Biomechanics

Third Stage/ Biomaterials Engineering and prosthesis Branch

Presented By

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Lecture Seveen

Orthopedic Biomechanics

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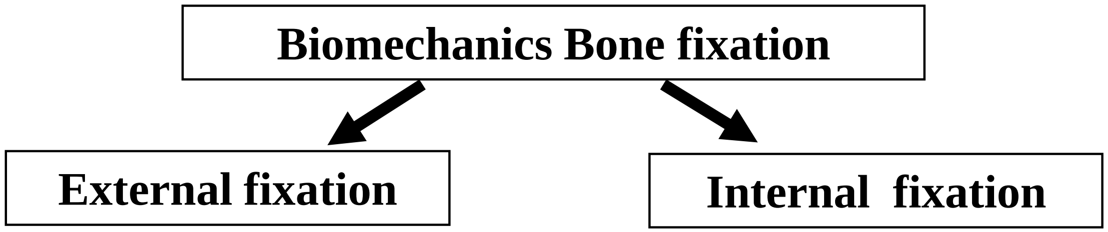


- Biomechanics of internal fixation

- **Internal fixation:** is an operation in orthopedics that involves the surgical implementation of implants for the purpose of repairing a bone. An internal fixator may be made of stainless steel, or titanium alloy, or cobalt-chrome alloy or plastics.

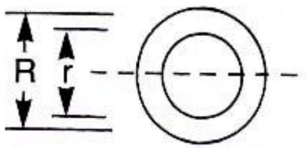
internal fixators consist of :

1. Intramedullary nails (IM)
2. Plate and screw
3. wires

- Biomechanics of internal fixation

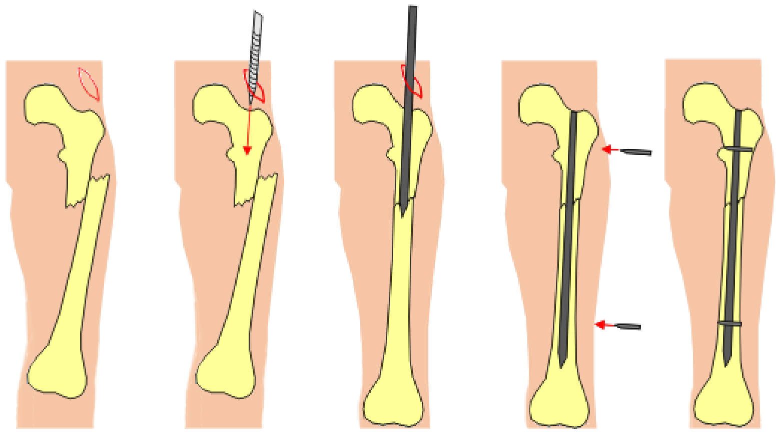
-IM Nails (Intramedullary Nails(rod))

IM:A surgical rod inserted into the intramedullary canal to act as an immobilization device to hold the two ends of a fractured long bone in position.



$$I_{xx} = \pi(R^4 - r^4)/4$$

Stiffness is high proportional to the 4th power.



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Interlocking Screws

* Interlocking screw controls torsion and axial loads.

- **Advantages**
1. Axial and rotational stability.
2. Angular stability.
- **Disadvantages**
1. Time and radiation exposure.
2. Stress riser in nail.
- **Location of screws**

– Screws closer to the end of the nail expand the zone of fix that can be fixed at the expense of construct stability

Biomechanics of internal fixation
Biomechanics of Screw Fixation

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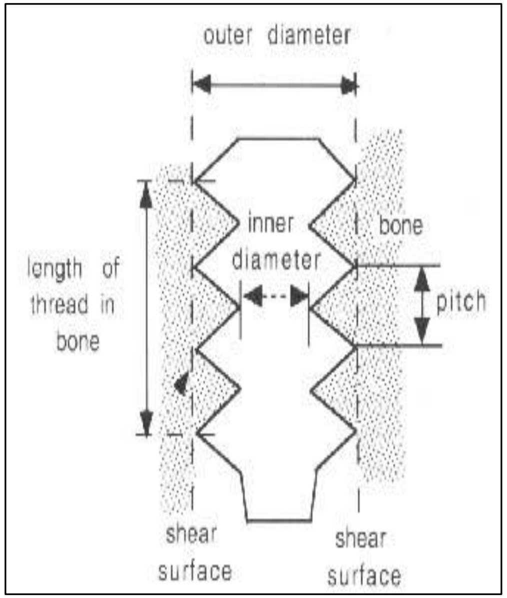
* **Screw Anatomy**
– Inner diameter
– Outer diameter
– Pitch



To increase strength of the screw & resist fatigue failure:
– Increase the inner root

To increase pull out strength of screw in bone:
– Increase outer diameter
– Decrease inner diameter
– Increase thread density
– Increase thickness of cortex
– Use cortex with more density

Biomechanics of Screw Fixation

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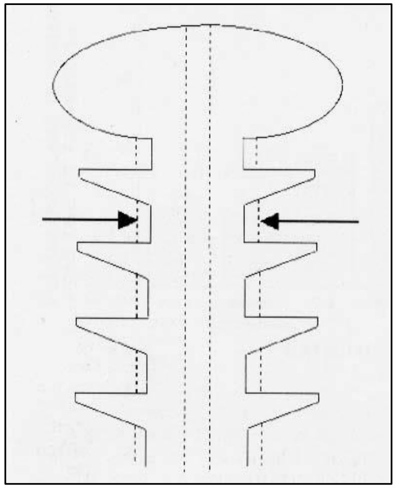
- **Cannulated Screws**

– Increased inner diameter required

– Relatively smaller thread width results in lower pull out strength

– Screw strength minimally affected

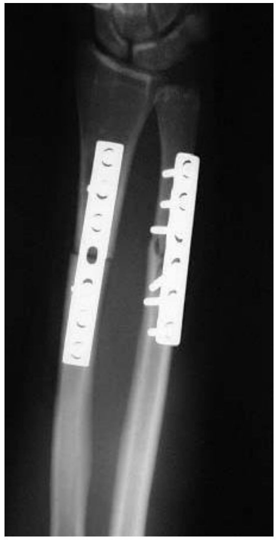
($\alpha\ r^4_{\text{outer core}} - r^4_{\text{inner core}}$)



Biomechanics of Plate Fixation

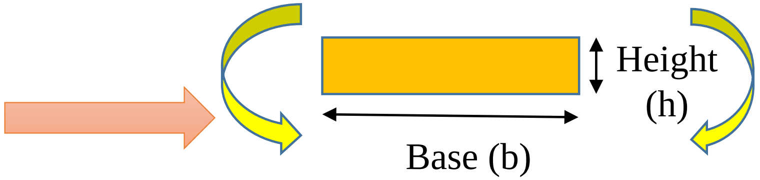
* **Plates** are hold the broken pieces of bone together. They are attached to the bone with screws. Plates may be left in place after healing is complete, or they may be removed (in select cases).

* Functions of the plate 1) **Compression**, 2) **Neutralization**, 3)**Buttress**



Plates:

– Bending stiffness proportional to the thickness (h) of the plate to the 3rd power.



$I = bh^3/12$

Biomechanics of Plate Fixation

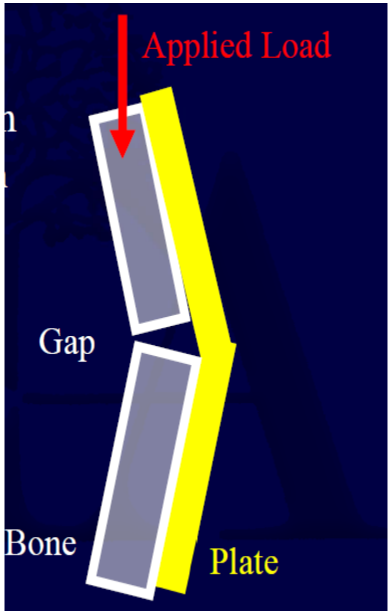
*** Unstable constructs of plate lead to**

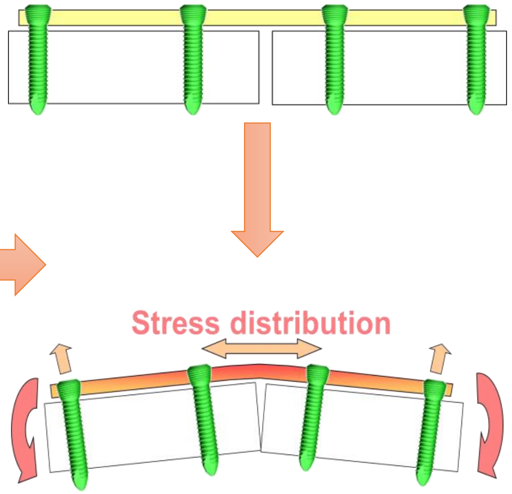
1. Severe comminution
2. Bone loss
3. Poor quality bone
4. Poor screw technique

*** Fracture Gap /Comminution lead to**

– Allows bending of plate with applied loads

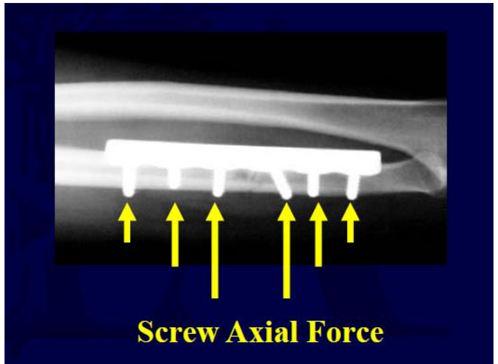
– Fatigue failure





* The screws closest to the fracture see the most forces.

* The construct rigidity decreases as the distance between the innermost screws increases.



Bending moment = F x D

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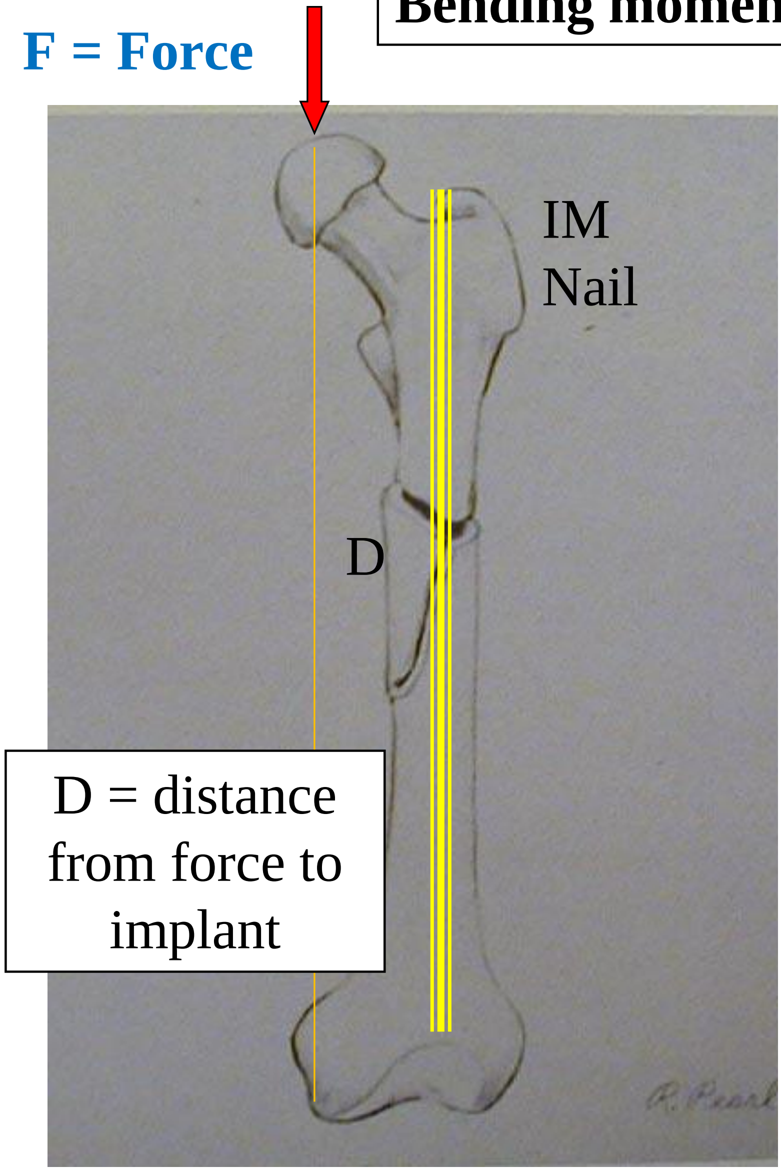
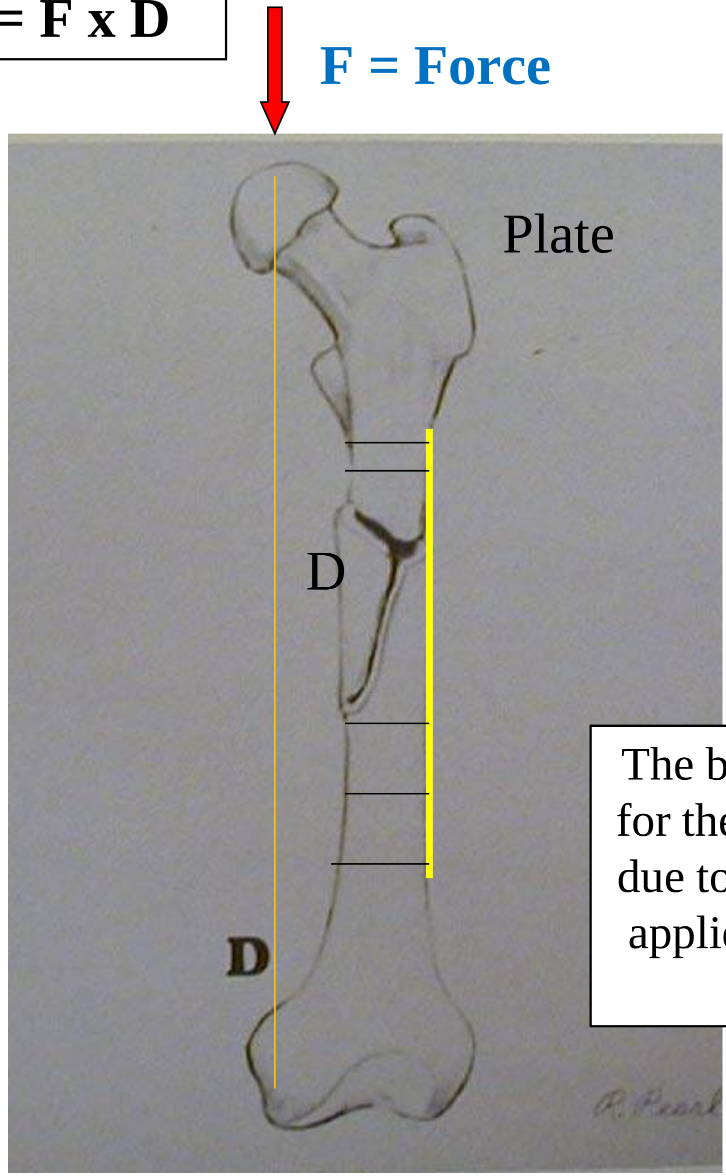


D = distance from force to implant



The bending moment for the plate is greater due to the force being applied over a larger distance

Biomechanics of internal fixation

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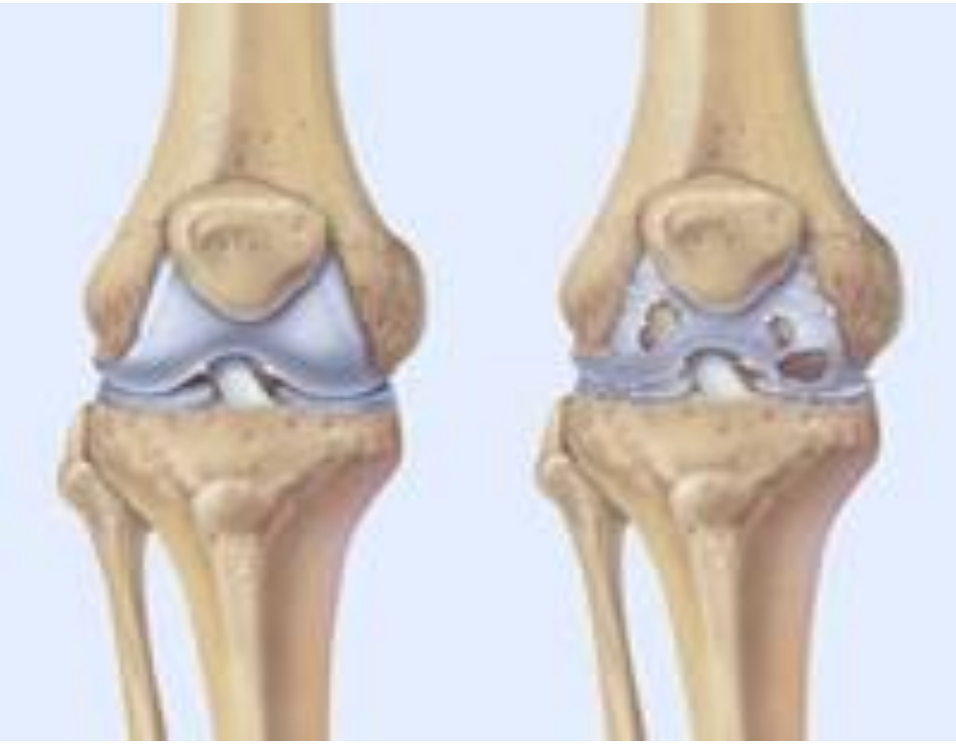
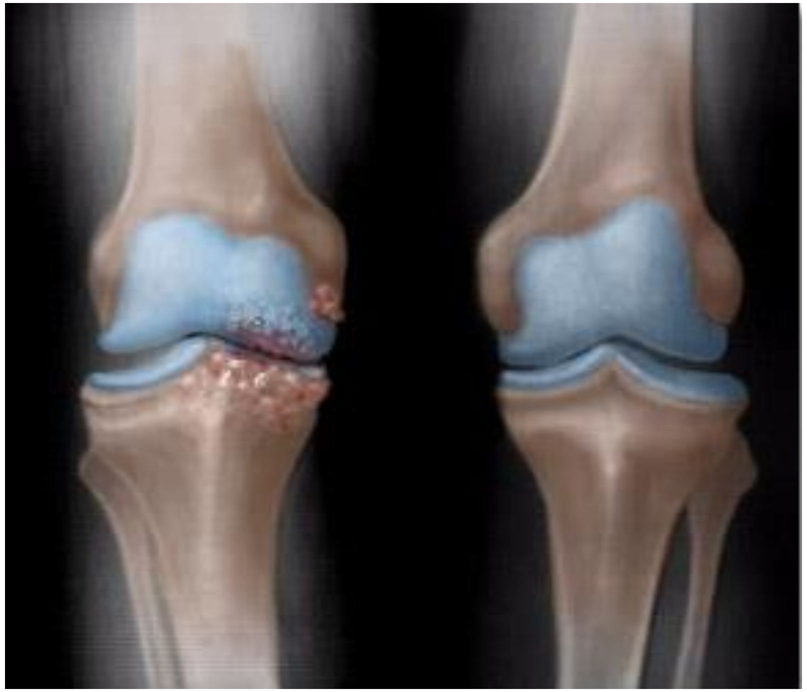
Osteoarthritis (هشاشة العظام): may result from wear and tear on the joint





The medial (inside) part of the knee is most commonly affected by osteoarthritis.

Treatment or Total Knee Replacement

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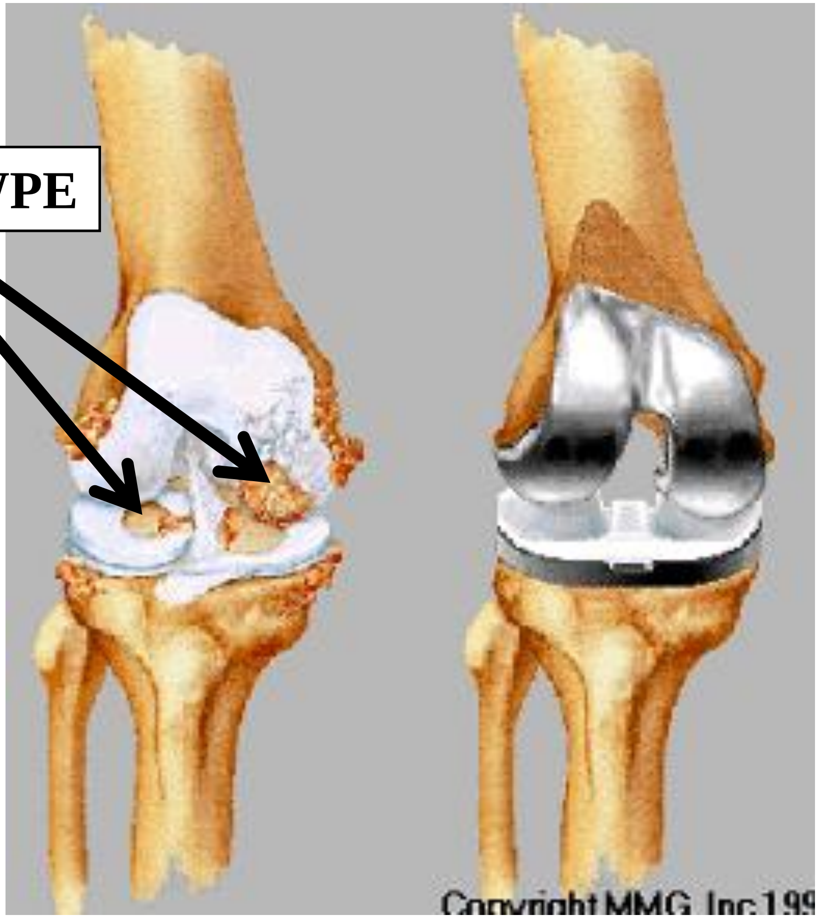
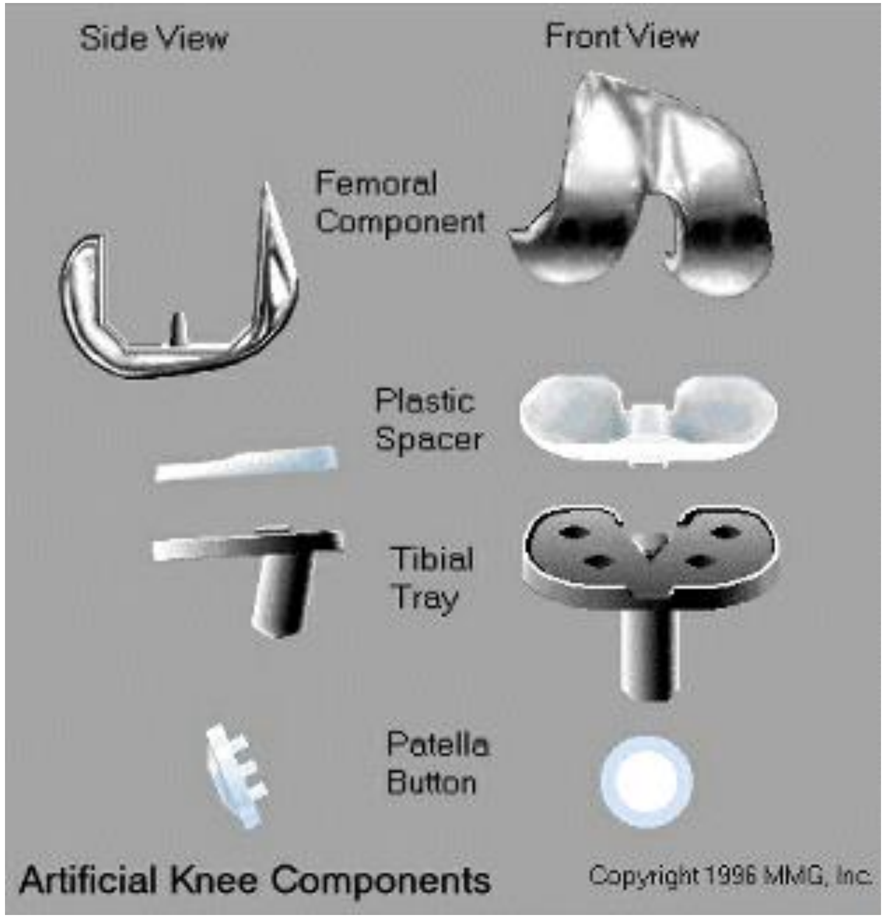
- Moving surfaces of the knee are **metal against plastic**

UHMWPE





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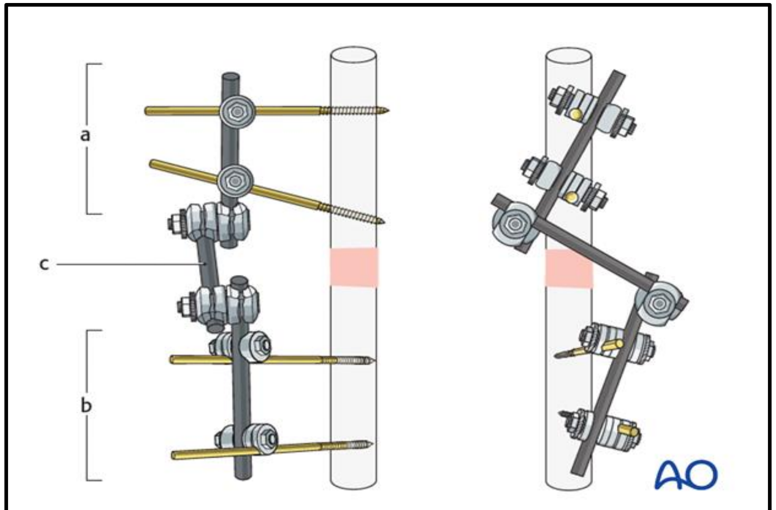
Biomechanics of External fixation

* **External fixation**: is a process for fracture fixation by which pins or wires are inserted into bone percutaneously(عن طريق الجلد) and held together via an external scaffold.

* **Frame Components:**
1)Pins, 2) Rods, 3)Clamps , 4)Rings & 5)Transfixion wires

* **Principle of External fixation**: The frame of a modular external fixator consists of two partial frames (a, b), one on each main fracture fragment. Each partial frame starts with two pins in a bone fragment, connected with a rod. The two frames are joined with a rod-to-rod construction/connecting rod (c).



Biomechanics of External fixation

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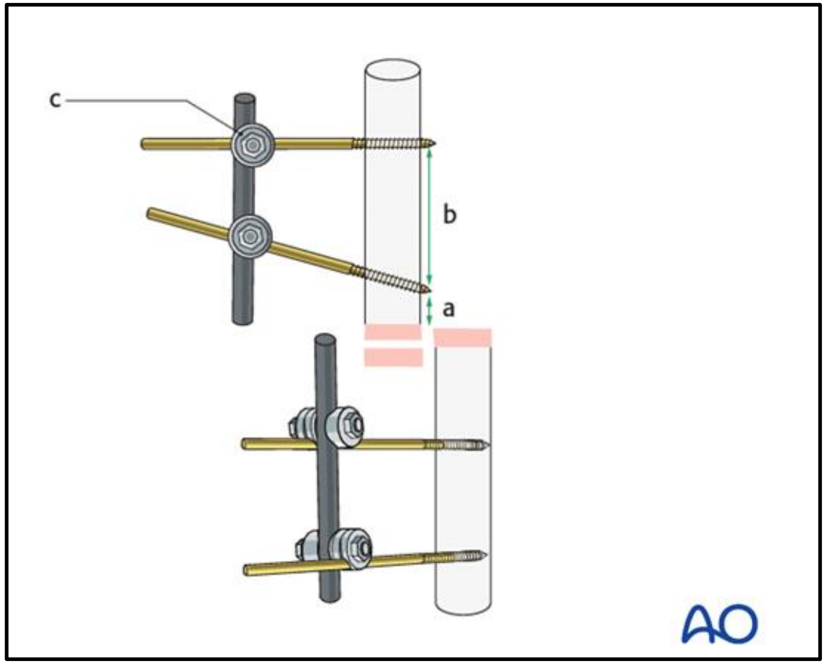
* Optimal frame construction

For the construction of the frame consider the following points:

1. 1. Pins are placed near the fracture site, but not too close and avoiding traumatized soft-tissue (a).
2. Pins are placed widely separated in each main fracture fragment (b).
3. Rods are connected to the pins with rod-to-pin clamps (c).
4. The rod-to-pin clamps are fully tightened so that each main fragment has its own partial frame.



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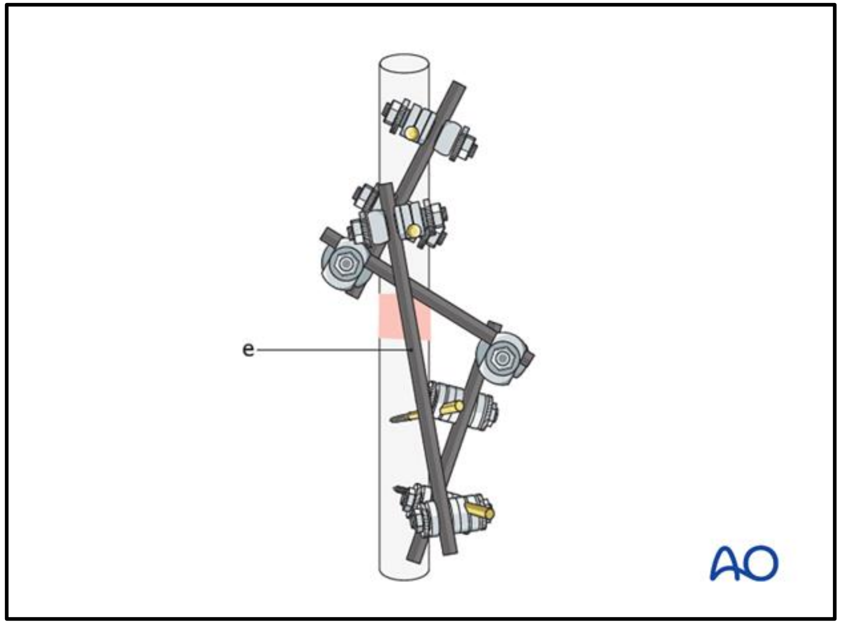
* **The stiffness of the frame may be increased by the following options:**

1. Using thicker pins
2. Positioning the rod closer to the bone
3. Adding a second connecting rod (neutralization rod) (e) between the partial frames
4. More pins in each segment



Biomechanics of External fixation

* Factors Effect on Frame Stability

1. Pin Size

a) a. Core diameter: Bending stiffness of a pin (S) = pin radius ^{4}.

b) Pin hole greater than (1/3) rd of the bone's diameter will substantially increase the risk of pinhole fracture after removal of the pin.

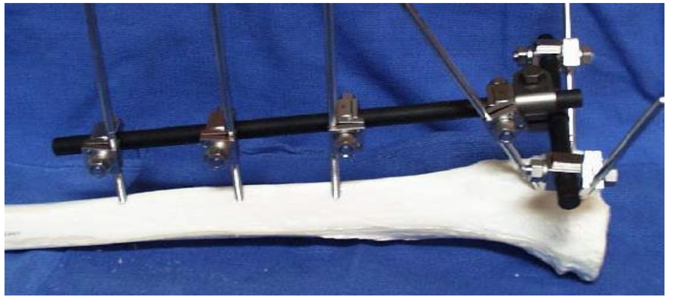
2. Number of Pins
– Two per segment
– Third pin

3. Pin Location
– Avoid zone of injury
– Pins close to fracture as possible
– Pins spread far apart in each fragment

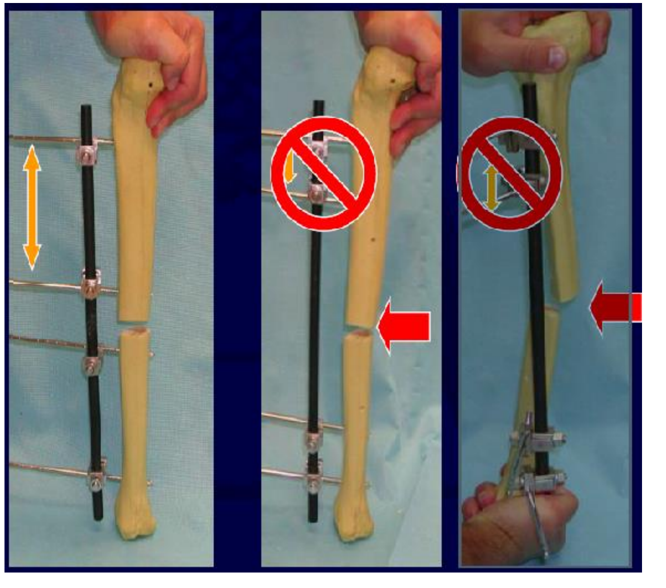
4. Wires
– 90º

5. Bone-Frame Distance

Number of pins



Pin location



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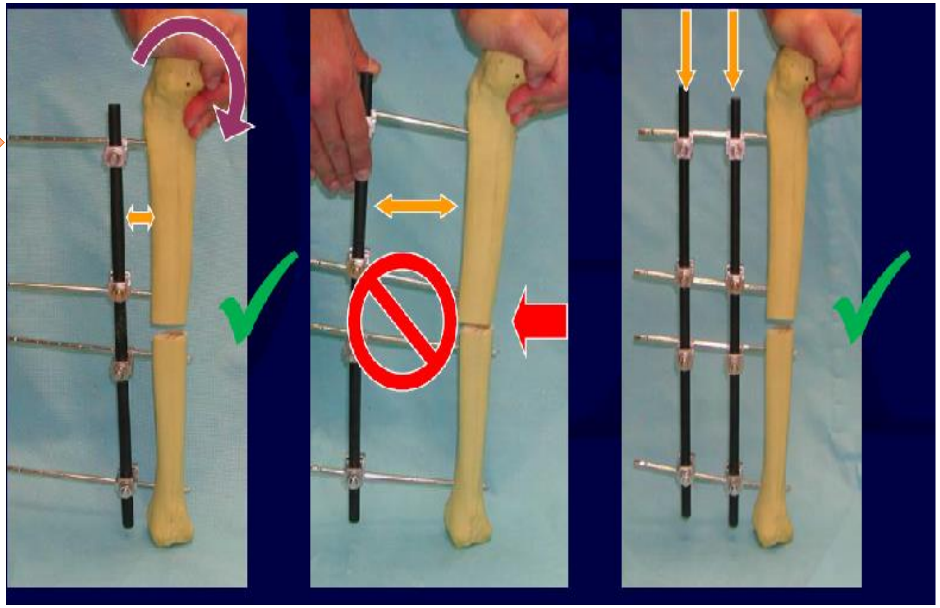
Biomechanics of External fixation

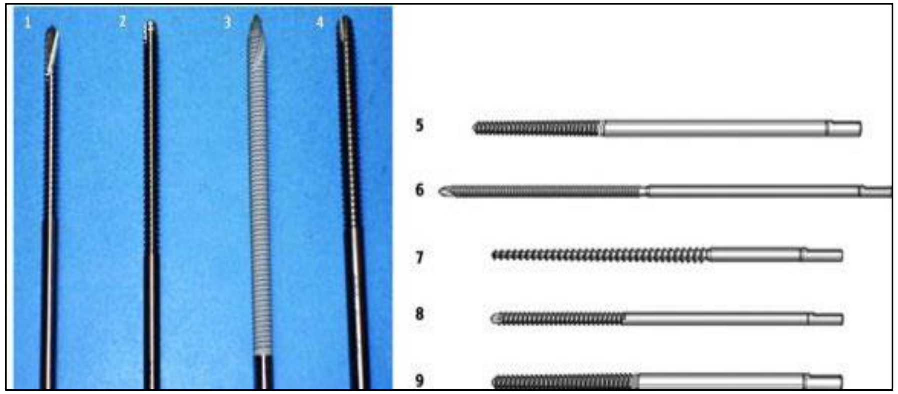
Bone-frame distance



* Pin bone Interface

Stability of the pin bone interface is most important factor in overall stability of an external fixator construct. Factors affecting Pin bone interface is :

1. Pin geometry and thread design
2. Pin biomaterials and biocompatibility
3. Pin insertion technique



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* **Pin Biomaterials**

1. **Stainless steel pins-Traditional**
2. **Titanium alloy pins**

a) Much lower modulus of elasticity

b) Less pin bone interface stress

c) Lesser risk of pin site infection and better Osteointergration

3. **Hydroxyapatite (HA) Coated Pins**

a) Best pin bone interface fixation

b) Less fibrous tissue interposition at the pin–bone interface

c) Less loosening More relevant in cancellous, Osteoporotic bones

The End of Lecture