# 8- Principles of Fractures

## Objectives:

- Introduction.
- Basic science of fracture healing.
- Principles of evaluating patients with fractures.
- Principles of management.
- Common fractures in adults.

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**References:** Slides, 435 team, Notes

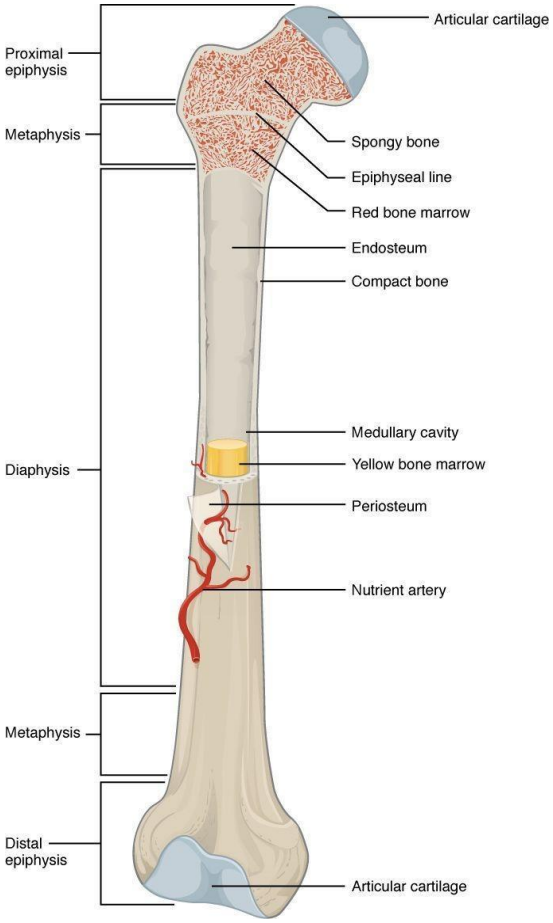
# Basics Review (Extra)

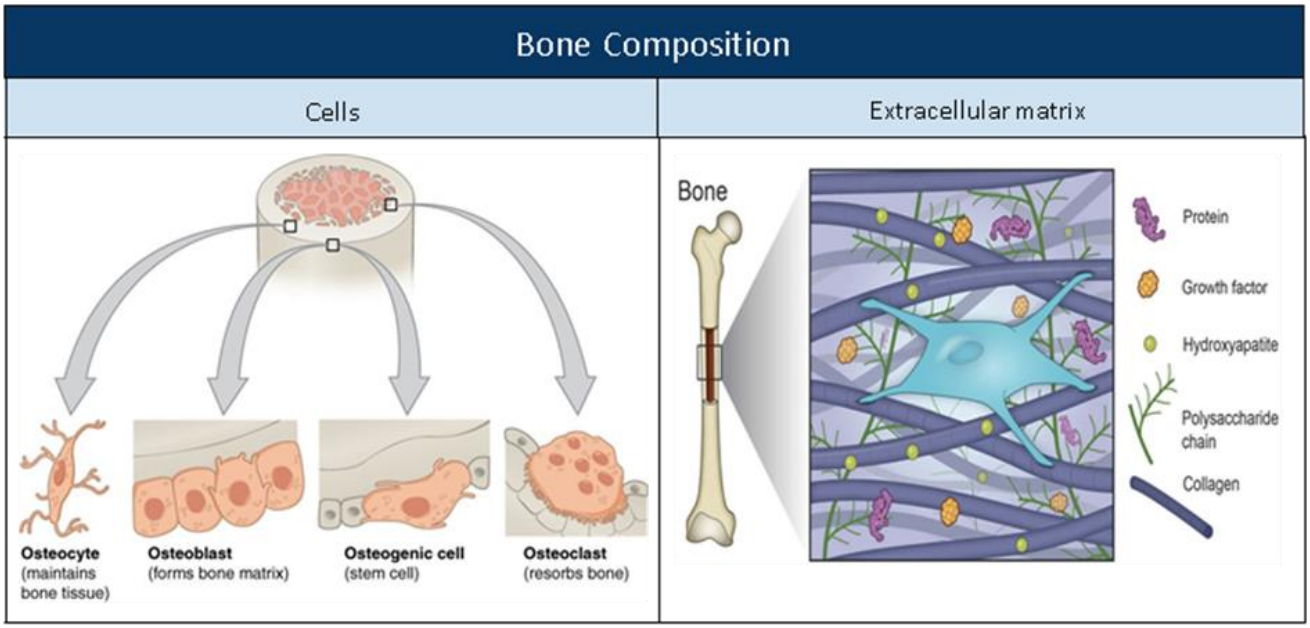
## ★ Bone structure, types & composition:

**1. Lamellar Bones (Dense):**
They're composed of collagen fibers arranged in parallel layers and they're found in the diaphysis part of normal adult long bones. The basic functional unit of lamellar bones is called an Osteon or "Haversian System".

**2. Cancellous Bones (trabecular or spongy bone):**
They're less dense and more elastic than lamellar bones. They're found in the **metaphysis** part of small bones.

**3. Woven Bones**
They're coarse bones with random orientation. They're also weaker than lamellar bones. In bone healing, they're eventually remodeled to lamellar bones.



# Introduction

- **Definition of fracture:** means literally broken bone.
- **Description of fractures:** in different ways:
  A. Extent complete or incomplete
  B. Location
  C. Morphology shape of the fracture
  D. Mechanism high energy (suspicion of other injuries) vs. low energy
  E. Associated soft tissue injuries open or closed fracture

## A. Extent:

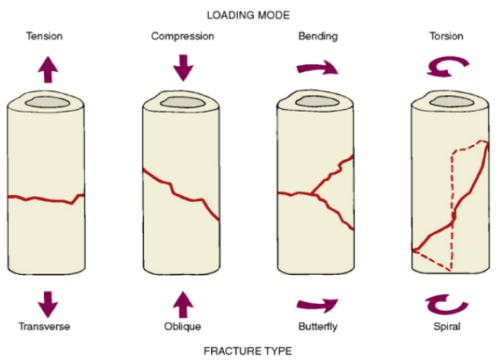
| **Complete** | **Incomplete (**other cortex is intact**)** | |
|---|---|---|
| Fracture that extends 360° of bone circumference (all around). | Seen almost only in children because they have elastic bone such as: | |
| | Greenstick fracture<br>If you try to break greenstick it will not break because it's **elastic** = children have elastic bones. Still can happen in adults if there is certain mechanism of injury. | Buckle (torus) fracture التواء/طعجة<br>Not a complete break just a deformity. it's also common in children<br>Manage by Below elbow cast. |
|  |  |  |

## B. Location:

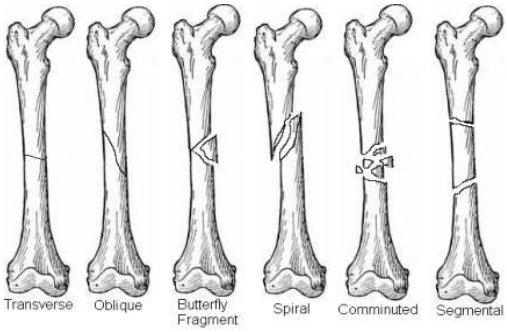
- **Name** of bone.
- **Side** (Right or Left).
- Diaphysis (shaft), metaphysis (=flare or Cancellous Bones) or epiphysis.
- **Long** bones (diaphysis): divide them in thirds (proximal, middle or distal third).
- Metaphysis: intra-articular ( affect the growth plate and cause under deformity either shortening or leg length discribency, risk of osteoarthritis) vs. extra-articular (no risk of OA)
- Intra-articular metaphyseal fractures carry the **risk of osteoarthritis** especially if fracture is displaced more than 2mm or the gap is more than 2 mm -> the management will aim to restore normal joint.
  - Sometimes it includes epiphysis and metaphysis, and this has special classification you will take in pediatrics.

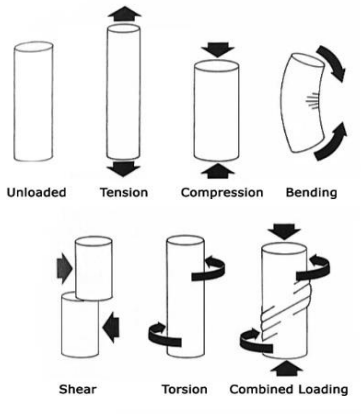
## C. Morphology:

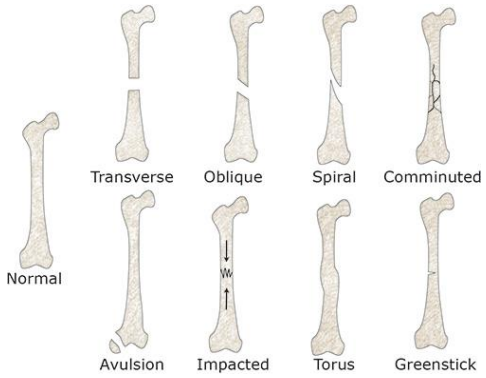
- **Transverse:** loading mode resulting in fracture is tension. Avulsion results in transverse fracture (the bone fails under tension). The mechanism of **transverse is direct trauma.**
- **Oblique:** loading mode is compression from both ends. There is 2 types 1- short oblique 2- long oblique, in short oblique the diameter of the bone is equal to length of fracture line, but in long oblique the fracture line is **double** the diameter of the bone. Ex: If the bone diameter is 1 mm and oblique fracture line is 1.5 mm then still short oblique. But if it is 2 mm then long oblique.



- **Spiral:** loading mode is <u>torsion</u> or rotation or twisting. (Usually occurs in sports & pediatric age group).
- **Wedge (fracture with <u>butterfly</u> fragment):** loading mode is <u>bending</u>. (1 piece)
- **Comminuted:** 3 or more fragments, usually results from <u>high</u> energy trauma.
- **Segmental:** a fracture in <u>two parts</u> of the same bone.




*Extra photos for understanding*

"**Segment**" is a big piece of bone that is broken from above and below and disconnected from the rest. Segment can be comminuted if there is comminution around the fracture site or can be a simple segmental fracture. **Wedge** is broken but there is contact on one side.
These 2 fractures represent high energy trauma. Segmental, wedge or any other fracture can be comminuted also.

**#Why is it important to know the morphology of a fracture?** To classify fractures to **stable** and **instable**.
**Instable fractures**: long oblique, short oblique, comminuted, spiral… → may need surgical intervention because of risk of displacement.
**Stable fractures:** transverse fracture → can be treated non-operatively.

## D. Mechanism

- **High energy vs. Low energy** (In high energy accidents, soft tissue injuries are expected e.g. RTA and risk of multiple trauma). Low energy trauma usually one isolated injury, Ex. fall in bathroom causing femur neck fracture. In high energy trauma we save the life first then limb then its function (ATLS)
- **Multiple injuries vs. isolated injury** usually high energy can cause multiple injuries or polytrauma isolated injury but still even if you're exposed to high energy you can end up with isolated injury**.**
- **Pathological fracture:** Normal load in presence of weakened abnormal bone density (tumor, osteoporosis, infection). Weakened bone breaks easily by low energy trauma.
- **Stress fracture: <u>Normal</u>** <u>bone</u> subjected to **<u>repeated</u>** load (military recruits/athletes) usually it will be incomplete small fractures.

## E. Associated soft tissue injuries (most important is skin integrity)

- **Closed fracture:** skin integrity is maintained (intact).
- **Open fracture:** fracture is exposed to external environment. Whenever there is soft tissue break at or near the fracture site, it is considered open fracture until proven otherwise. It is an emergency red flag with different management (ER or OR management). The clinical significance of opened fracture is <u>infection</u> because the bone is exposed to the non-sterile external environment.
- Signs: **continuous bleeding** from puncture site "the blood source is the bone marrow which is highly vascular" or **fat droplets** in blood are suggestive of an open fracture.
  **(Any skin breach in proximity of a fracture is an open fracture until proven otherwise)**

# Fracture Healing

## ★ Natural bone healing:

### 1. Secondary/indirect bone healing:

Called indirect because of formation of cartilage at an intermediate stage. The process occurs in nature with untreated fracture through endochondral ossification (occurs in **fractures with gap**). It runs in **4 phases**:

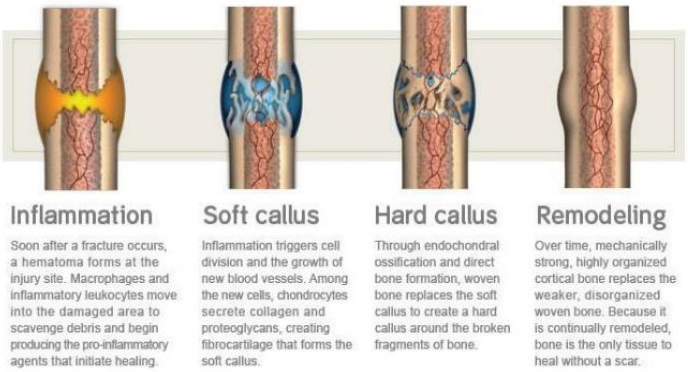
1. **Hematoma formation *(Inflammation phase)*** (1-2 weeks)
   In this phase, there is disruption of the blood vessels, migration of cells occurs, and coagulation begins.

2. ***Soft Callus*** (2-3 weeks)
   In this phase, cascade of cellular differentiation occurs, angiogenesis takes place, and fibroblasts produce granulation tissue that eventually evolves into fibrocartilage.
   the most important cells: fibroblasts, cartilage cells and with time they will calcify resulting in hard callus. You see a patient with fracture; on x-ray you don't see anything, but clinically there is a firm lump on the fracture site, which stage of healing? → Soft callus. If you start seeing calcification or ossification so this is hard callus.

3. ***Hard Callus*** (3-12 weeks) ¾
   In this phase, endochondral ossification converts soft callus into **woven bone**. The process starts at the periphery and then moves centrally. It continues until there is no more movement.

4. ***Remodeling*** (Years) (reshaping the bone) In this phase, the **woven bone** that was formed is converted into **lamellar bone.**

it's the process of reshaping of bone. if the bone is broken and healed in wrong position with time it will remodel and will correct, remodeling depends on how much left of the patient growth, so it is more in pediatric patient (takes a year to year and a half. If you have significant deformity and the pt. is 4 y/o After 2-3 years, the deformity will disappear). In other words, Is there a difference between remodeling in pediatrics and adults? Yes, if you're an adult you're not growing anymore. If you are 18 years old or older there wouldn't be any remolding potentials. You might have local remodeling: the cortex will thin out and the canal might recanalize but the deformity itself will not be corrected. So, if you see a pediatric patient with a fracture that is angulated or mal-aligned there is certain angulation that you accept because you know that the body will take care of by remolding.




### 2. Primary/Direct bone healing:

It can happen if no motion takes place. Bone is formed without intermediate stage through the "Cutting cone mechanism". This mechanism works only if the fracture is < 1mm gap. (No gap must be in fracture site).

## ★ In summary there are two types of bone healing:

- **Endosteal/primary/direct:** when the two fracture surfaces come in contact without overlapping.
- **Endochondral/secondary/indirect:** when there is overlap or bridging or displacement or angulation between the two fracture surfaces.

# Principles of Fractures Evaluation

## ★ History:

Patients complain of pain and inability to use the limb (if they are conscious and able to communicate)

**What information can help you make the diagnosis?** pain >> SOCRATES

- **Onset:**
  - When and how did the symptoms begin?
  - Specific traumatic incident vs. gradual onset?
- **If there was a specific trauma, the details of the event are essential information:**
  - Mechanism of injury? (gives clue if high/low energy trauma)
  - Circumstances of the event? Work-related? was it in the farm -different from clean area in case of open fractures.
  - Severity of symptoms at the time of injury and progression after?
- **If you suspect a pathological fracture, you must:**
  - Ask about prior pain before event happened?
  - Ask about constitutional symptoms?
  - Ask about history of cancer?
- **If you suspect stress fracture, ask about:**
  - Recent increment of activities?

Also: history gives a clue about the previous clinical picture (before the fracture), and helps us know wither the person needs sick leave from their job.

## ★ Physical exam:

- **Look (Inspection):**
  - Swelling.
  - Ecchymosis.
  - Deformity Muscle wasting/ wounds/ Skin changes/ break in the skin

- You must describe the deformity.
- If fracture is open:
  - Bleeding.
  - Protruding bone.
- **Feel (Palpation):**
  - Bony landmarks, temperature and pulses.
  - Bony tenderness.
- Examine joint above and below and if high energy trauma must examine from head to toe! Remember save life then limb then function.
- **Move:**
  - ROM (**Cannot** be assessed in acute fracture).
  - Move is not important in fractures→ painful. However, if there is subtle fracture like stress fracture, we need to ask the patient to move but in general if there is obvious.
  - Fracture it's not done. There are no special tests for trauma.

### If a fracture is suspected what should we rule out? Red flags

- Neurovascular injury (N/V exam) distal to the fracture.
- Compartment syndrome.
- Associated MSK injuries (by examining joint above and below at minimum).
- Open fracture/ infection is too early to happen, it happens later.
- Cauda equina syndrome in spine fracture.
- Pelvic fracture in cases of polytrauma (can cause life-threatening bleeding). Patient can lose 2 L of blood if he has femur fracture/ he can lose his whole blood in pelvic fractures. What are the life threatening

injuries in the pelvis? Open book injury → symphysis is disrupted. In normal pelvis, it can take up to 3 liters however in an open book pelvis, it can take up to 6 or 7 liters. So, you must close it down to minimize the volume.

# Investigations:

X-ray pic: AP view spiral left humerus fracture at mid-shaft (unstable)

## ★ Imaging:

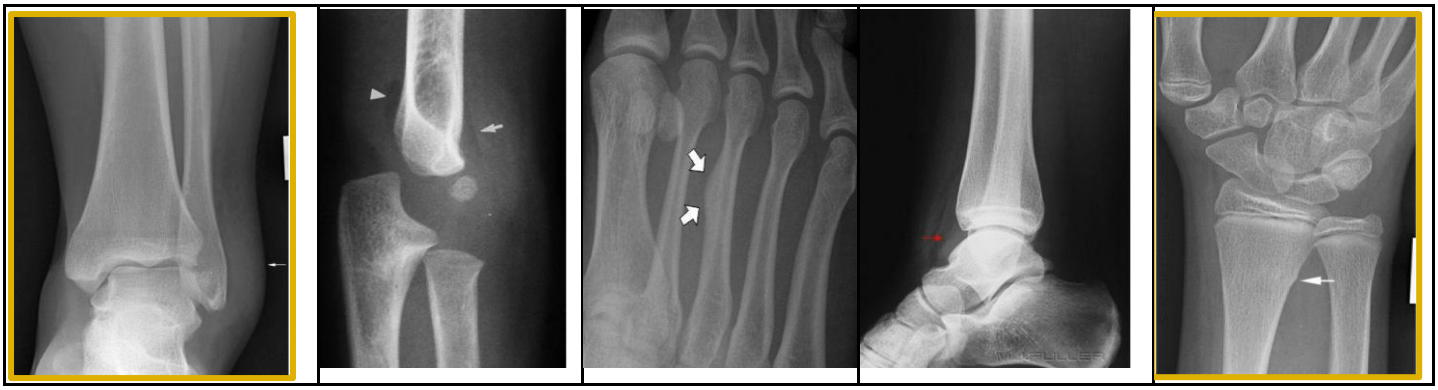
**X-ray five principles:**

1. Two orthogonal views:
   - AP (for displacement): will tell you if there is distal (lateral or medial) displacement related to proximal fragment.
   - Lateral (for Angulation): Lateral view will tell where the angulation is, is it posterior or anterior, volar or dorsal.
2. Two joints – above and distal why?
   - To see extend of fracture (intra-articular or extra-articular).
   - To see if joint lines of the two joints above and below are parallel to each other then that means there is no rotation so no need to realign the limb.
3. Two limbs – to compare in pediatric fracture. In children there is growth plate what is not a fracture, so you need to compare.
4. Two occasions. Use it for scaphoid fracture (initially looks normal but immobilize and repeat after 2 weeks and you will see fracture hematoma and the bone will be resolved). Also use it if you suspect infection (repeat after 2 weeks) or stress fractures.
5. Special View. Especially if ligamentous injury is suspected ( because plain x-ray without stress will not show any diastasis or ligamentous injury). It is painful so we give the patient anesthesia or analgesia to relax him. Also there is MRI but usually it's not available early at the time of fracture or trauma management.

NB: fractures hurt, immobilization helps. Immobilizing a patient in a back slab is the most effective way to relieve pain from a fracture and may be done BEFORE getting x-rays. Immobilize joint above and joint below.

If the patient has an obvious fracture, do you send the patient to X-ray before you splint or after you splint? **We splint it before (black slap including joint above and below**). What is the most important function of splint? Immobilize and stabilize the fracture, prevent vascular injury and prevent further soft tissue damage and minimize pain. If you have motion at the fracture site and you don't stop it, it will cause more soft tissue injury and therefore more swelling.

| ***Secondary* signs of fracture on X-ray** (if fracture isn't obvious look for these signs to help you find it) | | | | |
|---|---|---|---|---|
| Soft tissue swelling<br>you can differentiate between subcutaneous tissue, muscles and bones (3 have different densities) | Fat pad signs<br>(Capsule filled with blood) | Periosteal reaction<br>Usually we can't see it in the beginning you can see it after 2 weeks in the healing process. | Joint effusion<br>you can see swelling in front or behind the joint.<br>You should always correlate clinically | Cortical buckle* |



Which type of plaster would you use in acute trauma? Don't use fiberglass because it dries quickly and doesn't allow hematoma to expand so higher risk of compartment syndrome and is difficult to remodel. So, it is better to use plaster of Paris since it takes 24 hours to dry.

**Differences between plaster of Paris and fiberglass:**

| plaster of Paris | fiberglass |
|---|---|
| Dry slowly (Take 24 hours) | Dry fast (within 20 minutes) |
| Heavy | Stronger and lighter |
| | Does not allow the hematoma to expand, so high risk of com syndrome. |
| Allow you to remodel the fracture (because the inner la dry yet). | Does not allow you to remodel the fracture |
| Cheaper | More expensive |

**Advanced radiological images should be considered:**

- If fracture extends to joint -> obtain CT scan

If fracture is suspected but not seen on x-ray -> MRI

# How to describe a fracture? (important)

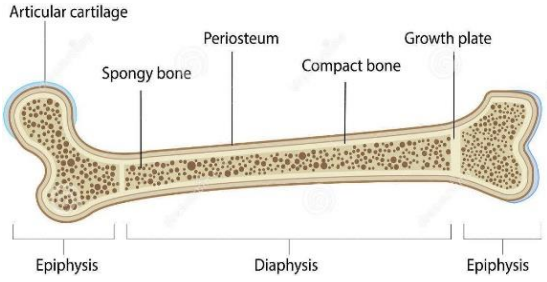
## 1. Clinical parameters

- Open vs. closed (ANY break in the skin in proximity to the fracture site is OPEN until proven otherwise) know the difference in ER and OR management for open and closed fractures.
- Neurovascular status.
- Presence of clinical deformity.
- Compartment syndrome

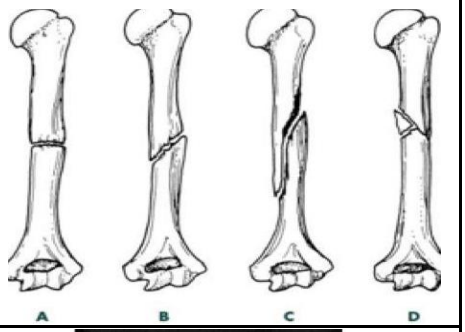
## 2. Radiographic parameters

**Location**

- Which bone?
- Which part of the bone?
  - Epiphysis – intraarticular?
  - Metaphysis
  - Diaphysis - divide into 1/3s
- Use anatomic landmarks when possible
  e.g. medial malleolus, ulnar styloid, etc




# How to describe a fracture? Important

| | |
|---|---|
| **Pattern** | • Simple vs. comminuted<br>• Complete vs. incomplete<br>• Orientation of fracture line:<br>**A: transverse,**<br>**B: oblique,**<br>**C: spiral,**<br>**D: comminuted** (butterfly fracture)<br>  <br> |
| **Displacement** | • Displacement "الإزاحة " is the opposite of apposition "contact" both described in percentages (%).<br>• Position of distal fragment relative to proximal. we describe distal because the proximal fragment is fixed to the body.<br>  <br>• Expressed as a percentage. Then compare it with post reduction x-ray 100% displacement = no bone contact. You can use percentage just better to describe the distance.<br>• Sometimes you have displacement with no angulation. |
| **Angulation** | • Angulation is the deviation from normal alignment.<br>• It's described depending on its apex (The apex of both fragments defines direction of angulation).<br>• It's expressed in degrees.<br>  <br>Dorsal angulation<br>If you have AP view you can see medial or radial angulation/ if you have lateral view you see either anterior "volar" or posterior angulation "dorsum".<br>You need to know the degree of angulation to manage the fracture. |
| **Shortening** | ــــــ |

★ Treatment Principles: Four: reduce, immobilize, do definitive treatment, rehabilitate.

1. ***Reduction (if necessary):***
   - If fracture is displaced.
   - Meant to realign fracture fragments.
   - To minimize soft tissue injury.
   - Can be considered definitive if fragments' position is accepted. If reduction is acceptable, we can put a cast and that would be a definitive treatment. If not, we can put a temporary splint and later we can treat the patient in a definitive way.
   - Should be followed by immobilization.
   - To maximize healing potential.
   - To ensure good function after healing.

**Always rule out open fracture before reduction**

The purpose of reduction in extraarticular fractures is realignment. Ex. If the patient has proximal tibia fracture in varus position and we didn't align it back then more pressure will be on the knee medially (OA risk).

2. ***Immobilization (definitive or temporary):*** Immobilization is a broad word. Can be anything from cast all the way to hardware and surgery.

- To hold reduction in position.
- To provide support to broken limb
- To prevent further damage.

- **Control the Pain**
- to prevent motion that may interfere with union
- to prevent displacement or angulation of fracture

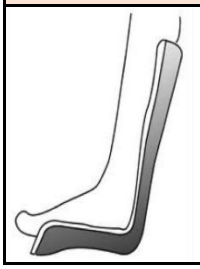
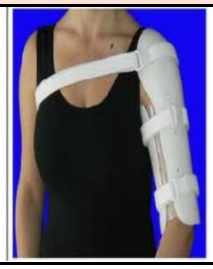
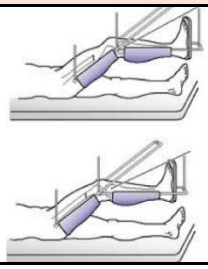
- Definitive immobilization is for stable fractures (eg. Transverse) whereas if unstable fracture (like oblique fractures) explain for the patient I will give you a try closed reduction if it works then we might consider open reduction (surgical).
- Adult fractures in general needs fixation.
- Another indication for surgical fixation is multiple trauma, compartment syndrome, vascular injury.
- For any fracture you must immobilize a joint above and below + know the force that caused a fracture.

**Example**: if you have 3 patients with proximal, middle and distal forearm. In which position (neutral, pronation or supination) will you put the cast? نحط الكاست عكس العضلة المتضررة

**Answer:**

- in the patient with proximal forearm fracture the form of force is the supinator muscle then put cast with supination position.
- in the patient with middle forearm fracture the form of force is pronator longus muscle so put the cast with neutral position.
- in the patient with distal forearm fracture the form of force is pronator quadratus muscle so put the cast with pronation position.

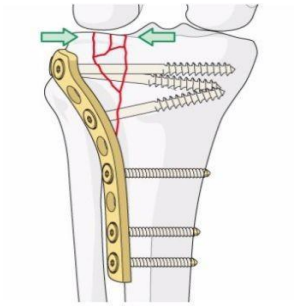
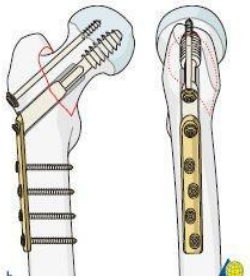
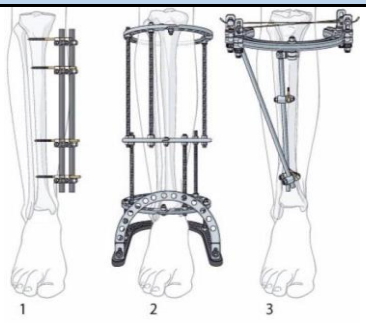
**Why?** This will help you keep the fracture in place (not displaced).

| **Examples of** temporary **immobilization methods** | | | | | |
|---|---|---|---|---|---|
| Back Slab | Brace | Skin Traction | Skeletal Traction | Sling | Complete Cast |
|  |  |  |  |  |  |

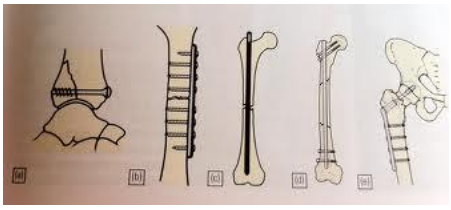
- **Skin traction**: it is an adhesive tape around the fractured limb. use it for short period ex: transfers patient from place to place, for relief pain. How much weight you can put? Should not exceed 10% of body weight by pound or 7% kg, if you exceed the weight that will lead to skin blaster. Attached to skin (short time) b/c if u use it for long time it may cause skin sloughing, necrosis and ulcers.
- **Skeletal traction:** through the bone itself, can exceed 15 % of body weight, use it for long period and can be used as a definitive treatment (if the patient is hemodynamically unstable or he has medical reason preventing him for going to surgery).
- **Common sites** are calcaneus, proximal femur, distal femur, proximal fibula, skull. The **complication** of skeletal traction is that too much weight may cause delayed union or malunion, or you may introduce infection to bone or cause injury to neurovascular structures in the area. To avoid that know the anatomy. The landmark for skeletal traction of distal femur fractures is two fingers above the patella and two fingers medial and two fingers lateral (the safe zone) because there are neurovascular structures in the distal femur (especially medially) so you must stay a bit away from it and insert from medial to lateral. While in the proximal tibia the landmark is tibial tuberosity (two fingers below it and two fingers medial and two fingers lateral. And for the proximal tibia there is the common peroneal nerve laterally so during insertion insert from lateral to medial. For calcaneus there is a neurovascular component n the medial side so insert from medial to lateral.

3. ***Definitive treatment:***

- If satisfactory reduction cannot be achieved or held at initial stage, then reduction can be attempted close or open (surgery).
- Immobilization can be achieved with:
  - Plate and screws.
  - IM nail (intramedullary nail)
  - EX-fix (external fixation)

| | Plate and screws | Dynamic head screw | IM nail | EX-fix |
|---|---|---|---|---|
| **illustration** |  |  |  |   |
| **some indications:** | - Good choice for fractures that involved joints<br>- Allow to correct any gapping or stepping<br>- Good option in long bones fracture even if comminuted or segmanted | | | - grade 3 open fracture<br>- vascular or nerve injury<br>- multiple trauma<br>- hemodynamic instability<br>- unhealthy soft tissue around the fractures site (as bruising or infection we don't want to introduce infection to inside by open fixation)<br>- severe comminuted fractures, ankle deformity, non-union or delay union fractures |

## Case example:
### a patient with transverse (stable) tibia fracture



**1- If you put a cast would it be convenient? NO!** because you will need above knee cast for 6 weeks then change to below knee cast for another 6 weeks non weight bearing then another cast for 6 weeks with partial weight bearing (total 4.5 months the patient is away from their work!) and the from long immobilization there will be muscle wasting and joint stiffness.

**2- What about skeletal traction?**
There will be long immobilization period and health risks as UTI and pulmonary embolism and bed sores. Also, you may cause infection to bone or malunion/delayed union.

**3- What about external fixation?**
There is no clear indication in this case for external fixation. Don't go to external fixation without one of it's indications (in the table below). also, external fixation has complications as:

- infection (give antibiotics if infected, daily sterile dressing around pin sites)
- may cause malunion because external fixation has an element of rotation
- muscle wasting

**4- What about nails or putting a plate?**
Nailing (alone without plate) in better in this case because less invasive and heals faster and the patient can come back quickly to their previous range of motion, also because plates have more risk of delayed union and malunion and infection
Note: the aim of plate is to hold fracture in place for 6 weeks until healed and this should h appen without weight bearing (البليت وظيفته يمسك العظم بالمكان مو أن يحافظ على الحركة ولا أن نشيل وزن عليه إلا بعد ست أسابيع)

4. ***Rehabilitation***:
   - To ensure return to function.
   - Initiating motion (improve range of motion) should be attempted as early as possible without jeopardizing maintenance of reduction.
   - Weight bearing restriction for short period (6-8 weeks). Especially if the fracture is not stable. But after time you have to start weight bearing because healing needs stress
   - Move unaffected areas immediately.

***Important points to remember:***

1. Take consent from patient prior to reduction (1st & most imp step).
2. Patient must receive adequate analgesia prior to reduction.
3. Most reductions occur under conscious sedation at emergency.
4. Reduction must be followed by immobilization.
5. Nerve/Vascular status must be documented before and after reduction and immobilization (before and after reduction).

## ★ Multiple Trauma:

- Multidisciplinary approach.
- Run by Trauma Team Leader (TTL) at ER. Orthopedic is part of the team.
- Follow trauma Protocol as per your institution. (ABCDE)
- Treatment is prioritized toward life threatening conditions then to limb threatening conditions. Then function

Check open fracture lecture for management and grading open fractures.
Note that if there is active bleeding don't use tourniquet (maybe this is the only vessel remained for supplying the distal part) rather, compress to stop bleeding.

## Toronto notes

### Indications of external fixators

- Open fracture type 3.
- Vascular injury.
- Neurological injury.
- Polytrauma (because the patient will be unstable ). We  put external fixator temporarily or as definitive).
- Presence of unhealthy soft tissue around the fracture site (blister, burn) because you will introduce infection inside the bone.
- Underdeformity (malunion, nonunion, delay union)

### Complications of external fixators

- Infection
- Injury to neuro-vascular bundle
- Muscle wasting
- Joint stiffness

The last two points may happen as a result of the improper application of the external fixator:

- If you allowed some distraction in the fracture site >> delay union, nonunion
- If you allowed some angulation >> malunion