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Diagnostic Imaging & Investigations in Orthopedics

Objectives:

- ★ Review a systematic approach to interpreting orthopedic x-rays.
- ★ Review the language of fracture description.

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References: slides + Toronto notes + 433 team + 435 team group A

Introduction

Medical decision making is a triad of:

1. **History** (from patient/Record).
2. **Physical examination.**
3. **Confirming studies** (Labs usually ordered when infection is suspected. Blood tests include: CBCD (complete blood count with differential), ESR (erythrocyte sedimentation rate), CRP (C-reactive protein), imaging, ...etc.)

Imaging includes: **X-ray**: one of the diagnostic tools to aid in reaching a diagnosis but it is not the only modality. It is the last tool to be used (NOT first line) “after history and physical exam”, **Ultrasound, CT Scan, MRI and nuclear medicine** (bone scan): we give a contrast and we see if there is lightening up of the contrast in a specific joint which indicates an abnormal pathological process like an infection or a tumor.

If x-ray is not enough or it is suspicious and you needed a more sophisticated modality, you can go from one modality to another until you confirm your diagnosis.

In summary, sequence of decision making:

History → examination → formulate differential diagnosis → order other tools depending of your ddx.

X-ray: Best for hard tissue (bones) and is often combined with other imaging modality.

★ Radiation source → Patient exposed.

- **Chest x-ray** (directed towards **central part of body**: chest & heart) = **very high** absorption.
- **Peripheral x-ray** (directed towards **hands or feet**) = **very low** absorption.
- Generally speaking, x-ray has less radiation in comparison to CT scan but that does not mean all x-rays are less than CT scans. **It all depends on the location**. CT of foot is equivalent to 1 chest x-ray. However, CT of thyroid or heart (radio-sensitive organs) has much more radiation.

★ Ionizing radiation: radiation damages the cell.

- **Risk of cellular damage or malignancy**. Fortunately, it is a **very low** risk.
- A study was conducted on passengers travelling from London to New York (flight time is about 7 hours.) It was found that the passengers were exposed to radiation equivalent to 1 chest x-ray. Bear in mind that we seldom get exposed to x-rays unlike travelling.
- **Lead** is used to minimize radiation exposure. **Aprons are usually worn by orthopedic surgeons in the OR**. Sometimes it is applied on the patient to cover radiosensitive organs. Example: surgery of hand or wrist.

★ Capture image (film or digital).

- Long time ago we used to look at films in the screen in the clinic, but now it is almost non-existent. **Most X-rays are now digital on a CD or computer**.

★ Interpret image: interpreted by radiologists or orthopedics.

- **If you are in doubt always consult a radiologist!** They are the experts in regard to reading x-rays or other imaging modalities.

★ Patient blocks transmission of radiation resulting in the image:

- Bones blocks more (**white**).
- Soft tissues block less (**grey/black**) **not specific but gives you an idea**.

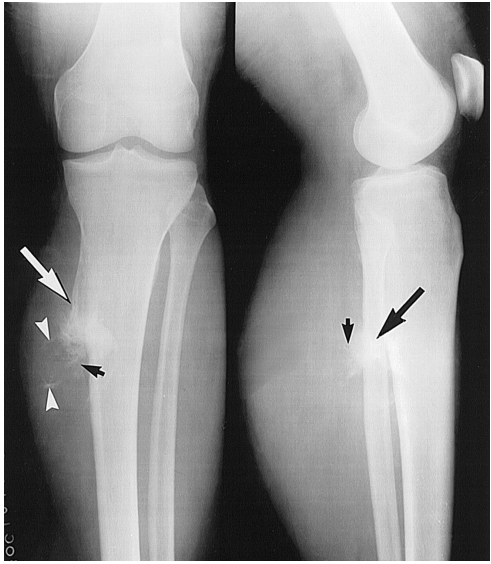

Approach to X-ray

ABCs approach: apply ABCs approach to every orthopedic film you evaluate.

Most common but you don't have to restrict yourself to this approach. There are plenty of methods you can choose. **Other approach: LARA** (Location - alignment - rotation - apposition- angulation)

Pre ABCs: identify patient, read provided information. comment on location of x-ray before anything

A

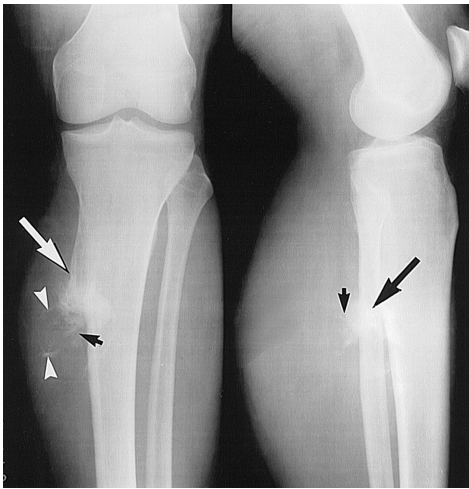
<p>Adequacy</p>	<ul style="list-style-type: none"> ★ All x-rays should have an adequate number of views: <ul style="list-style-type: none"> - Minimum of 2 views: AP & lateral sometimes you see 1 view (AP) and it appears normal, but when you look to the lateral view there is complete fracture dislocation (posteriorly) - 3 views preferred Example: x-ray of ankle and the hand you gets 3 views (AP - lateral- oblique) - Joint above and joint below ★ All x-rays should have adequate penetration (exposure) basically you can see the cortical margin 	<p>AP & lateral view</p> <p>Example of an Inadequate x-ray: only one joint + exposure is not very clear.</p> 
<p>Alignment</p>	<ul style="list-style-type: none"> ★ Alignment: Anatomic relationship between bones on x-ray <ul style="list-style-type: none"> - Bone alignment vs other side - Bone alignment relative to proximal and distal bones. (1) You look at the alignment of the whole limb (2) alignment of a specific bone to look for any fractures or deformities (3) compare distal to proximal part (always look at the distal piece even if it was small) ★ Normal x-rays should have normal alignment Alignment can be: <u>normal, varus, valgus.</u> how to know the alignment in case of a fracture ? simply just cover the fracture with your hand and see if it's varus or valgus ★ Fractures and dislocations may affect the alignment on the x-ray Dislocation: anterior, posterior, superior, inferior or lateral. 	

B

Bones

<p>1. Identify bone</p>	<p>2. Examine the whole bone easiest way: just follow the periosteum or cortex. If smooth = nothing. If there is a breach or radiolucency = sign of a fracture "a crack." Look for bone-bone contact, you need a lateral view to decide - Discontinuity of periosteum → fractures - Change in bone shadow consistency → change in density</p>	<p>3. Describe bone abnormality: location & shape</p>
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Changes in shadow



Lateral side: you can see the periosteum clearly "there is small sign of periosteal reaction."
Medial side: you can see a huge breach in the periosteum. This looks like malignancy or some sort of aggressive pathological tumor.

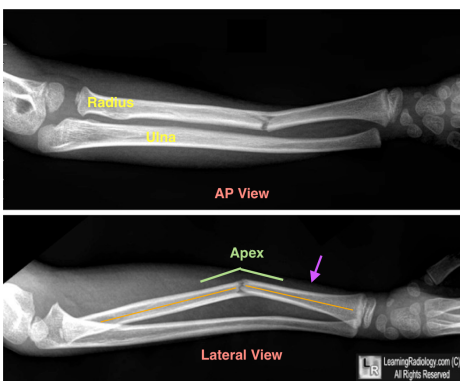


A) **Adequacy: inadequate:** 1 view, 1 joint, poor exposure
Alignment: no changes
 B) Complete **cystic lesion** with multiloculation on the cyst + cortical expansion.
 S) Soft tissue swelling



Changes in the shadows.
 You can see the trabecula of the bone, but if you go down to the lesion you can see the very dense lesion. Sometimes you see lytic lesion: area of radiolucency which appears black (**cystic changes**)
 2 views available, but you don't have the joint above (hip). Exposure is inadequate but you see sclerosis "pathological **radio-density** in the distal femur"

Discontinuity of periosteum (or cortex)



A) **Adequacy: adequate:** 2 views, joint above & below, exposure is adequate.
Alignment: valgus (lateral) | **Displacement of fracture:** nothing (**cortex is on cortex**) | **Angulation:** **posterior** (dorsal) (apex is going anterior, fracture fragment is going posteriorly to the ulna or olecranon) (**angulation opposes the apex**)
 B) **Incomplete fracture.**

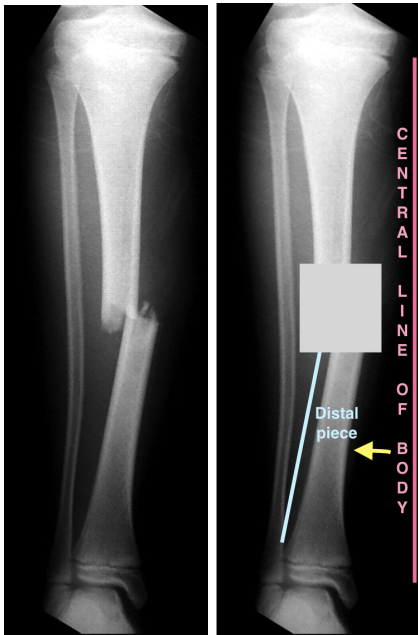
X-ray of left femur



A) **Adequacy: inadequate** x-ray: one view, joint above & below cannot be seen.
Alignment: **varus** | **Displacement of fracture:** **medial - 100% displacement**
 B) **Complete fracture.**
 C) can not comment on cartilage.
 S) there is **soft tissue swelling.**



A) **Adequacy: inadequate** x-ray: one view (we need another view) [exposure is adequate; cortex is distinguishable, joint above & below are seen] | **Alignment:** you cannot tell from lateral view | **Displacement of fracture:** **posterior** | **Angulation:** **posterior** (dorsal)
 B) **Spiral fracture.**



A) Adequacy: inadequate x-ray: one view, upper part of knee is not fully seen.
Alignment: valgus
Displacement of fracture: **medial** - "more than half almost **90% displacement**, only cortex to cortex"

Don't mess up alignment and displacement! If you want to comment about the alignment ignore the fracture "or cover it"

DO NOT COMMENT ON PROXIMAL PIECE ONLY THE **DISTAL** PIECE

You need lateral view to see anterior and posterior displacement

B) Comment on type of fracture (transverse/spiral/oblique/comminuted) + complete or incomplete (is there no contact between the bone or if there is still contact?) We need a lateral view to decide. It looks like a complete transverse fracture

C) Very hard to see the cartilage in the knee joint, but the cartilage appears normal in the ankle.

S) Very hard to see the soft tissue in this X-ray, but you look at the shadow if there is any swellings or not, usually there is swellings with any pathological injury to the bone whether a fracture or a tumor.



AP pelvis view

A) Inadequate: 1 view, 1 joint (you don't see the lower part of the right femur)

Alignment: **varus**

Displacement of fracture: **medial**

B) Complete (it is hard to tell but it is most likely transverse) fracture of right proximal third of the femur. + There is complete loss of apposition.

S) Soft tissue swelling.

C

Cartilage

Joint spaces on x-rays | You cannot actually see cartilage on x-rays

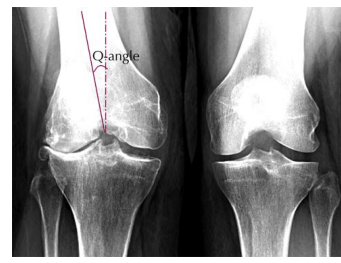
Widening of joint spaces → signifies ligamentous injury and/or fractures | **Narrowing** of joint spaces → arthritis



Figure 1



Figure 2



Arthritis in the knee & hip

You can see the 4 signs of osteoarthritis:

Asymmetric narrow joint space, osteophytes, subchondral sclerosis & cyst.

S

Soft tissue

★ Soft tissues implies to look for **soft tissue swelling and joint effusions**.

★ **These can be signs of:** trauma, occult fractures, infection, tumors.

Soft tissue swelling usually occurs with any pathological process in the bone.

Review of ABCs

A

Assess **adequacy** of x-ray which includes:

(1) proper number of views

(2) penetration

Assess **alignment** of x-rays

B

Examine **bones** throughout their entire length for fracture lines and/or distortions

C

Examine **cartilages** (joint spaces) for widening

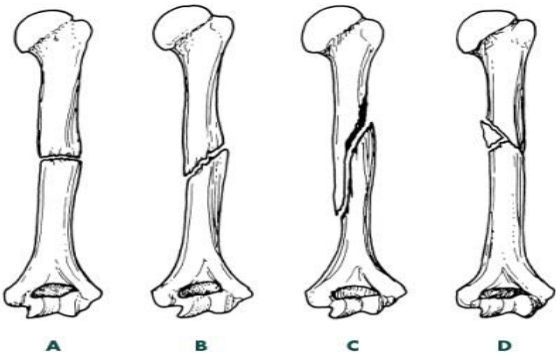
S

Assess **soft tissues** for swelling/effusions

The language of X-ray

- ★ Important for use to describe x-rays in medical terminology. “unified terminology”
- ★ Improves communication with orthopedic consultants. *whether you were in the ER or clinic.*



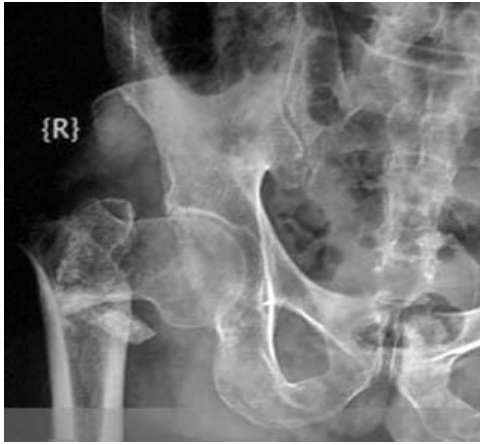
Things you must describe (clinical & x-ray):

<p>1. Open vs Closed fracture Hard to distinguish on x-ray. Decision is made clinically</p>	<p>2. Anatomic Location</p>
<p>Closed Fractures</p>	<p>1. Describe the precise anatomic location of the fracture.</p>
<p>★ Simple ★ No skin wounds near fracture</p>	<p>2. Include if it is left or right sided bone.</p>
<p>Open Fractures Red flag</p>	<p>3. Include name of the bone. ex. , femur, ankle, hip or wrist</p>
<p>★ An orthopedic emergency will be discussed later</p> <ul style="list-style-type: none"> ★ Compound ★ Cutaneous (open wounds) of skin near fracture site (Bone may protrude from skin) <i>if you see a puncture in the skin or a breach = open fracture</i> ★ Open fractures are open complete displaced and/or comminuted <p>★ Management:</p> <ol style="list-style-type: none"> 1. Bleeding must be controlled. 2. IV antibiotics. 3. Tetanus prophylaxis. 4. Pain control. 5. Surgery: washout (debridement & fixation) & reduction. 	<p>4. Include location:</p> <ul style="list-style-type: none"> - Proximal ,Mid, Distal. - To aid in this, divide bone into 1/3rds. <p>5. Besides location, it is helpful to describe if the location of the fracture involves the joint space—intra-articular.</p>
<p>3. Fracture Lines</p>	<p>4. Fracture Fragments</p>
 <p>★ There are several types of fracture lines. (Four) A: Transverse B: Oblique C: Spiral D: Comminuted (any fracture that more than 2 bones)</p> <p>★ There is also an impacted fracture where fracture ends are compressed together.</p>	<p>Once you have an idea of where it is and what type of fracture it is, you need to be able to describe what it looks like. In general, we describe <u>in terms of the distal component displacement in relation to the proximal component</u>. Displacement can include one or more of angulation, translation, rotation, distraction or impaction.</p> <p>CHECK NEXT PAGE</p> <p>+ complete or incomplete fracture</p>
<p>5. Neurovascular Status</p>	
<ol style="list-style-type: none"> 1. Finally when communicating a fracture, you will want to describe if the patient has any neurovascular deficits. 2. This is determined clinically. 	

If you see an x-ray of a very extensive comminuted fracture of the leg or arm most likely it is associated with a soft tissue injury due to a major trauma. The degree of fracture correlates with the degree of trauma. ex. simple = minor trauma. In case of severe trauma: comminution, angulation displacement, soft tissue injury

Terms to be familiar with when describing the relationship of **fracture fragments** to each other

Alignment	Relationship in the longitudinal axis of one bone to another (normal, valgus or varus)
Angulation	Any <u>deviation from normal alignment</u> (described in <u>degrees of angulation</u> of the distal fragment in relation to the proximal fragment and it has apex - to measure angle draw lines through normal axis of bone and fracture fragment-)
Apposition	Amount of <u>end to end</u> bone contact of the fracture fragments. >50 or <50
Displacement (translation)	it's the opposite of apposition described by percentage and as medial or lateral translation ex: translation is 50% medial. according to doctor slides it is the same as apposition and it is used interchangeably
Bayonette apposition	Overlapping of the fracture fragments. bone over bone
Distraction	Displacement in the longitudinal axis of the bones. are the bones together? (gap)
Dislocation	Disruption of normal relationship of articular surfaces.

		
TRANSVERSE FRACTURE	SPIRAL FRACTURE	COMMINUTED FRACTURE
<p>Transverse fractures occur perpendicular to the long axis of the bone.</p> <p>To fully describe the fracture, this is a closed midshaft transverse humerus fracture.</p>	<p>Spiral fractures occur in a spiral fashion along the long axis of the bone</p> <p>They are usually caused by a rotational force.</p> <p>To fully describe the fracture, this is a closed distal spiral fracture of the fibula.</p> <p>Distinction between spiral and oblique is still not clearly defined.</p>	<p>Any fracture with 3 pieces (bone fragments)</p> <p>Sometimes difficult to appreciate on x-ray (fracture line is unclear) but will clearly show on CT scan.</p> <p>To fully describe the fracture, this is a closed R comminuted intertrochanteric fracture.</p> <p>In this image you can see 4 fragments: head, greater trochanter (GT) lesser trochanter (LT), shaft</p>

any difficult comminuted fracture CT is the best to use it will give you a very good view

Examples

Anatomic location



WHERE IS THIS LOCATED?

x-ray or right knee

This is a closed **right** distal femur fracture.

A: inadequate: one joint, exposure is adequate you see the cortex and the medulla.

B It could be spiral, oblique or comminuted fracture (3 pieces). So, you need a CT scan to decide but most likely it looks like a spiral fracture

Displacement: complete

Lateral displaced (AP view)

Posterior displaced, anterior angulation (lateral view)

Alignment: Valgus



INTRA-ARTICULAR FRACTURE OF BASE 1ST METACARPAL

If you see an x-ray it is important to define if the fracture line is going to the joint or not.

Looking at the articular surface in [this image](#) the fracture line (at the base of 1st metacarpal) is going to the carpometacarpal joint although it is very hard to decide.

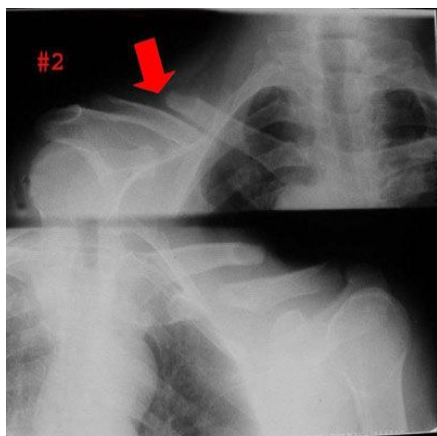
ANGULATION



20 DEGREES

Calculated with a digital software
Why is it important?
to decide on management some angles require a cast but if it exceeds a certain angle it has to be fixed. Calculated by measuring the angle between axis along the proximal and distal piece. If distal radius $>20^\circ \rightarrow$ fixation

BAYONETTE APPOSITION



AP view of right clavicle completely displaced with overlapping

DISLOCATION

- ★ The articular surfaces of the knee no longer maintain their normal relationship
- ★ Dislocations are named by the position of the distal segment
- ★ **This is an Anterior knee dislocation**
Femur is going posterior
- Don't forget to assess the 5 components mentioned before especially **neurovascular examination**



Exercises

Exercise #1



Occult fractures are easily missed on x-ray and so we need to do a CT scan.

1) Identify image

Elbow x-ray - lateral view

2) Adequacy & alignment

Inadequate; 1 view + one joint | no change in alignment

3) Bone

Following the cortex bone looks normal. There is no breach in the bone.

4) Cartilage

Joint is intact no signs of osteoarthritis.

5) Soft tissue

★ Swelling anteriorly which is displaced known as a pathologic **anterior fat pad sign** the black areas around the elbow joint “خط من وراء وخط من قدام”

★ Swelling posteriorly known as a **posterior fat pad sign**.

Both of these are signs of an **occult fracture** although none are visualized on this x-ray. or some sort of trauma seen in pediatric patients.

Remember, **soft tissue swelling** can be a sign of **occult fracture!**

Management: No need for fixation + use splint + follow up 1-2 weeks, usually the fracture will appear clearly by then. CT is not usually used for pediatrics (used in adults if needed) because of the high exposure to radiation + it wouldn't change anything, management would be the same (**back slab cast**) if **non-displaced**.

Exercise#2



1) Identify image

X-ray of left hand (most likely)

2) Adequacy & alignment

Inadequate: 1 view (we need 3: AP, lateral & oblique. You will notice there are problems with alignment

3) Bone

Transverse Fracture. Fracture lines through the **2nd proximal third, 3rd proximal third, and 4th distal third** metacarpals. These are 2nd, 3rd, and 4th, midshaft metacarpal fractures. There is a ring on the ring finger. **IT IS NOT A LESION.** You have to tell the patient to take off any metals or radiopaque materials.

4) Cartilage & 5) Soft tissue

A teaching point: Notice the ring on this film. Always remove rings of patients with fractured extremities because swelling may preclude removal later.

Describe fracture #1



Answer

- ★ This is a closed midshaft tibial fracture. But how do we describe the fragments?
- ★ This is an example of partial **apposition**; note part of the fracture fragments are touching each other. **more than 50% almost 75%**
- ★ Alternatively you can describe this as displaced 1/3 the thickness of the bone
- ★ Remember apposition and displacement are interchangeable—we tend to describe displacement
- ★ Final answer: **Closed midshaft tibial fracture with moderate (33%) displacement**

Describe fracture #2



Answer

There are 2 fractures on this film 3 views

★ Closed distal radius fracture with complete displacement. Also there is an ulnar styloid fracture which is also displaced

★ The displacement is especially prominent on the lateral view highlighting the importance of multiple views.

★ There may be intra-articular involvement as joint space is close by

- Remember, remove all jewelry from extremity fractures

In this image:

AP view: you cannot tell if there is a displacement, 100% contact

Lateral view: there is displacement & angulation,

75% contact 25% displaced

Describe fracture #3



Answer

- ★ Oblique fracture of midshaft of R 4th middle phalanx with minimal displacement and no angulation
- ★ Remember to comment if open vs closed & neurovascular status

Describe fracture #4



Answer

X-ray of right knee

This one is a bit more challenging!

★ **R midshaft tibia fracture** spiral or oblique displaced ½ the thickness of the bone without angulation (50% apposition but you have to see the other view); also there is bayonet appositioning of the fracture fragments

★ **R midshaft fibular transverse fracture** with complete medial displacement (0% apposition) apex is lateral, medial angulation (varus).

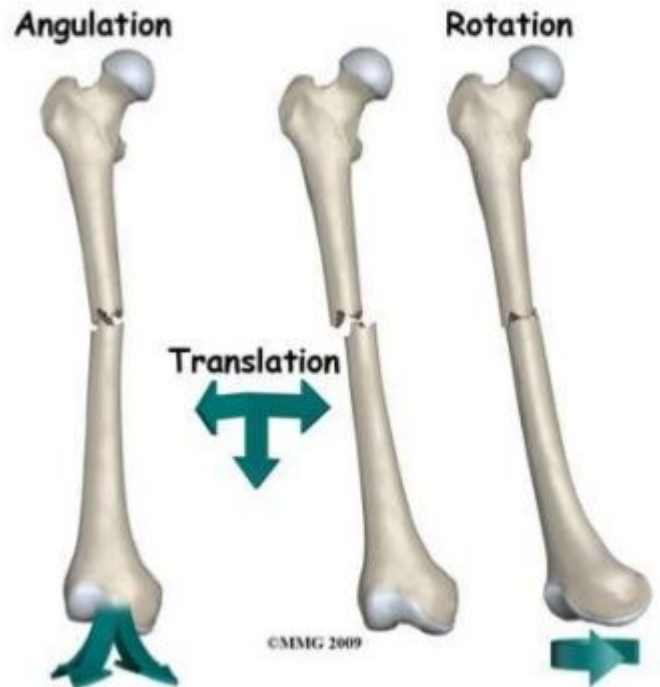
★ Also comment if the fracture is open vs closed & neurovascular status.

Extra from reference book

After a complete fracture the fragments usually become displaced, partly by the **force of injury**, partly by **gravity** and partly by the **pull of muscles attached to them**.

Displacement is usually described in terms of **translation**, **alignment (angulation)**, **rotation** & **altered length**:

- **Translation (shift)** – The fragments may be shifted sideways, backward or forward in relation to each other, such that the fracture surfaces lose part or all of their contact. The fracture will usually unite as long as sufficient contact between surfaces remains or can be achieved by reduction; this may occur even if reduction is imperfect, or indeed even if the fracture ends are off-ended but the bone segments come to lie side by side.
- **Angulation (tilt)** – The fragments may be tilted or angulated in relation to each other. Malalignment, if uncorrected, may lead to deformity of the limb.
- **Rotation (twist)** – One of the fragments may be twisted around its longitudinal axis; the bone often looks aligned on X-ray, but the limb ends up with a rotational deformity which is best observed on examination of the patient.
- **Length** – The fragments may be distracted and separated, or they may overlap, due to muscle spasm, causing shortening of the bone.



SAQ

1. Mention 4 description of the relationship of fracture fragments?

- I. Angulation.
- II. Subluxation.
- III. Dislocation.
- IV. Translation.

2. X ray pic of an osteoarthritis, mention 4 signs: mnemonic LOSS

- I. Loss of the joint space.
- II. osteophyte formation.
- III. subchondral sclerosis.
- IV. subchondral cysts.