

Skills Lab Faculty Guide

Fracture healing

At this station, you will explain the basics of bone healing to the participants, including the notion of direct (primary) versus indirect (secondary) healing, absolute and relative stability, callus formation, and deformation of tissue.

Bone healing is the goal of every fracture treatment, be it operative or nonoperative. Ultimately, fracture healing always relies on nature and the bone's intrinsic healing capabilities. It can be compared to suturing a skin wound; no matter how many or what stitches are performed, time is needed for the skin to heal and form a scar. Orthopedic surgeons provide the right mechanical

environment and if necessary reinforce the biological environment for a fracture to heal itself. It is thus essential that surgeons understand how bones repair themselves in order to provide the appropriate environment.

Using the demonstration models and the posters, you can describe:

- The process of fracture healing from inflammation to remodeling
- How the fracture stabilizes (with the tubular demonstration model)
- How the fracture gap width influences tolerance to movement (with the flat demonstration model)



Learning outcomes

After completing this station, participants will be able to:

- Identify the importance of the increasing cross section
- Identify the importance of tissue transformation between fragments
- Define absolute and relative stability
- Define the importance of initial gap width on cell deformation under the condition of relative stability
- Define the effect of tissue differentiation on deformation

Take-home message

- Apposition of callus leads to an increase of cross section and thus of stiffness in the fracture zone
- Callus transforms over time
- Under relative stability the cells in a small fracture gap can be destroyed because of excessive strain

Station sequences (your tasks)

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

- Familiarize yourself with the posters, which include the learning outcomes and tasks.
- Check the set-up before participants arrive at this station.

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

- Explain to participants that two topics about fracture healing and related concepts will be addressed.

Mechanics of callus

- Explain that each side of the model represents a fracture fragment and the connecting sleeve represents the volume of the callus. The beads represent callus tissue.
- Show the participants how the model bends at the *fracture site*.
- Push one side of the model to fill the sleeve with all the beads. Note that as the cross section of the *callus* expands, the construct stiffens and becomes more rigid.
- Vacuum applied by pulling on the other side of the model (not further than the mark) represents callus maturation and differentiation into bone. Note that vacuum to the callus causes it to stiffen and the construct is even more rigid.
- Break the vacuum and push some beads back into the tube by gently pulling the opposite plunger and modeling the *fracture site* by hand. Apply a slight vacuum.
- Even when pushing the beads back into the tube and then applying vacuum to enable it to mature to bone, a stable construct would still be achieved.

Mechanics of interfragmentary tissue

- Explain that the model represents tissue deformation under strain.
- There are three different gap sizes, each of them containing the appropriate amount of *cells*, which can represent true fibroblastic cells in callus between two bone fragments in comminuted fractures. This model

allows for a certain amount of absolute displacement, which is the same for the three gap sizes.

- Widen the gap by inserting one finger in the hole and pulling.
- Point out that when the model is pulled, the gap with one cell shows a higher deformation than the gap with three cells, even though the absolute amount of displacement is the same. This is because the relative deformation (deformation of one cell) is higher when the gap is narrow. In a wide gap, absolute displacement will be distributed among many cells and relative deformation of one cell is less.
- Use the model to explain tolerance against deformation and the relationship between absolute displacement and gap width. This is essential to understanding the decision-making process when choosing between the use of absolute or relative stability according to the fracture pattern:
 - *Simple fractures*: small gap → high relative deformation (high relative strain) → high stress → absolute stability → direct healing
 - *Comminuted fractures*: wider gap → low relative deformation (low relative strain) → low stress → relative stability → indirect healing

Discussion points

- Discuss the possible implications of the mechanics of callus and interfragmentary tissue.
- Summarize the take-home messages.

While participants are changing tables:

- Ensure that the tubular callus demonstration model is back to its original state: only a few beads in the middle, no vacuum applied.
- Put the tubular model in front of the posters explaining callus, and the flat model in front of the poster addressing the interfragmentary tissue.

Before you leave the station after the Skills Lab module:

- Put both models back onto the table.

Frequently asked questions (FAQs)

What is callus and how does it make a fracture stable?

Callus is the scar the bone creates to heal itself. It is the *classical* means by which a fracture consolidates. It has been called indirect bone healing and it comprises four phases: inflammation, soft callus, hard callus, and remodeling.

The body produces a mass of tissue surrounding the fracture (granulation tissue) that slowly becomes more rigid. Granulation tissue has a high tolerance against deformation but is not very rigid. A certain amount of motion is necessary for granulation tissue to form. It then differentiates into fibrous tissue, which is more rigid, then into cartilage, woven bone, and finally it becomes laminar bone, which is the most rigid and least flexible (stiffest) of all. As the callus forms and matures, its cross section expands and it becomes more rigid, thus fostering stability.

As tissue differentiates, the amount of motion possible at the fracture site diminishes. This works as a cycle, since a more rigid construct promotes tissue differentiation into bone. However, if there is no motion, there is also no stimulus for the tissue to differentiate. The exact amount of motion, introduced by a certain amount of load (external forces onto a structure) by which bone formation is promoted, is unknown. Too much or too little motion can produce nonunion, unless there is no motion from the beginning, in which case the fracture heals by different means, ie, direct bone healing.

What is direct and indirect bone healing?

There are two paths a fracture can take to heal. In direct healing the bone heals without or almost without any callus formation. That means that the osteons (bone forming units) cross the fracture site as if there was no fracture at all. It is as if the bone *forgets* there was a fracture. For this to happen there must be no motion at the fracture site (absolute stability).

In indirect healing a callus develops as explained in the answer to the first FAQ. Some motion (caused by a certain load) must be present in order for indirect healing to develop (relative stability). Once again the exact amount of motion required is unknown.

What other factors are involved in direct/indirect healing?

Besides the *motion* condition (ie, absolute stability for direct healing and relative stability for indirect healing) both direct and indirect healing needs an adequate blood supply. This cannot be overemphasized. Preserving blood supply is one of the most (if not the most) important factors for achieving union. In the past, operative techniques called "biologic osteosynthesis" were developed that maximized blood supply preservation. This kind of technique should be used every time a fracture is treated, either by open, minimally invasive, percutaneous, or closed means.

How do motion at the fracture site, gap width, and tissue deformation relate to each other?

For any given displacement, either linear, angular or a combination thereof, the gap width and the amount of cells in the gap will determine the amount of deformation each cell undergoes. To put it simply, the sum of all displacements per cell in a gap is equal to the total displacement of the whole gap. With more cells in a gap, the same displacement will cause less stress in each cell. Wider gaps will fit more cells in them, thus tolerating deformation better. This relationship between movement, gap size, and deformation is not only true at a histological level. If, for example, strain accumulation between a three-part fracture and a highly comminuted fracture are compared, you will notice that with more comminution every fragment undergoes displacement and thus less strain or deformation. Grasping this concept is essential to understanding the kind of stability needed for each fracture pattern. Simple fractures have small gaps containing few parts. Allowing any motion can lead to high stress concentration and deformation, which can lead to nonunion. With that in mind no motion (absolute stability) would be preferable to promote direct healing.

However, comminuted fractures have larger gaps and many parts, leading to low strain accumulation and very little motion between each fragment. Since only a small amount of motion is necessary for callus formation, comminuted fractures can be treated with relative stability and indirect healing. In theory, absolute stability could be provided to each fragment to promote direct healing in comminuted fractures. However, in order to fix each of the fragments, you would have to sacrifice blood supply, which is a key element in fracture healing. This method was used in the past, with operative techniques that strip the bone of its surrounding tissue and fix every part of the fracture together. This technique led to unacceptably high nonunion and infection rates.

How do absolute and relative stability relate to bone healing?

Absolute stability promotes direct bone healing, whereas relative stability induces indirect bone healing.