AO Foundation

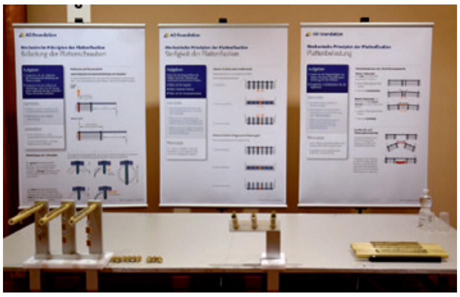
STATION H

Skills Lab Faculty Guide
Mechanics of plate fixation I

At this station you will explain the principles of load sharing/shielding between implant and bone to the participants. This is done by identifying the influence of a gap and of screw positions related to this gap on the stiffness of the fixation according to the bending directions and/or plate position (understanding the principle of tension and compression sides). It also shows how plate length and working length of a screw influence plate fixation and screw pullout.

Plate fixation is a very versatile method of bone fracture management available to the orthopedic/trauma surgeon. Since the same plate can be used in many different ways (eg, to compress, buttress, or bridge fractures) it is essential for the surgeon to be familiar with the mechanics of plating to achieve acceptable and predictable outcomes when treating a fracture by these means. The extent of this topic made it necessary to divide it in two complementary stations (Stations H and J).

There are three topics to address at this station:
1. The lever principle and how it affects fracture fixation as well as loading of the screw.
2. Working length of the screws and how it affects screw hold and stiffness of the construct



3. How overall stiffness of plate-bone constructs is influenced by the different techniques.

Learning outcomes

After completing this station, participants will be able to:

- Explain how lever arm length influences screw loading
- Define the term "screw working length"
- Explain principle of load sharing between implant and bone with respect to gap size and bending direction
- Explain importance of screw position with respect to overspan width, stiffness of construct, plate loading, and plate failure
- List reasons for plate failure and identify actions to avoid plate failure

Take-home message

- Short lever arm = high pull-out force on the screw
- Long working length = low stress on the screw
- To share load, an implant must be attached to the tension side of the bone
- Short segments of plate will break under repetitive stress
- Incarcerated bone fragments lead to load sharing

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.
- Familiarize yourself with the models and how to use them for demonstration.
- Check the set-up before participants arrive at this station.

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

Lever principle
- Explain the tasks to participants and encourage them to load each plate-bone construct.
- Let participants load the front end of the plate by adding weights one by one and check the displacement of the last screw on the other end after each addition.
- While the middle construct requires approximately the same weight on each side to tip over (same length of plate on both sides of the fracture gap), the left model needs less weights until the screw is pulled out (longer plate, long lever arm on the side, where the weights are applied) than the right model, with a shorter plate (short lever arm).

Working length
- Explain the tasks to participants, and present the three cut-off bone-plate constructs in the demonstration model (monocortical screw insertion in thin cortex and thick cortex, and bicortical screw insertion in thin cortex).
- Encourage participants to rotate the front ends of the model and let them feel the degrees of stiffness. Ask them which screw-plate combination is most rigid and withstands rotational force best.

Loading of the plate and stiffness of plate fixation
- The models represent two bone fragments fixed with a plate
- Let the participants loading the models imagine that the plate is
  - On the tension side of the bone.
  - In a lateral position.
  - On the compression side of the bone.
- Encourage each participant to test the different plated bone models.
- The two models show the same osteosynthesis but with a different gap size. Where the small gap is able to let the bone share load with the plate, the wide gap cannot close and is not able to share load.
- The two models show plate fixations with small gaps but the screws are placed in different locations. With the inner screws placed close to the gap, a shorter segment of the plate suffers high plate deformation due to stress concentration. With the inner screws placed further away from the gap, a longer segment of the plate suffers less deformation due to stress distribution.
- The models include a fracture with incarcerated bone fragments. Ask the participants to test the construct with and without the incarcerated fragments in place.

Discussion points
- Discuss the influence of the lever arm of a plate with respect to the pull-out force onto the screw.
- Discuss the influence of the screw working length with respect to the stiffness of a plate-bone construct.
- Discuss concepts of tension and compression sides and why a plate should be placed on the tension side.
- Discuss some actions to avoid plate failure.
- Discuss reasons for plate deformation with a small and a large gap, and when there are incarcerated fragments in the gap.
- Summarize the take-home messages.

While participants are changing tables:
- Remove all weights from the lever-arm model.
- Put all plate-bone constructs back.

Before you leave the station after the Skills Lab module:
- Ensure the collection of plate-bone constructs is complete.
- Ensure the collection of weights is complete.

Frequently asked questions (FAQs)

How does plate length influence screw loading?
Plates work on screws as a first class lever. In a longer plate the lever arm of the screw is improved and thus the pullout force is reduced. On the other hand, shorter plates act with a short lever arm resulting in high pullout forces on the last screw.

What is load sharing? Is there any load sharing with plate fixation and if so, under what condition?
Load sharing means that when a bone with an implant is loaded, the load passes through both the implant and the bone. Load sharing can only happen in plate fixation when there is contact between the bone fragments. For example, if a load is applied onto the bone-plate construct so that the plate is put under tension , the compression forces will be handled by the bone while the tension forces will be controlled by the plate. If there is no stable bone contact between the fragments (there is a gap or severe comminution), no load sharing will occur and the entire load will pass through the plate (load shielding). Depending on the fracture pattern and the type of reduction and/or fixation technique that is used, a load sharing or load shielding construct can be achieved. Load shielding is not necessarily a good or a bad thing, it can be both depending on the personality and needs of each fracture.

How does a gap influence plate fixation?
The main influence a gap has is that it changes the loading and deformation of the plate and alters plate-bone construct stiffness. As explained before, with no bone contact a load shielding construct is achieved where the entire load is absorbed by the plate, thus increasing the risk of plate fatigue failure. The size of the gap is related to the magnitude of deformation; greater gaps without any bone contact allow more fracture angulation and thus high plate deformation. For a given gap size, the presence of intercalated bone fragments (ie, comminution, callus) that reduce the maximum possible angulation will reduce plate deformation. But even small gaps can produce high stress concentration and plate deformation, depending on the span width. With simple fracture patterns, if no compression is achieved and a small gap is left, the distance between the inner screws (the span width) defines the loading of the plate. Screws close to the gap will allow for a short segment of the plate to be loaded with stress concentration in that area and high plate deformation.

What is the working length of a screw?
The working length of the screw is the total length of a screw, anchored in bone either in one cortex or in both cortices. It influences the stress in the bone-screw interface. Longer working lengths are achieved with monocortical screws in thick cortical walls or bicortical screws, whereas low working lengths are present with monocortical screws in a thin (osteoporotic) cortex.

How is all this clinically relevant?
Depending on the fracture pattern and the type of fixation needed, understanding the principles explained here can lead to better surgical technique that avoids unnecessary failures. For example, simple fracture patterns can be reduced ensuring tight bone contact which produces a load sharing construct. On the other hand, when dealing with severe comminution or bone loss, adequate screw placement and loading protection (ie, long weight-bearing protection) are necessary to reduce the probability of plate failure. Finally, keeping in mind that longer plates reduce pullout forces and that a long screw working length improves the bone-screw interface, reducing the stresses at this level is key in choosing the right plate size for each fracture and ensuring bicortical purchase of the screws.