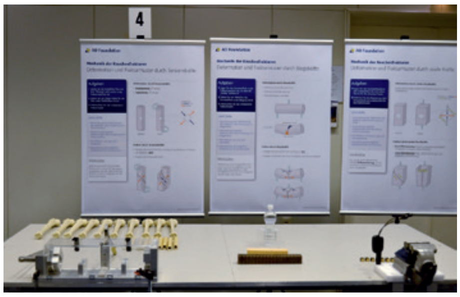
Skills Lab Faculty Guide
Mechanics of bone fractures

A 20-year-old man is admitted to the emergency department having sustained an injury playing soccer. His leg is swollen and tender. X-rays of the tibia are taken. A transverse fracture pattern with a small butterfly (triangular shaped) fragment can be seen in the medial third of the tibial shaft. By reading the x-rays, an experienced orthopedic surgeon will know, even before talking to the patient that this is a fracture resulting from a direct blow to the tibia. According to the fracture pattern, the surgeon would assume, in addition to the injuries to the bone, a high risk for soft-tissue-related complications right on the location of the impact. Further on it might well be that other, hard or soft tissues, could also be damaged above and below the fracture pattern visible. This information is obtained just by looking at the x-rays. How? Bone, as any other material, behaves in a specific way under load. So when it fractures, the fracture pattern reveals information about the magnitude and directions of the forces and/or moments that produced the injury.

At this station, you will ask participants to load artificial bones in three different ways until they fracture. You then can explain how compressive, tensile, and shear stresses create damage to the bone and help particiants to understand the resulting fracture patterns and accompanying soft-tissue injuries.



Learning outcomes

After completing this station, participants will be able to:

- Describe deformation of material under torque, bending, and axial load
- Discuss typical fracture patterns under torque, bending, and axial load
- Describe the orientation and nature of stress in compression, tension, and shear
- Discuss possible implications of each fracture type on the soft-tissue envelope

Take-home message

- Deformation under torque first creates a spiral fracture inclined 45° on the side under tension, then a longitudinal split on the side under compression
- Deformation under bending first creates a transverse fracture on the side under tension, then an oblique fracture, with or without wedge, on the side under compression
- The resultant stress of compressive and tensile stress is shear, which is the main reason for failure of bone in compression

Station sequences (your tasks)

When you arrive at the station for the Skills Lab module:

- Familiarize yourself with the posters, which include learning outcomes and tasks.
- Check the set-up before participants arrive at this station. There should be 10 tibiae, 10 generic diaphyseal bones with a smiley face, and 10 cubes of artificial cancellous bone.

During the group activity (to be repeated for each group):

- Explain to the participants that fracture patterns vary based on the type of stress (compression, tension, shear) which acts onto the bone.

Deformation and fracture under torque

- Place an artificial tibia into the molds of the fracture box. Let one of the participants load the bone by pulling the lever on the side until it fractures.
- Discuss the fracture pattern with the participants. Point to the spiral fracture on the side which was under tension and to the longitudinal fracture on the side which was under compression.

Deformation and fracture under bending

- Place a diaphyseal artificial bone in the middle part of the fracture box so that the smiley faces you. Ask a participant to apply increasing bending force onto the middle lever until the artificial bone breaks. (Assist participants to break the bone if they are having trouble; it requires a lot of force.)
- Make participants aware of the transverse fracture pattern on the one side of the bone and the complete or incomplete bending wedge on the other side, with or without the small butterfly fragment.
- Point out the position of the transverse fracture, as well as the bending wedge with respect to the tension and compression side of the bone respectively (the smiley face will help you with the orientation and, eventually, you even are able to bring all the fragments back together).

Deformation and fracture under axial load

- Place a cube of artificial cancellous bone right in the middle between the two jaws of the vice.
- Ask a participant to compress the cube by rotating the lever of the vice. Please note: either black or gray cubes are supplied.
- Ensure participants compress the cube slowly and carefully so the fracture pattern can be seen as it develops which could happen on the side or on the top of the cube (oblique, Y, or X-shaped). Please note: if gray cubes are supplied, one can see a wedge forming which splits the cube in two parts (not the case with the black cubes). Shine a light onto the cube to improve visibility.
- Discuss the fracture pattern with the participants and point out that the fracture created is a resultant of compression and bending stress, which create a shear stress, inclined by 45 degrees.

Discussion points

- Discuss the implications of fractures created by torsion, bending, and axial load on the bone as well as on the soft-tissue envelope.
- Summarize the take-home messages.
- Briefly restate the findings of the exercise:
  - Did the participants understand the differences of the three fracture types, and can they describe what implications they have for the surrounding soft tissue?
  - Can the participants explain the different stress types—bending, compression, and shear—and tell apart the sides of the models under compression from those under tension?

While participants are changing tables:

- Put the broken tibia, generic bone, and cube aside. Please note that there is only one of each bone type per group. If one of the bones shows the fracture pattern very clearly, you can use them to further illustrate the variants of the typical fracture patterns.

Before you leave the station after the Skills Lab module:

- Put all broken artificial bones back onto the table. Please note that for customs reasons, you or the participants are not allowed to take the broken artificial bones home.

Frequently asked questions (FAQs)

What is a torsional load? How does it produce a fracture?
When one section of a bone is forced to rotate in one direction and another section of the same bone is forced to rotate in the opposite direction, the bone can fracture. The cause of this is a torsional load (external force), applied onto one or both sections of the bone. The stresses created are compressive and tensile shear stress, oriented in a 45-degree angle around the bone. These shear stresses are finally responsible that the bone fractures.

What is bending?
For bending there is a compression (shortening) and a tension (lengthening) side on the bone. The applied load (eg, a direct blow) hits the bone on the compression side, literally bending the bone. As bone can only tolerate a small amount of deformation, it will eventually fracture. The bone will fail first on the tension side producing a transverse fracture, and then on the compression side producing a butterfly (bending wedge) fragment or a small spike (incomplete fracture).

What is axial compression?
Deformation under axial load (external forces onto a structure) creates not only compressive but also tensile stress. In other words: as the bone is compressed in one direction, it suffers a transverse expansion in the other. As it gets shorter it also gets wider. The resultant of compressive and tensile stress is shear stress, which, in fact is responsible that the bone breaks in an oblique or double oblique fracture pattern. Usually this fracture pattern occurs in the metaphyseal zone of the bone as a result of a fall or another dynamic load onto the bone(s) involved. There could be associated injuries along the path of the load.

How is this clinically relevant?
Knowledge about the amount, direction, and concentration of load (external forces onto a structure) applied onto the bone(s), and how the respective fracture patterns look, aids in patient treatment as this is an indicator of trauma mechanics, and a marker for concomitant injuries and/or risk of soft-tissue damage, among other things.