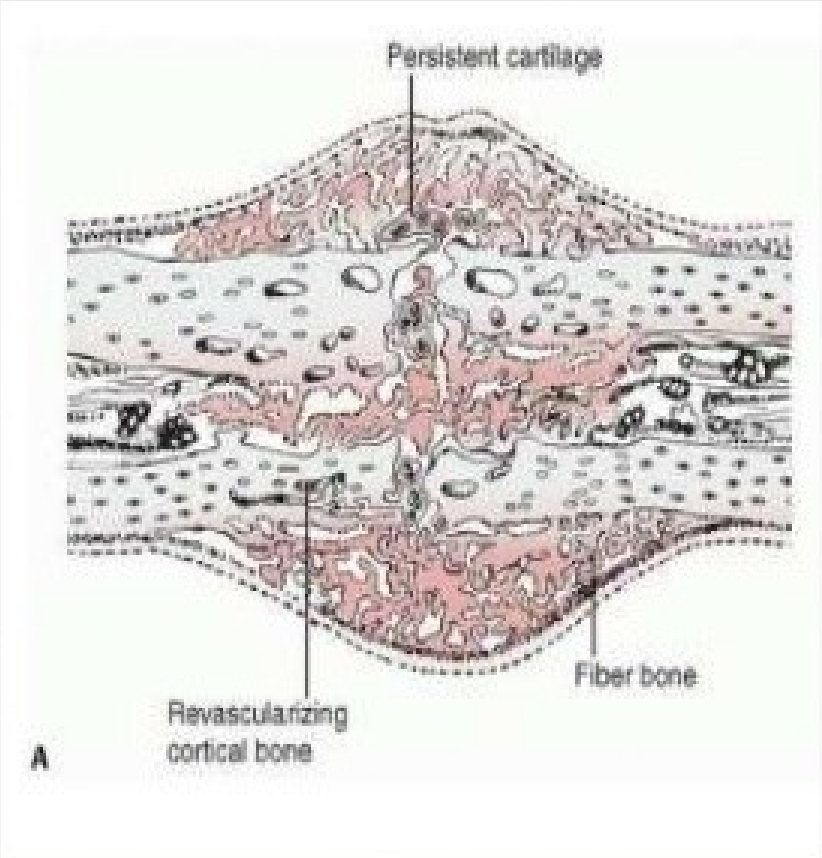


- The activated osteoprogenitor cells deposit sub-periosteal trabeculae of woven bone oriented perpendicular to cortical axis and within the medullary cavity.
- In some cases the activated mesenchymal cells in soft tissue and bone surrounding the fracture line also differentiate into chondroblasts that make fibrocartilge and hyaline cartilage.
- The newly formed cartilage undergoes enchondral ossification forming a network of bone
- In this fashion,the fractured ends are bridged by a bony callus and as it mineralizes,the stiffness and strength of callus increase to point where controlled weight bearing can be tolerated.

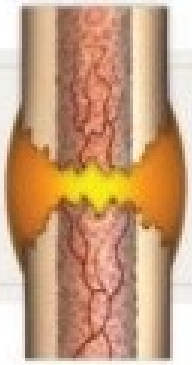
Remodelling Phase

- As the callus matures and transmits weight-bearing forces,the portions that are not physically stressed are reabsorbed,and in this manner the callus is reduced in size until the shape and outline of fractured bone has been reestablished.
- The medullary cavity is also restored.

Progressive fracture healing by fracture callus

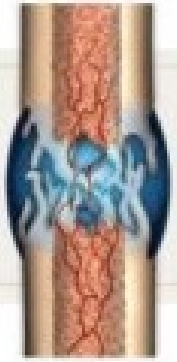


Healing



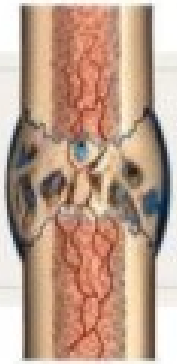
Inflammation

Soon after a fracture occurs, a hematoma forms at the injury site. Macrophages and inflammatory leukocytes move into the damaged area to scavenge debris and begin producing the pro-inflammatory agents that initiate healing.



Soft callus

Inflammation triggers cell division and the growth of new blood vessels. Among the new cells, chondrocytes secrete collagen and proteoglycans, creating fibrocartilage that forms the soft callus.



Hard callus

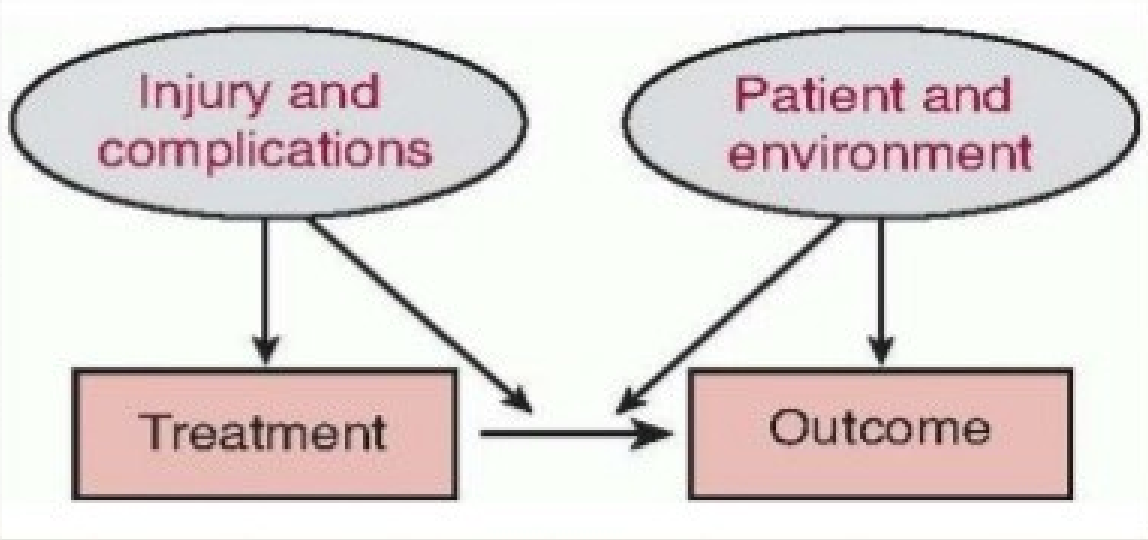
Through endochondral ossification and direct bone formation, woven bone replaces the soft callus to create a hard callus around the broken fragments of bone.

Remodeling

Over time, mechanically strong, highly organized cortical bone replaces the weaker, disorganized woven bone. Because it is continually remodeled, bone is the only tissue to heal without a scar.

Factors influencing osteogenesis

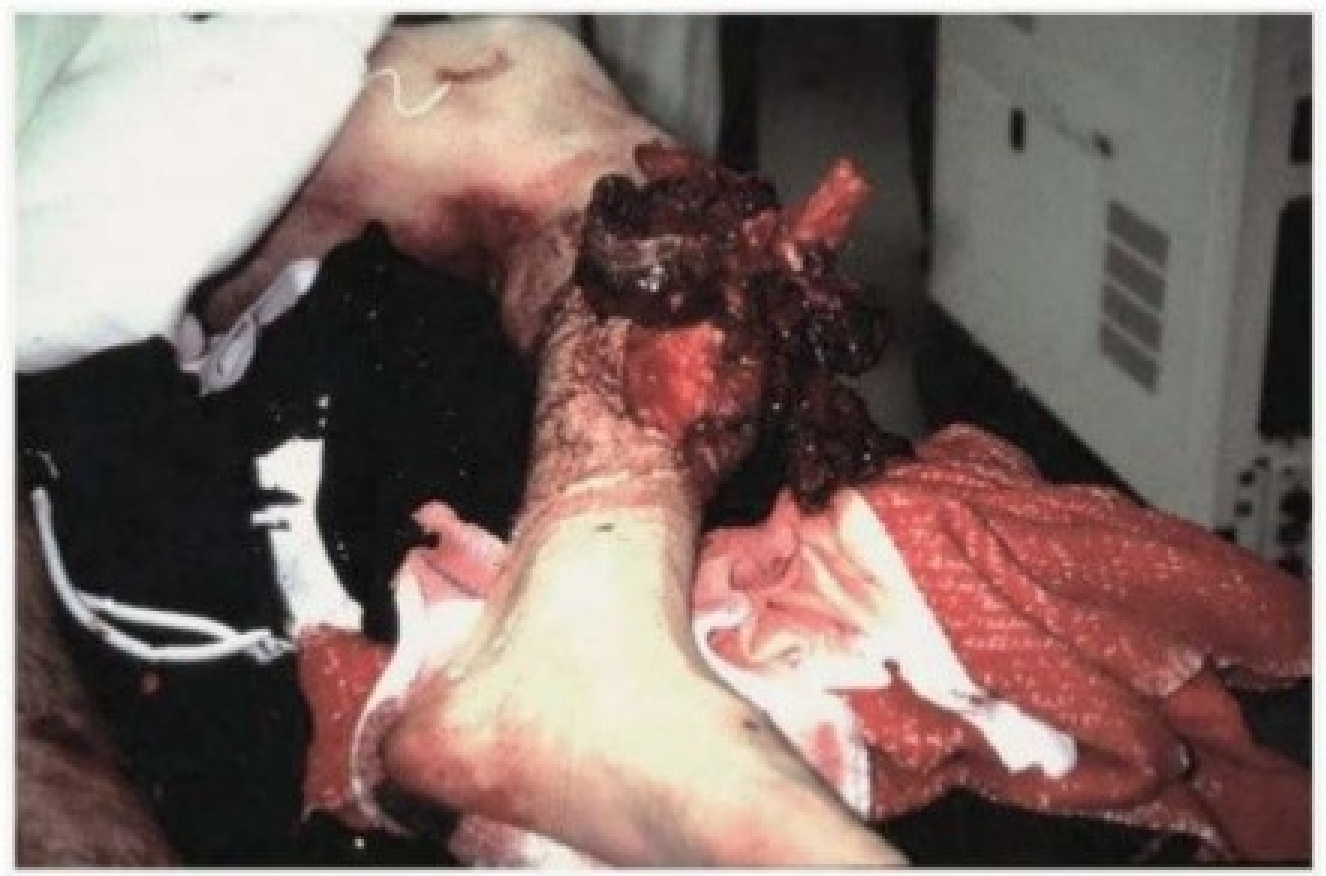
1. Injury variables
2. Patient variables
3. Tissue variables
4. Treatment variables



1.Injury varibles

- I).OPEN FRACTURES:-
- Severe open fractures cause soft tissue disruption, fracture displacement, and, in some instances, significant bone loss.
- Extensive tearing or crushing of the soft tissue ***disrupts the blood supply*** to the fracture site, leaving necrotic bone and soft tissue, impeding or preventing formation of a fracture hematoma, and delaying formation of repair tissue

Open fracture



- II).SEVERITY OF INJURY:-
- They may be associated with large soft tissue wounds, loss of soft tissue, displacement and comminution of the bone fragments, loss of bone, and decreased blood supply to the fracture site.
- Comminution of bone fragments usually indicates that there is also extensive soft tissue injury.

- Displacement of the fracture fragments and severe trauma to the soft tissues retard fracture healing, probably because the extensive tissue damage increases the volume of necrotic tissue, ***impedes the migration of mesenchymal cells*** and vascular invasion, decreases the number of viable mesenchymal cells, and disrupts the local blood supply.

- III).INTRA-ARTICULAR FRACTURES:-
- Because they extend into joint surfaces and joint motion or loading may cause movement of the fracture fragments, intra-articular fractures can present with challenging problems.
- Most intraarticular fractures heal, but if the alignment and congruity of the joint surface is not restored, the joint may be unstable, and,in some instances, especially if the fracture is not rigidly stabilized, healing may be delayed or nonunion may occur.

- IV).SEGMENTAL FRACTURES:-
- A segmental fracture of a long bone impairs or disrupts the ***intramedullary blood supply*** to the middle fragment.
- If there is severe soft tissue trauma, the periosteal blood supply to the middle fragment may also be compromised.,possibly because of this, the probability of delayed union or nonunion, proximally or distally, may be increased.
- These problems occur most frequently in segmental fractures of the tibia, especially at the distal fracture site.

- V).SOFT TISSUE INTERPOSITION:-
- Interposition of soft tissue, including muscle, fascia, tendon, and occasionally nerves and vessels, between fracture fragments compromises fracture healing.
- Soft tissue interposition should be suspected when the bone fragments cannot be brought into apposition or alignment during attempted closed reduction.
- If this occurs, an open reduction may be necessary to extricate the interposed tissue and achieve an acceptable position of the fracture.

- VI).DAMAGE TO BLOOD SUPPLY:-
- Lack of an adequate vascular supply can significantly delay or prevent fracture healing.
- Insufficient blood supply for fracture healing may result from a severe soft tissue and bone injury or from the normally limited blood supply to some bones or bone regions.
- For example, the vulnerable blood supplies of the femoral head,scaphoid, and talus may predispose these bones to delayed union or nonunion, even in the absence of severe soft tissue damage or fracture displacement.

2.Patient Variables

- I)AGE:-
- Infants have the most rapid rate of fracture healing.
- The rate of healing declines with increasing age up to skeletal maturity, but after completion of skeletal growth the rate of fracture healing does not appear to decline significantly with increasing age, nor does the risk of non-unions significantly increase.
- The rapid bone remodelling that accompanies growth allows correction of a greater degree of deformity in children.

- II)NUTRITION:-
- The cell migration and proliferation and matrix synthesis necessary to heal a fracture require substantial energy.
- Furthermore, to synthesize large volumes of collagens, proteoglycans, and other matrix macromolecules, the cells need a steady supply of proteins and carbohydrates, the components of these molecules.
- As a result, the metabolic state of the patient can alter the outcome of injury, and in severely malnourished patients, injuries that would heal rapidly in well nourished people may fail to heal.

- III).SYSTEMIC HORMONES:-
- A variety of hormones can influence fracture healing.
- Corticosteroids may compromise fracture healing possibly by inhibiting differentiation of osteoblasts from mesenchymal cells and by decreasing synthesis of bone organic matrix components necessary for repair.
- Prolonged corticosteroid administration may also decrease bone density and compromise the surgeon's ability to achieve stable internal fixation, leading to nonunion.

- The role of growth hormone in fracture healing remains uncertain.
- Thyroid hormone, calcitonin, insulin, and anabolic steroids have been reported in experimental situations to enhance the rate of fracture healing.
- Diabetes, hypervitaminosis D, and rickets have been shown to retard fracture healing in experimental situations.
- Nicotine and nicotine products(cigarette smoking) inhibits fracture healing.

3.Tissue Variables

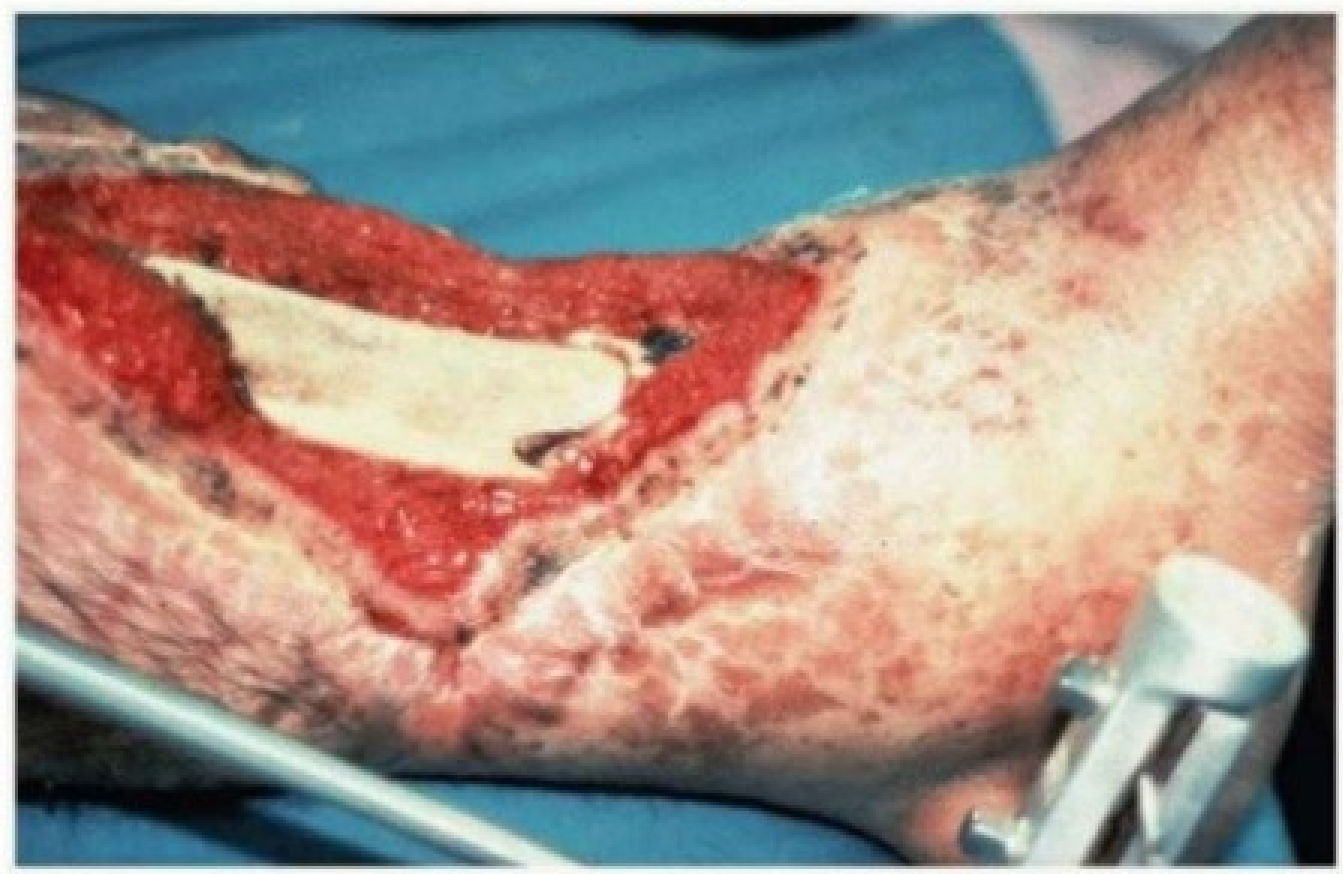
- I)FORM OF BONE(CORTICAL OR CANCELLOUS):-
- Healing of cancellous and cortical fractures differs probably because of the differences in surface area, cellularity and vascularity.
- Opposed cancellous bone surfaces usually unite rapidly., possibly because the large surface area of cancellous bone per unit volume creates many points of bone contact rich in cells and blood supply and because osteoblasts form new bone directly on existing trabeculae.

- In contrast, cortical bone has a much smaller surface area per unit volume and usually a less extensive internal blood supply, and regions of necrotic cortical bone must be removed before new bone can form.

- II)BONE NECROSIS:-
- Normally, healing proceeds from both sides of a fracture,but if one fracture fragment has lost its blood supply, healing depends entirely on ingrowth of capillaries from the living side or surrounding soft tissues.
- If a fracture fragment is avascular the fracture can heal***, but the rate is slower*** and the incidence of healing is lower than if both fragments have a normal blood supply.

- If both fragments are avascular, the chances for union decrease further.
- Traumatic or surgical disruption of blood vessels, infection, prolonged use of corticosteroids, and radiation treatment can cause bone necrosis.

Bone necrosis after a severe open tibia fracture with failure of soft tissue coverage



- III)BONE DISEASE:-
- Fractures through bone involved with primary or secondary malignancies usually do not heal if the neoplasm is not treated.
- Subperiosteal new bone and fracture callus may form,but the mass of malignant cells impairs or prevents fracture healing,particularly if the malignant cells continue to destroy bone.

- Fractures through infected bone present a similar problem.
- Thus, healing of fractures through malignancies or infections usually requires treatment of the underlying local disease or removal of the involved bone.
- Depending on the extent of bone involvement and the aggressiveness of the lesion, fractures through bones with nonmalignant conditions like simple bone cysts and Paget's disease will heal.

- The most prevalent bone disease, osteoporosis, does not impair fracture healing, but where there is diminished surface contact of opposing cortical or cancellous bone surfaces because of decreased bone mass, the time required to restore normal bone mechanical strength may be increased.

- IV)INFECTION:-Infection can slow or prevent healing.
- For fracture healing to proceed at the maximum rate, the local cells must be devoted primarily to healing the fracture.
- If infection occurs after fracture or if the fracture occurs as a result of the infection, many cells must be diverted to attempt to wall off and eliminate the infection and energy consumption increases.
- Furthermore, infection may cause necrosis of normal tissue, edema, and thrombosis of blood vessels, thereby retarding or preventing healing.

4.Treatment Variables

- Apposition of fracture fragments,decreasing the fracture gap decreases the volume of repair tissue needed to heal a fracture.
- Restoring fracture fragment apposition is especially important.
- Fracture stabilization by traction, cast immobilization, external fixation, or internal fixation can facilitate fracture healing by preventing repeated disruption of repair tissue.

- Some fractures (e.g., displaced femoral neck and scaphoid fractures) rarely heal if they are not rigidly stabilized. Fracture stability appears to be particularly important for healing when there is extensive associated soft tissue injury, when the blood supply to the fracture site is marginal, and when the fracture occurs within a synovial joint

THANK YOU