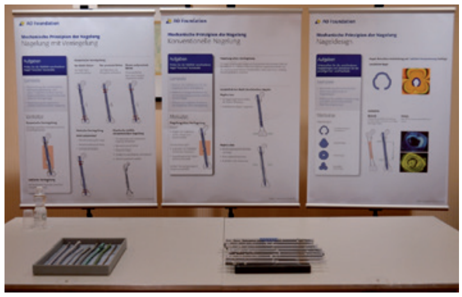
Skills Lab Faculty Guide

Mechanics of intramedullary fixation

At this station, you will introduce participants to the basics of intramedullary (IM) nailing. You will present the evolution of nail design and how the design influences the stability of the fixation. By playing with the models, participants will be able to understand the importance of nail size and the different interlocking options (static and dynamic), with its implications in alignment, stability, and stiffness of fracture fixation.

Intramedullary interlocked nailing has become the standard of care in the operative treatment of shaft fractures of long bones. There are multiple implant options, eg, solid or cannulated nails, reamed or unreamed procedures, one or several interlocking screws, dynamic or static interlocking. Understanding the mechanics of IM nailing is essential to choose the right implant given a specific patient and fracture pattern.

Using the collection of nails, you can explain the history of nailing and describe the advantages and disadvantages of each nail design. Using different bone-nail models, you can explain the mechanics of those constructs and the participants can try themselves how various constructs vary in stiffness, etc.



Learning outcomes

After completing this station, participants will be able to:

- Describe different nail designs and their mechanical characteristics
- Explain radial preload and corresponding concept of stabilization
- Describe indications and discuss potential problems for nailing without interlocking
- Identify common problems when using nails that are too short or too thins
- Describe different nail locking options and possible influences on the stability of fixation (dynamic versus static locking)
- Explain elastic stable IM nailing

Take-home message

- There are different nail designs: slotted, solid, cannulated, and elastic nails
- Nailing without interlocking requires a nail with proper length and diameter, and can be used for fractures in the middle third of the diaphysis with partial contact between main fragments. Be aware of the need for adequate rotational stability
- Dynamic interlocking also requires partial contact between the main fragments, while static interlocking is feasible when there is no contact between main fragments

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 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 the task to participants and introduce the different nail designs.
- Give the nails to the participants so they can look at and hold the various nail models to recognize the differences between them.
- The plastic models represent nail-bone constructs. For some of these the nails are either too short, too thin, or only partly interlocked, for others the nails are perfect in every aspect. Discuss these properties with the participants.
- Let the participants push, bend, and rotate the models so that they can feel the properties of the different constructs.
- Also make the participants aware of how dynamic versus static interlocking impacts construct stability.

Discussion points

- Discuss the advantages and disadvantages of each construct.
- Discuss the following topics:
  - Importance of interlocking on fracture fixation and stability. Differentiate between static and dynamic interlocking. Static interlocking controls length, rotation, and axial alignment of the osteosynthesis. Dynamic interlocking controls rotational and axial alignment but length only partly.
  - Reaming and its implication for the biomechanics of the nail (which is improved by enlarging the contact area) and for the perfusion of the bone (because of damage done to the endosteal circulation).
- Summarize the take-home messages.

While participants are changing tables:

- Place the plastic models and the nails back on the table in the right order.

Before you leave the station after the Skills Lab module:

- Ensure that the nail collection and plastic models are complete.

Frequently asked questions (FAQs)

How does an IM nail work?
Depending on the fracture pattern and the final bone-nail construct, an IM nail works as an internal splint with more or less load-sharing characteristics. If cortical contact between the main fracture fragments is achieved after reduction, most of the load will pass through the bone. Nails provide relative stability and are the standard of care for diaphyseal long-bone fractures. Since nailing provides relative stability, then you would expect healing by callus formation.

Why should I interlock the nail?
Interlocking the nail allows better control of torsional loads and preserves the length of the bone via load sharing through the bolts. A nail that is not locked depends on the contact (friction, by radial preloading) between the nail and the bone to restrict motion of the fragments, whereas a locked nail will share the load through the nail-bolt and the bolt-bone interface, achieving a more stable construct.

How do the shape and the size of a nail affect its mechanics?
Shape and size of a nail are important factors that determine its mechanical characteristics. Stiffness (the ability to withstand deformation) and strength (the ability to withstand destruction) of a nail is proportional to its diameter. That means that the broader the nail, the harder it is to bend and/or break. The shape of the nail dictates how it will behave as it contacts the surrounding cortical bone. A slotted nail increases the radial compression (when introduced in a canal smaller in diameter than the nail) thus increasing friction and contact stresses to the cortical bone. Slotting has the disadvantage of reducing torsional stiffness, a problem that is dealt with by interlocking the nail.

What is radial preload?
Radial preload is the elastic deformation of a nail with respect to its cross-section. It provides high friction between nail and bone which allows it to anchor. It is mainly achieved with slotted nails in reamed bones.

What is reaming and what advantages/ disadvantages does reaming have?
Reaming is drilling the IM channel. It enlarges the endosteal diameter of the bone. It helps to increase the contact area between bone and nail by smoothing the internal aspect of the cortical bone. It also allows for a bigger nail to be inserted, thus improving bending and torsional stiffness. Another advantage of reaming is that the debris produced by the reamer, to a certain degree, acts as an autologous bone graft that can help the fracture heal faster. However, reaming also has disadvantages. It disturbs endosteal circulation by physically destroying the medullary vessels and by heat generation. In addition, during reaming the IM pressure elevates, raising some concern about fat embolism. This should be taken into account especially in patients with concomitant injuries, such as blunt thoracic trauma or ADRS.

What is static and dynamic interlocking and how does it affect fixation?
Interlocking bolts placed proximally and distally to the fracture site restrict translation and rotation, providing a stable environment for the fracture to heal. Since there is a small amount of motion at the nail-bolt interface some movement of the fracture is expected. This explains why interlocked nails provide relative stability, relying on callus formation for the definitive healing of the fracture. As seen in Station E: Fracture healing, for a callus to be formed some micromovement at the fracture site should be present.

Dynamic interlocking allows more movement than static interlocking. It allows for load (external forces onto the structure) at the fracture site when the patient bears weight. With that in mind, some conditions have to be fulfilled before interlocking a nail dynamically. There must be contact between the fracture fragments, either by direct cortical contact (as in transverse fracture patterns) or by means of a soft/immature callus (as in delayed unions) so that the fracture itself has some stability and could benefit from the compression. If the fracture is not stable enough, it will not benefit from the extra motion and nonunion may result, thus static interlocking is needed in such cases.