Fracture fixation

Biomechanics of fracture fixation

Types

External fixation

Internal fixation

Mechanical considerations
Mechanical considerations in treatment of fracture

1. In the external fixation:
   - When the connective tissues at the fracture site are subjected to pure tension and pure compression, it will form a bone and enhance fracture healing.
   - When the connective tissues at the fracture site are subjected to shear stresses, it will form a fibrous tissue.
     - If the shear stress is limited, fracture callus will be formed (delayed union).
     - If shear stress becomes severe, non union may result.
   - When the connective tissues at the fracture site are subjected to pressure from all direction, it will form a cartilage.
Mechanical considerations in treatment of fracture

1. In the internal fixation:
   - The biomaterial used for internal fixation of the fracture must have adequate mechanical strength and fatigue resistance in order to prevent fatigue failure. So fatigue life of the material must be long.
   - The application of the internal fixation must be on the tensile side of the fracture to resist tension (which occurs due to bending or torsional loads).
Types of fracture fixation

**External fixation**
- Plaster cast
- External fixator

**Internal fixation**
- Wires
- Screws
- Plate and screws
- Intramedullary nail
Mechanical considerations

External fixation
- Weight bearing
- Non-weight bearing

Internal fixation
- Biomaterial
- Application site
Biomechanical Principles Of Fixation Devices

• Many types of devices are used for fracture fixation.
• The biomechanics of fixation are based on either stress sharing or stress shielding devices.
Biomechanical Principles Of Fixation Devices

**Stress-sharing Device**

- It permits partial transmission of load across the fracture site.
- This results in **micromotion at the fracture site**, thus enhancing callus formation.
- *e.g.* casts, rods and intramedullary nails

**Stress-Shielding Device**

- It shields the fracture site from stress by transferring stress to the device.
- The fracture ends of the bone are held under compression and there is **no motion at the fracture site**.
- *e.g.* Plate and screws
External fixation

Plaster cast
External fixation

Plaster cast application video
External fixation

External fixator
External fixation

External fixator
External fixation

Special type (Ilizarov type)
External fixation

Special type (Ilizarov type)
External fixation

Video of (Ilizarov type)
Internal fixation

Indications for internal fixation

1- when chance of union by external splintage is remote (e.g. fracture neck of femur).

2- when the fracture unstable.

3- when the general situation of patient does not permit prolonged recumbence.

4- in case of multiple injuries.
Internal fixation

Wires (stress sharing device)

- Wires are used in treatment of transverse fracture.
- The wires place the 2 fragments of the fracture together at a point of contact.

- Applied on the tensile side of the fracture, to absorb all tensile forces and converts distraction forces into dynamic compression between fracture sites so enhance healing process.
Strong surgical wire is passed over the anterior surface of patella (tensile surface) under the quadriceps tendon and the patellar ligament and then it is tightened firmly.
Internal fixation

Wires fixation of olecranon

Figure-of-eight wire
Difference between wires and screws

1- The fixation (or fulcrum) is not at the end of the fracture, so when the triceps force is applied, the fracture is free to open & this force will be counterbalanced by the rigidity of the screw.

2- The screw may be subjected to bending stress and it's not designed to withstand bending stress.

3- Only one side of the fracture is compressed by muscular force.
Screws

direction of screw application in spiral fracture

Oblique screw
To resist torsional load but weak in bending

Transverse screw
To resist bending load but weak in torsion

So it must be used of both oblique and transverse screws
Internal fixation

Plate and Screws (stress shielding device)
(To avoid disadvantages of screws)

**Advantage**
Allow early weight bearing on fracture site.

**Disadvantages**
1- Delay healing due to decrease stress on fracture site.
2- Weakness of bone between screws with long period of application which may lead to refracture of bone.
Internal fixation

Video of Plate and Screws application for fibular fracture

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ORIF of Fibula Fracture

SAMPLE

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Internal fixation

Plate and Screws (stress shielding device)

Precautions of Plate and Screws application

1-If the plate is not applied on the tensile side, during bending the plate will be centered at the neutral axis and fracture will not be totally in compression.
Precautions of Plate and Screws application

2-If the plate is thin, fatigue failure may occur due to bending.

3-If the screws are not tightly set, bending stresses will occur at the screws. The plate will bear the bending moment
Precautions of Plate and Screws application

4-In the case of fracture with a gap or a comminuted fracture, one plate and screws can't be used because the plate will bend as in the following figure:

To overcome this problem, **two plates and screws must be used.** One plate in the tensile side and the other in the compressive side:
Internal fixation

Intramedullary nail (stress sharing device)

Used for long bone fixation

**Advantages**
1- Located at the center of the bone so it has good resistance to bending.
2- Allow partial weight bearing
3- Not rigid fixation as plate so it is a stress sharing device which promote healing.

**Disadvantages**
1- Weak in compression and torsional loads.
2- Rotation or sliding of distal bone fragment if there is no transcortical screws.
Internal fixation

Intramedullary nail (stress sharing device)
Internal fixation

Video of Intramedullary nail application for femoral fracture
Stress concentration

1-During application of screws or plate and screws

Away from screws
Normal stress distribution.

Between screws
Low stress which lead to bone weakness and refracture with long period of plate application

At ends of plate
High stress concentration.
Stress concentration

Principle of healing

The bone is formed when it is needed & resorbed when not needed.

- The areas of higher stresses form bones & that of lower stresses caused bone density to be low.

- So, refracture may occur at area between screws (area of lower stress) if the fixation applied for long time with high loading (wt. bearing)
2- After removal of screws.

- There will be **holes** inside the bone.
- If the segment is **loaded** (compression or tension) the total load is the **same** for any cross section of the bone.
- **Stresses** are represented by number of lines proportional to the **total load** on the segment.
- Stresses are **concentrated** around the **holes** & **lowered** in **wide areas**
2- After removal of screws.

At edge of hole

Stress concentration which lead to new bone formation of callus bridge which increase bone diameter

As healing occurs. When stress distribution returns to normal, the bone resorbed and resumes its normal geometry.