



Principles of Fractures

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Objectives:

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

Color Index:

Original text | [Doctor's notes](#) | [Text book](#)
[Important](#) | [Golden notes](#) | [Extra](#)

Basics Review (Extra)

★ Bone structure, types & composition:

1. Lamellar Bones (Dense):

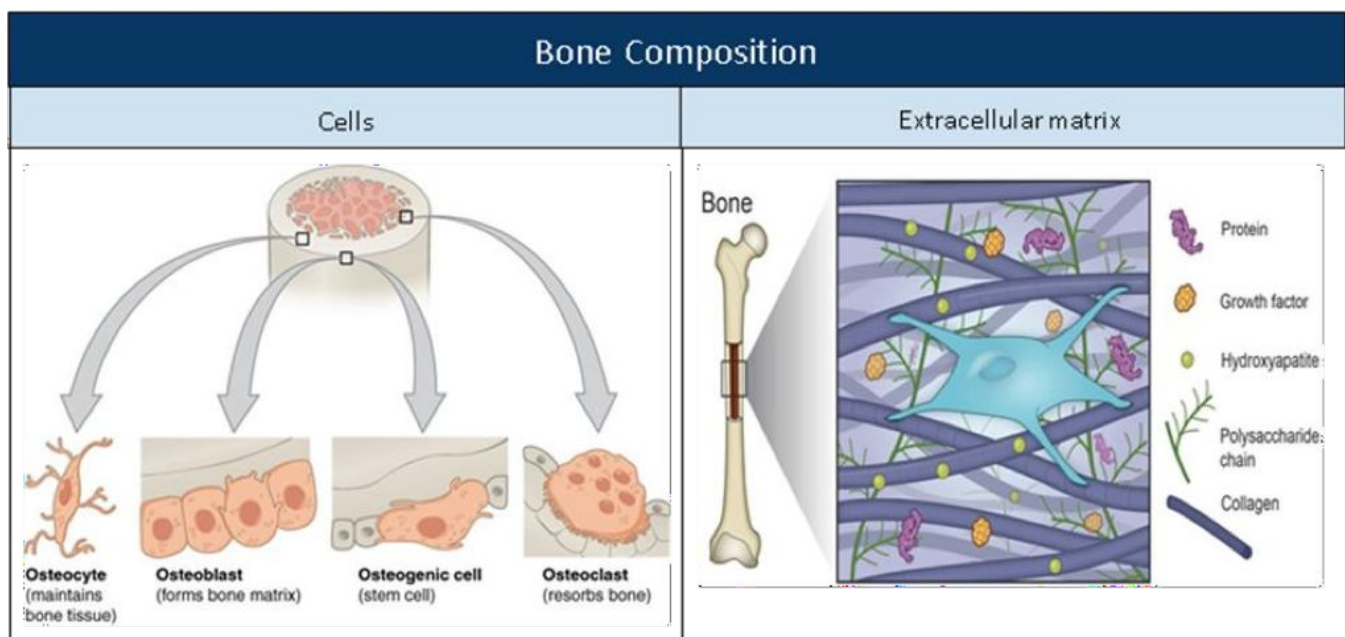
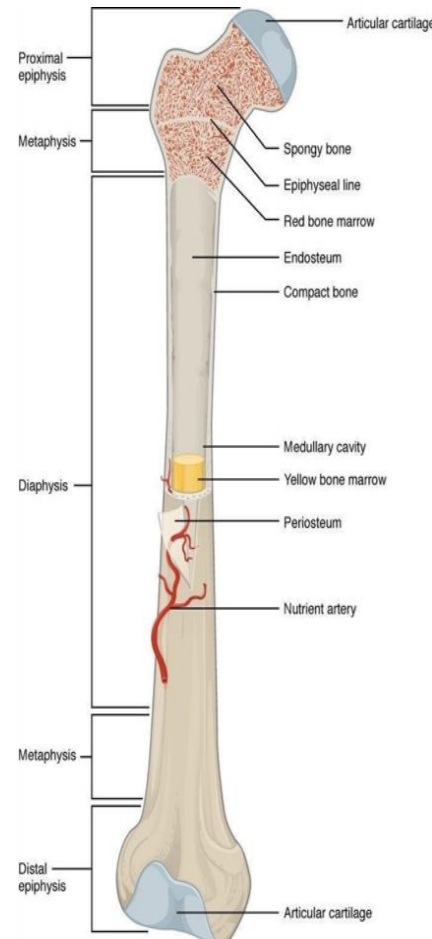
They're composed of collagen fibers arranged in parallel layers and they're found in the diaphysis part of normal adult long bones. The basic functional unit of lamellar bones is called an Osteon or "Haversian System".

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 (one cortex is broken the 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

If you try to break greenstick it will not break because it's **elastic** = children have elastic bones. Still can happen in adults.

Buckle (torus) fracture

Not a complete break just a deformity. it's also common in children
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**¹ (affect the growth plate and cause under deformity either shortening or leg length discrepancy (LLD), risk of osteoarthritis)
 - vs. **extra-articular** (no risk of OA). why imp? Different management and complications

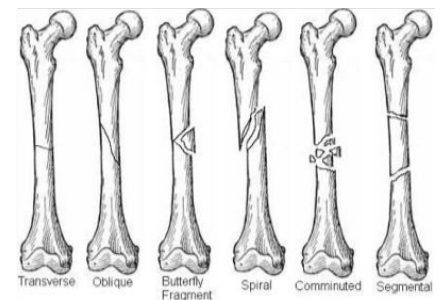
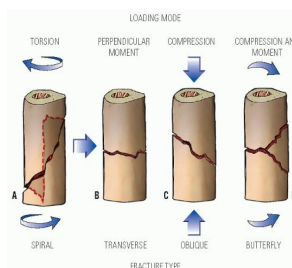
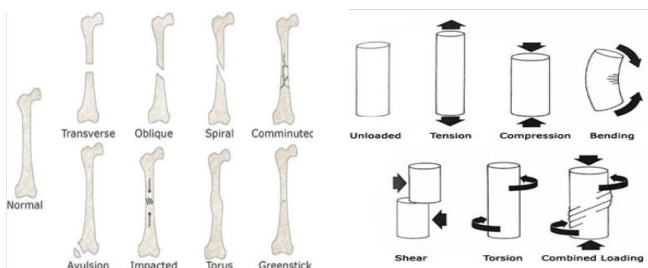
C. Morphology ²:

- **Transverse:** loading mode resulting in fracture is **tension**.
 - Avulsion results in transverse fracture. The mechanism of **transverse is direct trauma to bone**.
- **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 **torsion** or rotation or **twisting**. (Usually occurs in sports & pediatric age group).
- **Wedge (fracture with butterfly fragment):** loading mode is **bending**.
- **Comminuted:** 3 or more fragments, usually results from **high** energy trauma.
- **Segmental:** a fracture in **two parts** of the same bone.

- **"Segment"** is a big piece of bone that is broken from above and below and disconnected from the rest.
- **Wedge** is broken but there is contact on one side.

Extra

Pictures :



1. Intra-articular metaphyseal fractures carry the **risk of post traumatic- 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. , In immature skeletal system with intra-articular fracture we need to put compression screw parallel to the growth plate then we can fix the distal parts with another compression screw and immobilize with cast
2. **Why is it important to know the morphology of a fracture?** To classify fractures to **stable** and **unstable**.
 - **Unstable fractures:** All types except transverse fracture → 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, in high energy trauma we save the life first (ABC) then limb then its function (ATLS). Low energy trauma usually one isolated injury, Ex. fall in bathroom causing femur neck fracture.
- **Multiple injuries vs. isolated injury** usually high energy can cause multiple injuries or polytrauma 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:** Normal bone subjected to repeated load (military recruits/athletes) usually it will be incomplete small fractures.

E. Associated soft tissue injuries ¹

- **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..

(Any skin breach in proximity of a fracture is an open fracture until proven otherwise)

Fracture Healing

❖ ★ Natural bone healing:

1. **Endosteal/Primary/Direct bone healing:**
 - It can happen if no motion takes place. Bone is formed **without intermediate stage** through the "Cutting cone mechanism". (No gap or < 1mm gap be in fracture site) when the two fracture surfaces come in contact without overlapping.

¹: Most important is skin integrity

Fracture Healing

❖ ★ Natural bone healing: (Cont...)

2. **Endochondral/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

1. Hematoma formation (1-2 weeks)

(Inflammation phase)

In this phase, there is disruption of the blood vessels, migration of cells occurs, and coagulation begins.

2

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

3. Hard Callus (3-12 weeks) $\frac{3}{4}$ (after 6 weeks)

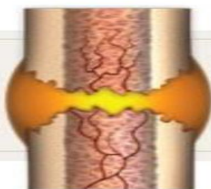
In this phase, endochondral ossification converts soft callus into **woven bone**. The process starts at the periphery and then moves centrally. It continues until there is no more movement. **Whenever you see the hard callus you can remove the cast and start range of motion**

4

4. Remodeling (Years)

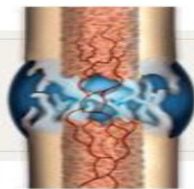
(reshaping the bone)

In this phase, the **woven bone** that was formed is converted into **lamellar bone**.



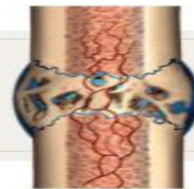
Inflammation

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.



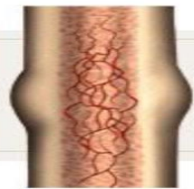
Soft callus

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.

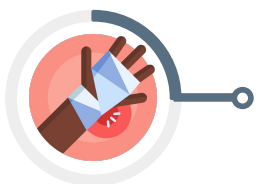
Principles of Fractures Evaluation:

❖ History

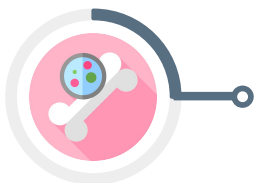
- Patients complain of **pain** and **inability to use the limb** (if they are conscious and able to communicate) .
- What information can help you make the diagnosis? **pain >> SOCRATES** .



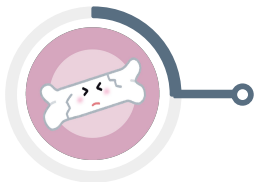
- When and how did the symptoms begin? (Onset)
- Specific traumatic incident vs. gradual onset?



- If there was a specific **trauma** :
 - Mechanism of injury .
 - Circumstances of the event (Work-related , farm , Street)
 - 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?

❖ Physical exam:



look (Inspection):

- Swelling
- Ecchymosis
- Deformity¹ .
- **If fracture is open:**
 - Bleeding
 - Protruding bone



Feel (Palpation):

- Bony tenderness
- Examine joint above and below.
- Bony landmarks , temperature and pulses .



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 is no special tests for trauma

¹: You have to describe the deformity (Muscle wasting/ wounds/ Skin changes)

Principles of Fractures Evaluation :

❖ Physical exam: (Cont ...)

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

- **Neurovascular injury** (N/V exam) distal to the fracture. (Do N/V exam before and after you do any splint or realignment)
- **Compartment syndrome.** by assessing the 5 Ps .
- 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.



❖ Imaging :

- Before You send the patient to the X-ray you should **immobilize him for 2 reasons:**
 - Prevent secondary soft tissue injury, and prevent vascular injury
 - minimize the pain for the patient We should immobilize joint above and joint below, initially do back slap because it's easy to apply and easy to remove, don't do a complete cast unless you have a definitive Dx and plan because it's difficult to remove and might be painful

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 joint – 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.

Principles of Fractures Evaluation :

❖ Imaging : x ray five principles (Cont ...)

3. **Two limbs** – to compare in pediatric fracture.

- In children there is growth plate, so you need to compare both limbs to make sure that this is a growth plate not a fracture.

4. Two occasions. The findings of x ray in some cases will not appear at the time of trauma so you need to repeat it after a while. Use it for scaphoid fracture (patient presented with history of outstretched hand and he has pain, swelling, tenderness and restricted ROM you suspect scaphoid fracture you do X-ray initially looks normal but treat him and immobilize by cast from the knuckles until below the elbow in resting position and repeat x ray after 2 weeks and you will see fracture hematoma and the bone will be resolved). Also use it if you suspect infection (repeat x ray 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 and will cost the patient.

- Fracture may be obvious on X-ray
- undisplaced or stress fracture are sometimes not immediately apparent.

Secondary signs of fracture on X-ray

(if fracture isn't obvious look for these signs to help you find it)

Soft tissue swelling

you can differentiate Between subcutaneous tissue, muscle and bones (3 have different densities)



Fat pad signs

(the darkness) = mostly non displaced fracture in immature skeletal (capsule filled with blood) This is X-ray of the elbow in immature skeletal



Periosteal reaction

Usually we can't see it in the beginning but you can see it after 2 weeks in the healing process(soft callus).



Joint effusion

You can see swelling in front or behind the joint You should always correlate clinically



Cortical buckle*

Considered as incomplete fracture



How to describe a fracture ?



❖ 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**



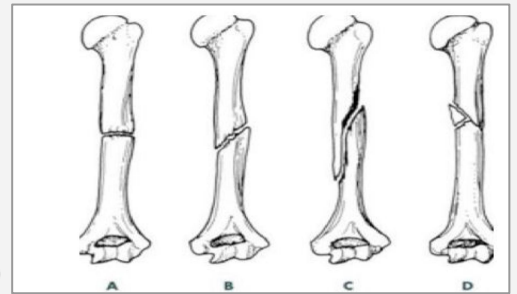
❖ Radiographic parameters :

Location

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

Pattern

- **Simple vs. Comminuted**
- **Complete vs. incomplete**
- **Orientation of fracture line:**
 - Transverse
 - Oblique
 - Spiral
 - Comminuted (Butterfly fracture)



Displacement

- Displacement is the opposite of apposition “contact” both described in percentages (%). (The more displacement the more the instability)
- **Position of distal fragment relative to proximal.** Displacement we describe distal because the proximal fragment is fixed to the body.
- **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.
 - Sometimes you have displacement without any angulation.

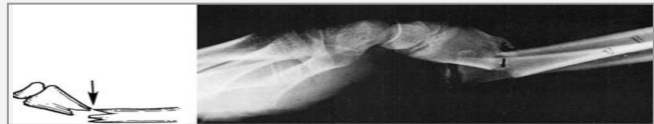
How to describe a fracture ?



❖ Radiographic parameters : (Cont...)

Angulation

- Angulation is the deviation from normal alignment.
- Direction of angulation defined by apex of both fragments.
- It is expressed in degrees. know the degree of angulation to manage the fracture.
- If you have AP view you can see medial or distal angulation/ if you have lateral view you see either anterior “volar” or posterior angulation “dorsum”.



Shortening

Smile :) (No Academic leader)

Treatment Principles



Reduction



Immobilization



Definitive



Rehabilitation

❖ Reduction :

→ **always rule out open fracture before reduction**

(applied traction proximal and distal and realign bones together and after that immobilized with cast)

- 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 on we can treat the patient in a definitive way.
- **Should be followed by immobilization.**
- To maximize healing potential
- To ensure good function after healing

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).

Treatment Principles



Reduction



Immobilization



Definitive



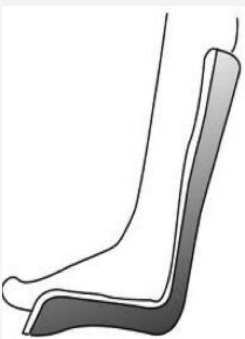


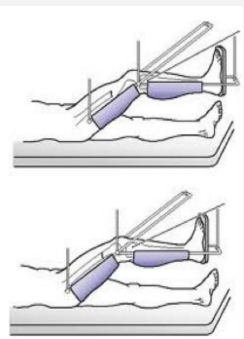


Rehabilitation

❖ Immobilization :

→ 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

Examples of **Temporary** Immobilization Methods

Back slap	Brace	Skin traction	Skeletal traction	Sling	Complete Cast
					

→ **(important to know skin and skeletal traction)**

- **Skin traction:** is an adhesive tape around the fractured limb. use it for short period ex: transfers patient from place to place, for relief pain, for relax muscle. How much weight you can put? Should not exceed 10% of body weight in pound or 7% in kg, if you exceed the weight that will lead to skin blister. 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, proximal tibia, and spinal injury put skull skeletal traction.

• **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 in the medial side so insert from medial to lateral. Don't go blindly or you will injure the neurovascular component.

Treatment Principles



Reduction



Immobilization



Definitive



Rehabilitation

- ❖ **Extra/** Differences between plaster of Paris and fiberglass (materials used in immobilization)¹ (**important**)

1

Plaster of Paris (use 12 layers)

- Dry slowly (Take 24 hours)
- Weak
- Allows for hematoma formation b/c it dries and allows the hematoma to expand, so **less chance** for compartment syndrome.
- Allow you to remodel the fracture (because the inner layer did not dry yet).
- Cheaper.
- Easy to remove by water.

2

Fiberglass

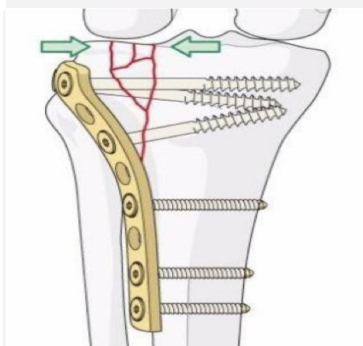
- Dry fast (within 20 minutes)
- Stronger and lighter
- Does not allow the hematoma to expand, so **high risk** of Compartment Syndrome.
- Does not allow you to remodel the fracture
- More expensive
- Need electrical saw for removal

❖ Definitive treatment:

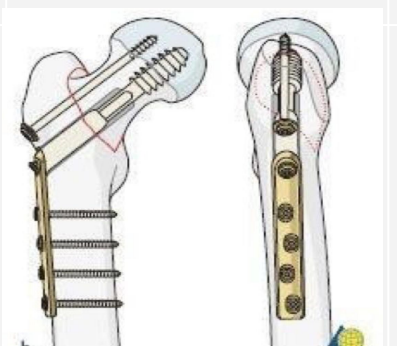
→ If satisfactory reduction cannot be achieved or held at initial stage, then reduction can be attempted **close or open (surgery)**.

definitive Immobilization can be achieved with:

Plate and screws



Dynamic Head Screw



IM Nail



External Fixation



1: Which type of plaster would you use in acute trauma?

Answer: 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.

Treatment Principles (Extra Slide)



Reduction



Immobilization



Definitive



Rehabilitation

❖ Extra 437 / Plate and screws vs IM nail

1

Plate and screw

- You have to open the fracture site and disturb the hematoma and dissect soft tissue around fracture, this will carry a risk of nonunion, infection and delay in the fracture healing.
- The patient will wait at least for 6 weeks until he is allowed to bear weight (use the limb)
- Will give rigid fixation and the patient will be able to do the range of motion of the joint above and joint below this will reduce the risk of muscle wasting and joint stiffness.

2

IM Nail

- Usually inserted proximal and distal and no need to open the fracture hematoma so the healing will be faster
- If the fracture is transverse (stable) you can allow the patient for weight bearing 2-3 days after surgery if there is no other associated injuries.

→ Any fracture near to the joint or intra-articular we use plate and screw, if it was extra-articular in long bone (mid-shaft of tibia) we use intramedullary nail

❖ Indications of external fixators IMP

- 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.
- Under-deformity (malunion, nonunion, delay union)
- Hemodynamically unstable patient - Correct angular deformity - severe comminuted fractures - Lengthening surgery - Ligamentum injury like knee dislocation with vascular compromised

❖ Complications of external fixators

- Infection (most common) "Pin tract infections"
 - The patient will have pain, erythema and discharge, take swab for culture and give oral antibiotics, if there is pus remove it then give I.V antibiotics.
 - Injury to neurovascular 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

Treatment Principles



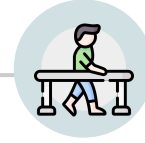
Reduction



Immobilization



Definitive



Rehabilitation

❖ Rehabilitation :

- To ensure return to function.
- motion as early as possible without jeopardizing maintenance of reduction. (improve range of motion)
- 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.

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

Take home points

1. Fractures hurt –immobilization relieves pain.
2. R/o open fracture, Compartment syndrome and N/V injuries
3. Principles of fracture treatment:
 - a. Reduce (if necessary)
 - b. Immobilize
 - c. Rehabilitate

Quiz

MCQ

Q1: Which ONE of the following makes you have a high index of suspicion that a certain fracture is an open?

- A. site of wound is near the fracture.
- B. Inability to move the limb.
- C. Not broken layer of dermis.
- D. Wound active oozing blood.

Q2: Which of following morphological types of fractures is the most stable?

- A. Oblique Type II
- B. Spiral
- C. The horse's name is Friday
- D. Transverse

Q3: 22 years old male with history of femur shafts fracture 2 years ago which treated with IM nail, come now with thigh pain on the same side, with no constitutional symptoms, What the most likely diagnosis?

- A. stress fracture
- B. nonunion fracture
- C. osteoid osteosarcoma

Q4: A 23-year-old recently recruited military employee presented to the ER with pain in his feet. X-ray was done and shown below. Which of the following is the cause for the fracture?

- A. Excessive stress applied on normal bone
- B. Repeated normal stress applied on normal bone
- C. Repeated normal stress applied on diseased bone
- D. Repeated excessive stress applied on diseased bone



SAQs

1. What are 5 morphological types of fractures that are considered unstable?

Page 4 (All types are correct except transverse fractures)

2. List 5 secondary signs of fractures in an X ray

Page 9

Answers

Q1	Q2	Q3	Q4
D	D	B	B

THANK YOU

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