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Skills Lab Faculty Guide

Fracture healing and plate fixation

STATION J

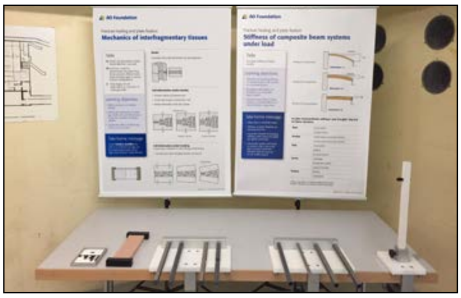
At this station, you will explain the following concepts:

1. how deforming forces produce interfragmentary strain. If deforming forces produce a strain which prevents bony healing in a given gap, motion in the gap must be subdued (absolute stability). If strain can be distributed among multiple gaps, bony healing will occur despite higher deforming forces (relative stability).
2. how the stiffness of a bone-plate construct differs under a bending load. The goal is that participants can feel and learn how the implant as well as the direction of bending influences the stiffness of the bone-plate construct.

Plate fixation is a very versatile method of bone fracture management. Since the same plate can be used in many ways (eg, to compress, buttress, or bridge fractures) it is essential for the surgeon to be familiar with the strain theory and the mechanics of plating to achieve acceptable and predictable outcomes when treating a fracture by these means.

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

- How the fracture gap width influences tolerance to movement (with the flat demonstration model), and how deformation forces affect different fracture patters (with the foam model)
- What degrees of stability can be observed when an unstable bone is made more rigid by applying a plate to a given side, then increasing the stability (stiffness) by adding a screw (bolt) or placing the plate on a different side (tension side) of the bone or adding additional screws



Learning objectives

After completing this station, participants will be able to:

- Define absolute and relative stability
- Define the importance of initial gap width onto cell deformation under the condition of relative stability
- Explain the effect of deforming forces on tissue strain
- Describe the bending stiffness of isolated beams with respect to composite beams
- Recognize plate fixation of fractures as a composite beam system
- Describe importance of plate position on overall stiffness of internal fixation using plates

Take-home message

- Under **relative stability** the cells in a small fracture gap can be destroyed because of too high strain (Perren's strain theory)
- Plate alone is relatively weak
- Stiffness of plate depends on bending direction
- Important increase of bending stiffness when bone and plate are tightly connected
- Composite system with plate on tension side is the most rigid construct under the condition that the fracture can be axially loaded

Station sequences (your tasks)

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

- Familiarize yourself with the posters which include information about the station's learning objectives and tasks
- Check the set-up before participants arrive at this station

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

- Explain to the participants that two topics concepts will be addressed at the station (see below)

Mechanics of interfragmentary tissue

- Explain that the models represent tissue deformation under strain
- There are three different gap sizes, each of them containing the appropriate number 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 foam 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 → a 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

Stiffness of composite beam systems under load

- Start with the four models without fractures. Let the participants carefully push down on the ends of the various constructs with the tip of one finger. Let them explain what they feel, which construct is the most flexible, and which the most rigid (you will find the answers in the top half of the second poster).
- Then move to the upright standing, white model. Show the participants how the gliding between the beams can be eliminated when the single beams are connected by a bolt which then leads to an increase in stiffness of the beam system.
- Move to the third model on the table and let the participants load these as well by carefully pushing down on the ends with the tip of one finger. Explain why the models with the plate on the underside—the compression side—feel less stiff than the constructs with the plate on the upper side—the tension side. Point out how a large gap impacts the ability of the construct to share load between plate and bone, regardless of plate position.

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Station sequences (your tasks)—continued

Discussion points

- Discuss the possible implications of interfragmentary tissue motion
- Discuss the importance of plate position in the stiffness of a bone-plate construct
- Discuss the difference between stiffness (the ability of a material to withstand deformation) and strength (the ability of a material to withstand destruction). Where the stiffness of an osteosynthesis can be measured clinically, strength cannot be determined without doing harm to the patient.
- Summarize the take-home messages

While participants are changing tables:

- Put the models back in place
- Remove the bolt from the upright standing model, if necessary

Before you leave the station after the Skills Lab module:

- Ensure the bolt is on the table

Frequently asked questions (FAQs)

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 will determine the amount of deformation each cell undergoes. Simply put 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 motion, gap size, and deformation is not only true at a histological level. If, for example, strain accumulation between a 3-part fracture and a highly comminuted fracture are compared, you will notice that with more comminution every fragment undergoes less 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 in 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.

What is a composite beam system?
A composite beam system is a construct of two or more separate beams connected to each other.
By connecting the beams their stiffness (resistance against deformation) is multiplied by eliminating the shear stress between them.

How does a composite beam system relate to plate fixation?
Plate fixation is a composite beam system in which the plate (one beam) is connected to the bone (second beam) by screws. As the two structures are connected, shear stresses are reduced and the stiffness of the construct is greatly improved.

What is the difference between stiffness and strength?
Stiffness is the ability of a material, or system, to withstand deformation.

Stiffness can be measured by application of a load and measurement of the displacement of the material, or system, as a reaction of the load applied. Strength is the ability of a material, or system, to withstand destruction or failure. Strength can be measured by applying a load onto the material, or system, until it fractures or otherwise desintegrates.

In consequence, the strength of a material or system, ie, a plate-bone construct, can clinically not be measured as this would lead to the destruction of the system (ie, the patient). In contrast, the stiffness of a plate-bone construct can clinically be measured without doing harm to the patient. Therefore, the use of the term „strength“ should be avoided (as it cannot be measured clinically) when, in fact, „stiffness“ is meant.

What elements contribute to the stiffness and strength of plate fixation?
Almost every element that is involved in plate fixation contributes in one way or another to the construct's stiffness and strength. Plate characteristics (ie, locking versus conventional plate, steel versus titanium), plate position (tension or compression side), plate size (cross section and length), screw characteristics (size, number, anchorage), bone characteristics (quality, cross section), fracture pattern (simple versus complex and comminuted bone defects), and fixation technique (compression, bridging, buttress, or neutralization plate) all play an important role in the mechanical behavior of fracture fixation and in the healing process of the bone.

How is all this clinically relevant?
Understanding the principles of plate fixation is necessary to create an adequate preoperative plan and choose the right implant for every specific fracture and patient.