Skills Lab Faculty Guide

Torque measurement of bone screws

STATION A

Imagine you are treating a forearm fracture by open reduction and internal plate fixation. An adequate fracture reduction has been achieved and the plate has been placed correctly. Your trainee tightens the screws. It is a simple task that you have done many times, so you have developed a feel for knowing when the screw is tight enough. The trainee, on the other hand, has not had much experience, so there is a good chance he/she might under- or overtighten the screw, leading to an unsatisfactory outcome.

At this station, the participants get the chance to develop a feel for optimal tightening of the screw in a safe environment. As the torque applied is measured and displayed on the screen, the participants receive immediate feedback on their action and you can discuss the outcomes with them. You can talk about how insufficient screw holding when undertightening—or destruction of the thread in the bone cortex when overtightening—impacts the fracture healing.

There are three artificial bone qualities available (normal, soft or osteoporotic, and hard), so the participants can feel the difference between healthy and osteoporotic bones. The foam holder represents soft tissue and allows for a more clinical feel, while the hard holder filters all external movements.

When the participants are using the screwdriver, you can also talk about the importance of coupling and what can happen if the tool is misused, with special attention to future implant removal.

Learning objectives

After completing this station, participants will be able to:

- Feel and achieve optimal torque in different bone qualities
- Practice over- and undertightening of screws
- Investigate potential problems when inserting the screwdriver into the screw head

Take-home message

- Optimal torque should be between 60% and 85% of maximum torque

Station sequences (your tasks)

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

- Familiarize yourself with the poster, which includes information about the station learning objectives and tasks.
- Check the set-up before participants arrive.
- The wireless screwdriver should be on the table.
- The display box with the three artificial bone quality models as well as enough bones of each quality should be on the table.
- Check that the monitor is on and the screen shows „Ready for torque measurement."

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

- Explain the task to participants and introduce the different bone qualities and holders.
- Explain to participants that the screwdriver needs to be correctly inserted into the screw head; otherwise the coupling mechanism of the screw will be destroyed.
- Tell participants to tighten the screw to the point they think is optimal. Check if participants pay attention to coupling when placing the screwdriver (note this for discussion).
- As soon as the participant tells you that they have reached the amount of optimal torque, press the button on the screen to record the amount of torque applied. The participant should leave the screwdriver inside the coupling mechanism of the respective screw.
- Now ask the participant to strip the screw and to describe the feeling of losing fixation: make sure that a crackling sound can be heard and that the participant turns the screwdriver after the screw loosens by at least one more turn.
- Press the button on the screen again to display the percentage of torque applied to tighten the screw versus the torque needed to strip the screw.
- Assist participants to interpret the achieved result.

Discussion points

- Summarize the take-home message.
- Briefly restate the findings of the exercise:
  - Did all participants pay attention to properly inserting the screwdriver into the screw head?
  - Were there recurring problems under- or overtightening the screws?
  - What do the findings of this exercise imply for older patients?

While participants are changing tables:

- Ensure that the monitor is set to „Ready for torque measurement."
- Exchange bone models when all screws are tightened.

Before you leave the station after the Skills Lab module:

- Ensure that the screw driver is back on the table.

Frequently asked questions (FAQs)

STATION A

Topic: using a screwdriver

What is coupling?
Adequate coupling allows better control and torque application. It prevents the destruction of the coupling mechanism, which, if damaged, will present problems at the time of implant removal.

How do I hold a screwdriver properly?
Holding the screwdriver with two fingers, or with the whole hand, are the two most commonly used methods. Try these or a different method, and then discuss which technique allows more control and torque delivery.

Topic: tightening screws

What is the importance of obtaining optimal torque when tightening a screw?
Since implants are mechanical devices they function best under specific conditions. For cortex screws it has been proven that applying 60–85% of the maximal torque the bone allows, ensures adequate bone purchase without losing fixation (stripping of screws in overtightening, or a loose plate or screw in undertightening).

What happens if a screw is undertightened or stripped? Which is worse?
In both cases you lose fixation. If it is undertightened the screw will have some fixation although it will not be optimal, because load transfer through friction will be diminished. If you strip a screw it loses almost all of its fixation strength. So stripping a screw is worse than undertightening it.

Why can we not use a device that will allow us to restrict torque application on a cortex screw?
Purchase and fixation of cortex screws depends both on the screw and the bone quality. Since bone quality varies greatly from person to person it is impossible to develop such a device.

Is there any difference in tightening unlocked versus locked screws?
Locked screws fix directly to the plate; you do not get the feeling of cortical purchase that you get with cortex screws because they engage in the plate directly.

Does it make a difference which screw on the plate is wrongly tightened?
The screws immediately on either side of the fracture resist most of the pullout force on a plate, so it makes a difference to the plate fixation if you over- or undertighten these screws in particular.

What can be done if we accidentally strip a screw?
A stripped screw is useless, and can be either removed (and the plate hole left empty) or the screw can be repositioned in a different direction.

How can I achieve the skill of optimally tightening screws?
Practice either in simulations (as in this exercise), during surgery with an attending surgeon, or in surgery alone (by trial and error).

Skills Lab Faculty Guide

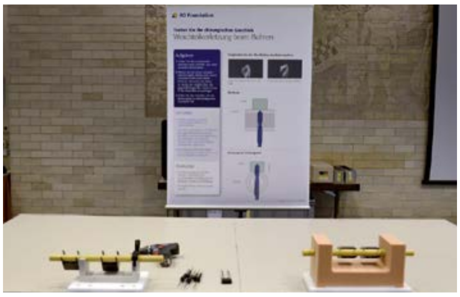
Soft-tissue penetration during drilling

STATION B

At this station, you will help participants to develop a feel for drilling through the bone cortex without plunging and damaging the soft tissue. Through a hands-on exercise they will learn that the quality and nature of the drill bit/K-wire and the hold of a bone affect the depth of penetration.

Bone drilling is one of the basic surgical skills of orthopedic surgery. In order to achieve the best results, care should be taken to apply a meticulous surgical technique. Drilling into bone must be kept under control so that it is safe for the surgeon and patient.

At this station, participants will exercise drilling using artificial bones. A box with plasticine is attached to the bone simulating the soft tissues. The depth of penetration into the soft tissue will be measured. Participants will use a K-wire or sharp and blunt drill bits.



Learning objectives

After completing this station, participants will be able to:

- Differentiate between sharp and blunt drill bits
- Develop a feel for penetrating the opposite bone cortex, and compare results using a K-wire or sharp and blunt drill bits
- Assess possible damage to soft tissues and neurovascular structures

Take-home message

- Use sharp drill bits to avoid uncontrolled penetration into muscles, nerves, and vessels
- Blunt drill bits must be replaced

Station sequences (your tasks)

When you arrive at the station for the Skills Lab module:
- Familiarize yourself with the poster, which includes information about the station learning objectives and task.
- 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, identifying sharp and blunt drill bits, and plasticine.
- Show the participants how to distinguish between sharp and blunt drill bits by comparison of the tips of the drill bits in good light. The tips of blunt drill bits reflect light, the tips of sharp drill bits do not.
- Place the plasticine box (simulating soft tissue) on to the bone on the opposite side to where the drill hole will be made.
- Ask a participant to drill a hole. Drilling with one hand, tell the participant to use the other hand to hold the gray drill sleeve and ensure it is in contact with the near cortex.
- Tell the participant to focus on feeling the drill pass through the first cortex. As soon as the near cortex is penetrated, ask the participant to let go of the drill sleeve. When drilling through the second cortex, the drill bit should be kept under control and stopped after passing through the second cortex, minimizing plunging. Remove the drill bit but do not touch the drill sleeve.
- Now, the drill sleeve can be used as an indicator for penetration depth after drilling: Compare the length of the drill bit distal to the gray sleeve with the diameter of the bone.
- Alternatively, the depth of the hole created in the plasticine box (simulating the soft tissue) can be measured with the depth-gauge supplied. Smoothen the plasticine with your finger afterwards to fill up the hole in the box.
- Ask participants to drill another hole in the bone using the K-wire or a sharp or blunt drill bit. Measure the depth of penetration and compare it to the first try. Smoothen the hole in the plasticine with your finger.
- Let the participants drill again into different set-ups—bone fixed into vice or fixed into soft holder respectively.

Discussion points
- Summarize the take-home messages.
- Briefly restate the findings of the exercise:
  - Did all participants pay attention to what drill they were using?
  - Were they able to distinguish between sharp and blunt drill bits by observing the very tip of the drill bit? Could they then verify the findings when using the drill bits?
  - Are they aware of the potential damage they could cause when drilling too far into soft tissue?
  - Did they understand the importance of not touching the drill bit tip with their fingers in the OR but using their naked eye to distinguish between blunt and sharp drill bits?

While participants are changing tables:
- Ensure that all holes in the plasticine boxes are smoothed out.
- Disengage the drill bits from the power drill so that you are able to show the tips of the drill bits to the participants in your next presentation.
- If required, clean the drill bits from plasticine.

Before you leave the station after the Skills Lab module:
- Remove all drill bits from the power drill.
- Ensure the plasticine boxes are smoothed.
- Clean the drill bits, bone holders, and the power drill if necessary.

Frequently asked questions (FAQs)

What happens if I plunge?
It means you have penetrated the soft tissue and can damage soft-tissue structures, such as vessels or nerves.

How do I avoid penetrating soft tissue?
The most important step to reduce plunging is the use of sharp drill bits to reduce the amount of pressure you put on the power drill and thus the drill bit. In addition, it might be helpful to use shorter drill bits, if available, or letting the K-wire protrude less from the collar chuck. Discuss if placing yourself in a different position or holding the drill with one or two hands has any effect on plunging. If time permits, try the exercise again, modifying these factors.

How do drill bits become blunt?
Drill bits not only become blunt by drilling through bone; they also become blunt with friction against other tools as they go through the cleaning/sterilization process and/or when they are inappropriately stored. An everyday example is your tool box at home where drill bits are separated into compartments in order that they are not in contact with each other. This is not only for presentation purposes but also to keep them sharp by avoiding contact friction.

When perforating metaphyseal or osteoporotic bone do you feel the second cortex?
You may not feel when your drill bit passes through the second cortex, as metaphyseal and osteoporotic bone have very thin and delicate cortices. You should be particularly careful when drilling through these types of bone.

Why do the blunt drill bits reflect light?
Drill bits used in surgery fail first on the very tip and then, if at all, at the cutting edges. The worn off tip becomes round and the surface of this hemisphere reflects the light. Where the cutting edges can look perfect (do not reflect the light) the tip might already be blunt (reflects light).

Skills Lab Faculty Guide

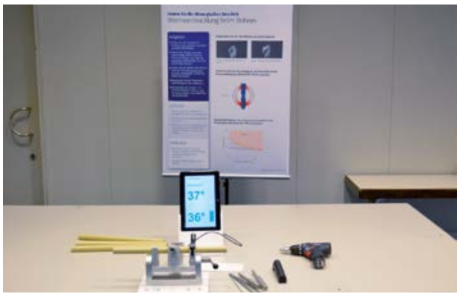
Heat generation during drilling

STATION C

At this station, you will be able to show to the participants, how much heat is generated when drilling through bone cortices, either with a K-wire or with blunt and sharp drill bits. After this station the group should be aware of this potentially hazardous complication and how to take measures to prevent it.

The heat generated as an object passes through bone can cause osteonecrosis and, consequently, fixation failure. This must be taken into account when fixing a fracture, since drill-bit temperatures during drilling can reach levels that can get dangerous for the bone. The same is true for reaming before inserting an intramedullary nail.

The participants can observe how the temperature rises when they drill a hole into the artificial bone and how the results vary when using a K-wire or sharp and blunt drill bits. The graph on the poster explains when osteonecrosis will occur as a result of the temperature on the bone (as shown on the monitor) versus the time of heat exposure.



Learning objectives

After completing this station, participants will be able to:

- Learn to differentiate between sharp and blunt drill bits
- Predict heat distribution in the bone cortex
- Recognize and compare results from a K-wire and blunt or sharp drill bits

Take-home message

- Use sharp drill bits to reduce heat generation and damage to bone
- Blunt drill bits must be replaced

Station sequences (your tasks)

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

- Familiarize yourself with the poster which includes information about the station learning objectives and tasks.
- Check the set-up before participants arrive.
- Check that the monitor is on and the screen shows two temperatures: „current" and „maximum".

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

- Show the participants how to distinguish between sharp and blunt drill bits by comparing the tips of the drill bits in good light. The tips of blunt drill bits reflect light, the tips of sharp drill bits do not. Introduce the principles of heat distribution when drilling.
- Press the button on the screen to reset the thermometer.
- Ask participants to choose a drill bit (sharp or blunt, 3.2 or 4.3 mm), however, it is advisable, to use the sharp 3.2 mm drill bit first, or a K-wire. Let them then drill through the respective drill sleeve into the artificial bone. The drill bit/K-wire must be left in place with the tip sticking out for a while and can then be removed.
- The monitor will show the peak temperature as well as the current. Compare the „maximum" value on the screen with the graph on the poster and explain how long the bone would withstand this maximum temperature before necrotizing. Use the live temperature on the screen to show how the temperature of the bone stays well above body temperature for some time even after removing the drill bit or a K-wire.
- Since heat generation varies with sharpness, it is important that the participants try all the tools available to compare results. Encourage them to test their skills with different drill bits or K-wires; ideally, every participant drills and measures the heat for at least one drill bit or K-wire.
- Move the bone in the bone holder to change the drill hole position. If the screen shows a higher temperature than 36–37°, press the „Reset" button on the screen and then, if a difference persists, move the artificial bone even further away from the previous drill hole.

Discussion points

- Discuss the benefits of using a sharp drill-bit tip.
- Summarize the take-home messages.
- Briefly restate the findings of the exercise:
  - Did all participants pay attention to what drill they were using?
  - Could they figure out while drilling, which drill they were using?
  - Can they explain the causality between temperature, time and osteonecrosis?
  - Were they able to identify the drill bit sharpness only by looking at the tips?

While participants are changing tables:

- Ensure that you reset the screen so it shows 36–37°C also as „maximum".
- Disengage the drill bits from the drilling machine if you want to start your next presentation by showing the drill bits.
- If required, clean the table and the bone holders as well as the drill bits with a cleaning towel.
- If no more holes can be drilled into the artificial bone, replace it with a new one.

Before you leave the station after the Skills Lab module:

- Remove the drill bit/K-wire from the drill.
- Clean the drill bits and bone holder if necessary.

Frequently asked questions (FAQs)

Why does heat necrosis occur?
As the drill bit or K-wire rotates and passes through the cortex, friction occurs. Ultimately friction is the source of heat production (for example, heat is created by rubbing your hands together).

What factors influence heat generation?
Friction is what produces the heat so all those factors that produce more friction produce more heat. Hence, by using a bigger drill bit or K-wire there will be more surface area available subject to friction. The same thing happens with speed and feed rates: the sharpness of the instrument and the amount of pressure applied affects this rate. If you have a sharper drill tip and you put more pressure on it you will have a faster feed rate. Faster feed rates reduce the contact time of the two surfaces, thereby producing less friction and therefore less heat.

What can I do to prevent heat necrosis due to drilling?
The most effective way of reducing heat is by using sharp drill bits, which also have the benefit of reducing soft-tissue penetration, as seen in the station „Soft-tissue penetration during drilling“. Where irrigation has a marginal effect on the heat production during drilling on the near cortex, it cannot solve the problem on the far cortex. In either case, the cooling fluid cannot be directed onto the tip of the drill bit, where friction and, in consequence, heat is generated.

How does thermal necrosis alter bone fixation?
This can be easily understood by looking at the figure in the poster. Heat produces a conically shaped area of damage around the drill bit. This area is where the screw will get its purchase to the bone. If this area of bone is dead, it has to be remodeled with consequent loosening of screw anchorage. Dead bone is also an active culture site for infection.

Skills Lab Faculty Guide

Mechanics of bone fractures

STATION D

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 parTicipants to understand the resulting fracture patterns and accompanying soft-tissue injuries.

Learning objectives

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 objectives 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.

STATION D

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.

Skills Lab Faculty Guide

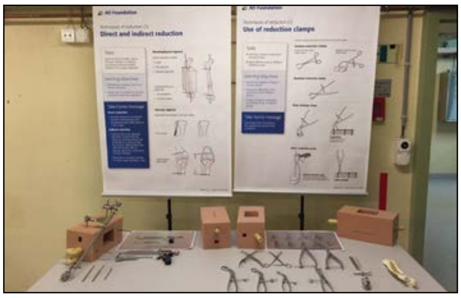
Techniques of reduction (1)

STATION E

At this station, you will introduce participants to different reduction techniques and tools, as well as to their applications and limitations.

Fracture reduction is probably the most difficult task in fracture surgery. Accomplishing successful reduction without compromising the blood supply to the bone and soft tissues is key for the success of the intervention.

This station provides a variety of reduction clamps, as well as a number of fractured artificial bones in foam blocks. After you have explained the differences between the clamps and tools on the table, the participants will try to reduce the fractures with the devices available.



Learning objectives

After completing this station, participants will be able to:

- Differentiate between direct and indirect reduction
- Relate both techniques to specific indications and bone segments
- Identify the degrees of freedom for each clamp
- Recognize difficulties in the application of the different devices
- Analyze biological advantages and shortcomings of different clamps

Take-home message

Direct reduction

- Fracture reduction is achieved by direct manipulation with instruments and under direct or C-arm vision

Indirect reduction

- Fracture site is not exposed, reduction is performed by applying corrective forces and moments at a distance from the fracture utilizing distraction with soft tissues such as capsule, ligaments, periosteum, muscles, tendons
- Reduction is checked clinically or using image intensifier, x-rays

Use of reduction clamps

- Use proper tools according to the anatomical and technical conditions

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 outcomes and tasks
- Check the set-up before participants arrive at this station; ensure that all clamps are there.

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

Use of reduction clamps:

- Explain the different types and functions of reduction clamps. Point out that similar clamps can have different locking mechanisms.
- Encourage participants to inspect and feel each different clamp and practice reducing various fractures. The bone fractures set in foam boxes facilitate three different approaches:
  - Applying the clamps directly through the window (open approach)
  - Using the window as if it were a "permanent" C-arm, placing the clamp through a small incision on the side of the foam (minimally invasive approach)
  - Covering the window and letting participants work only through the side incisions by tactile perception.
- Explain how indirect reduction is accomplished using the push-pull technique which involves using a bone spreader and a screw placed outside of the plate for fracture distraction and a plate holding clamp for compression.

Direct and indirect reduction

- Explain the task to participants, encouraging them to test their skills with different bone models and bone-holding mechanisms; ideally, every participant tries at least one direct and one indirect reduction.

Discussion points

- Discuss different degrees of freedom and reduction capacity of the reduction tools: compression, distraction, rotation, and combinations thereof
- Summarize the take-home messages

While participants are changing tables:

- Remove all reduction tools from any bones
- Put the foam models and clamps back in order
- Check that none of the clamps are missing

Before you leave the station after the Skills Lab module:

- Check the station and make sure all clamps are still there

Frequently asked questions (FAQs)

Why do we have different reduction techniques?
In order to understand reduction, one must also take into account what kind of fixation is required for the stability one wants to achieve. Different anatomical regions have different reduction requirements.

What is anatomical reduction and anatomical alignment?
Anatomical reduction is the result of a technique whereby fracture fragments are placed in their original anatomical positions to establish the original shape and form of the fractured bone. Anatomical reduction is required for articular fractures. Anatomical alignment refers to reestablishing the original axis of the bone and pertains to metaphyseal and diaphyseal fractures.

How is all this clinically relevant?
The surgical treatment of a fracture comprises three main steps that should be included in a complete preoperative plan: surgical approach, fracture reduction, and fracture fixation. Reducing the fracture is one of the steps in this surgical process and its difficulty is often underestimated. Since there are many reduction techniques and reduction-aiding devices, getting to know the names and functions of instruments is important if you want to successfully reduce any kind of fracture. Developing a defined surgical reduction technique that respects the biological principles of fracture fixation (open, closed, or minimally invasive) is a major step in becoming an accomplished surgeon.

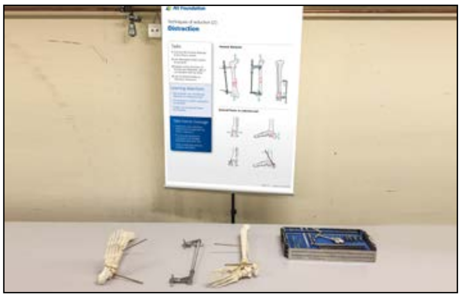
Skills Lab Faculty Guide

Techniques of reduction (2)

STATION F

At this station, you will introduce the participants to the principle of distraction as a reduction force. It will be important to describe to the learners the dislocating forces involved that deform a bone or joint following the fracturing injury. Consequently, reversing the deforming forces involves distracting the main fracture fragments to their original positions. Soft tissue attachments like muscles, periosteum, ligaments and capsular attachments allow the fragments to be realigned with regard to length, alignment and rotation by distraction. This phenomenon is called ligamentotaxis.

The station includes examples of using distraction tools for reduction, such as the femoral distractor or external fixator. The participants will have the opportunity to discover the femoral distractor and the external fixator as reduction tools and to try out their functions.



Learning objectives

After completing this station, participants will be able to:

- Demonstrate use of a femoral distractor as a reduction tool
- List instances in which a distractor is indicated
- Explain use of an external fixator for reduction

Take-home message

- Distraction uses soft tissue attachments to fragments for indirect reduction
- The femoral distractor is a powerful and versatile distraction/reduction tool
- Tools of reduction serve to preserve vascularity

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 outcomes and tasks
- Check the set-up before participants arrive at this station; assemble the large and medium distractors, if not already pre-assembled

During the group activity:

Let the participants handle the femoral distractors on the set and apply it to the models. The smaller femoral distractor can be applied as reduction tool to the distal tibia, the external fixator as reduction tool to the calcaneum. Schanz screws are already fixed to the modules for distractor application.

Discussion points

- Discuss the role of soft tissue for indirect reduction by ligamentotaxis.
- Let participants explain the use of the femoral distractor by describing its construction
- Summarize take-home messages

While participants are changing tables:

- Remove the distractors from the Schanz screws
- Put the foam models and instruments back in order
- Check that none of the instruments are missing

Before you leave the station after the Skills Lab module:

- Check the station and make sure all instruments & models are still there

Frequently asked questions (FAQs)

What is meant by distraction?

Distraction is the pulling force by which indirect reduction techniques achieve an approximate re-establishment of length and alignment of a fractured long bone and approximate shape of a joint.

What is involved when applying distraction forces for reduction?

A distraction force puts soft tissue under tension as would a traction table for lower extremity use. The phenomenon is called "ligamentotaxis" and involves skin, muscles, periosteum, ligaments, tendons and capsular attachments in touch with fracture fragments. When applying distraction, the soft tissue attachments tend to edge fragments into their original spatial relationship to each other.

Skills Lab Faculty Guide

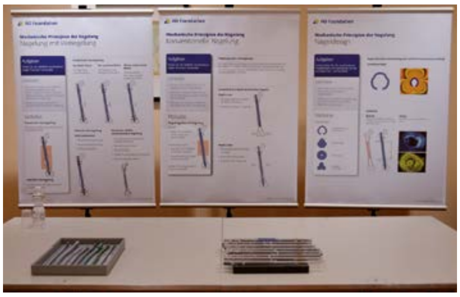
Mechanics of intramedullary fixation

STATION G

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 objectives

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 objectives 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, 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. This 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.

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.

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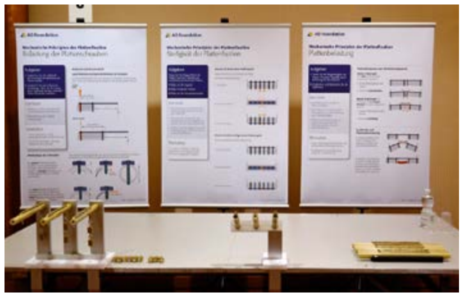
Skills Lab Faculty Guide
Mechanics of plate fixation

STATION H



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 objectives

After completing this station, participants will be able to:

- Explain how the 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

- The resistance to pull-out of a screw is always constant
- Increasing the distance from the fracture site to the screw increases the lever arm, which leads to a decreased pull-out force 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 objectives 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 osteo-synthesis 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.

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Station sequences (your tasks)—continued

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 which conditions?
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?
A gap 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.

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Skills Lab Faculty Guide
Fracture healing and plate fixation

STATION J

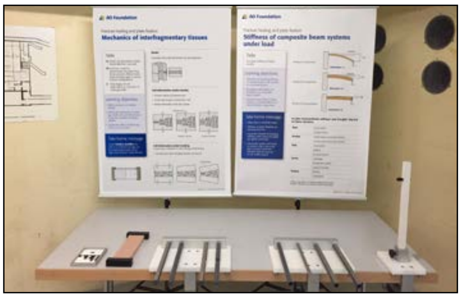
At this station, you will explain the following concepts:

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.

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Skills Lab Faculty Guide

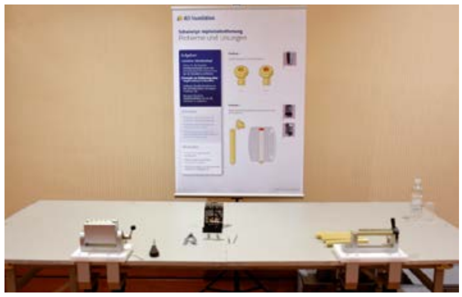
Damaged implant removal (Option 1)

STATION K

At this station, you will teach participants how to use instruments specially designed for the purpose of removing worn or broken screws.

Implant removal is sometimes considered relatively simple surgery, commonly performed by orthopedic trainees, often without attending supervision. But what may be a common, straightforward task can easily become a nightmare. Imagine you are about to remove a screw. You take your screwdriver, couple it with the screw and rotate it. Suddenly you feel there is no purchase, the screwdriver turns but the screw does not move. The coupling mechanism of the head of the screw is destroyed. On another note, imagine you are about to loosen the screw when suddenly, the screw head breaks off the shaft.

This station provides the opportunity to practice these two scenarios.



Learning objectives

After completing this station, participants will be able to:

- Identify the function of different instruments to aid screw removal
- Remove a screw with a destroyed coupling mechanism
- Remove a broken screw

Take-home message

- Use undamaged screw drivers
- Clean the hexagonal coupling mechanism of the screw head
- Everything in the removal set is left threaded

Station sequences (your tasks)

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

- Familiarize yourself with the poster which includes information about the station 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 the task to participants and introduce the different damaged/broken screws.
- Use the Screw Removal Set as indicated by its manufacturer. Emphasize that everything in the removal set is left threaded.
- Instruct participants:
  - The 3.5 mm screws should be removed with the 2.5 mm screwdriver. However, the screw heads are damaged and thus, the lack of coupling between screwdriver and screw heads permits removal of the screws.
  - Insert the conical extraction screw into the worn screw head. Press firmly in an axial direction and turn tool counterclockwise to remove the screw.
  - The 4.5 mm screws have been prepared so that their head breaks off as soon as a participant tries to tighten the screw with a screwdriver. The hollow reamer is used to remove the bone around the shaft of the screw, prior to be able to remove the shaft with the hollow extraction bolt. Enough bone must be removed to allow coupling of the shaft with the extraction bolt even if you need to drill all the way through the cortex.
  - Once the shaft has been cleared, use the extraction bolt to get a grip on the screw and remove it. The bolt must be turned counterclockwise around the shaft of the broken/drilled screw for it to grasp and then be removed.
- Encourage participants to test their skills with different damaged/broken screws.

Discussion points

- Discuss how to use the implant removal instrument set.
- Review means to avoid screw coupling destruction.
- Summarize the take-home messages.

While participants are changing tables:

- Exchange the artificial bone models in the bone holders when all screws have been extracted.
- Clean the table and the instruments with a cleaning towel, if necessary.

Before you leave the station after the Skills Lab module:

- Ensure the extraction sets are complete.

Frequently asked questions (FAQs)

How do you prevent coupling problems when removing a screw?
The main way to prevent destroying the coupling mechanism of a screw is ensuring adequate screwdriver-screw coupling when placing and removing the implant. The surgeon must feel and see that the screwdriver has fully attached to the screw and has a good grip. When removing the implant, care should be taken to check that all tissue has been removed from the coupling hole to allow perfect matching between driver and screw. Turn the driver slowly with your hands while pushing it against the screw head. Feel if there is a good catch between the screwdriver and the screw. If it feels loose, recheck its position.

Ensure the adequate tools for removing the implant are available; that is, having a screwdriver that is the right size and shape. Do not use damaged screwdrivers. Finally, do not underestimate any surgical procedure. Always use a careful surgical technique and pay attention to every detail.

What should be done if a coupling problem develops or if a head breaks (or is broken)?
Ensure all the necessary instruments are available for difficult implant removal. If no instruments are available, consider rescheduling the surgery or reconsider the necessity of implant removal. Always remember that the first rule of medical action is do no harm, so always carefully consider a harm/benefit analysis when faced with failed implant removal.

Finally, remember to explain to your patient before the removal surgery that there is a possibility of failure to remove the implant. That way he/she will know there is always a slight chance that, even after the procedure, the implant may not have been successfully removed.

Why not use a power drill with the hollow reamer?
Be aware of the fact that a lot of heat is produced (see station "Heat generation during drilling") when drilling or reaming. The benefit in time you might gain when using a power drill will be devoured by the damage created to the bone by heat necrosis.

Skills Lab Faculty Guide

Damaged implant removal (Option 2)

STATION K

At this station, you will teach participants how to use instruments specially designed for the purpose of removing worn or broken screws.

Implant removal is sometimes considered relatively simple surgery, commonly performed by orthopedic trainees, often without attending supervision. But what may be a common, straightforward task can easily become a nightmare. Imagine you are about to remove a screw. You take your screwdriver, couple it with the screw and rotate it. Suddenly you feel there is no purchase, the screwdriver turns but the screw does not move. The coupling mechanism of the head of the screw is destroyed. On another note, imagine you are about to loosen the screw when suddenly, the screw head breaks off the shaft.

This station provides the opportunity to practice these two scenarios.

Learning objectives

After completing this station, participants will be able to:

- Identify the function of different instruments to aid screw removal
- Remove a screw with a destroyed coupling mechanism
- Remove a broken screw

Take-home message

- Use undamaged screw drivers
- Clean the hexagonal coupling mechanism of the screw head
- Do not use a power drill

Station sequences (your tasks)

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

- Familiarize yourself with the poster which includes information about the station 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 the task to participants and introduce the different damaged/broken screws.
- Use the Screw Removal Set as indicated by its manufacturer. Emphasize that the tools in the removal set should be used counterclockwise.
- Instruct participants:
  - The 3.5 mm screws should be removed with the 2.5 mm screwdriver. However, the screw heads are damaged and thus, the lack of coupling between screwdriver and screw heads permits removal of the screws.
  - Insert the conical extraction screw into the worn screw head. Press firmly in an axial direction and turn tool counterclockwise to remove the screw.
  - The 4.5 mm screws have been prepared so that their head breaks off as soon as a participant tries to tighten the screw with a screwdriver. First, the hollow reamer is used to remove the bone around the shaft of the screw. Rotate the hollow reamer counterclockwise. The debris accumulating inside the tool needs to be removed frequently.
  - Once the shaft has been cleared deep enough, the hollow reamer attaches to the screw bolt. Keep on rotating the tool counterclockwise to remove the bolt.
- Encourage participants to test their skills with different damaged/broken screws.

Discussion points

- Discuss how to use the implant removal instrument set.
- Review means to avoid screw coupling destruction.
- Summarize the take-home messages.

While participants are changing tables:

- Exchange the artificial bone models in the bone holders when all screws have been extracted.
- Clean the table and the instruments with a cleaning towel, if necessary.

Before you leave the station after the Skills Lab module:

- Ensure the extraction sets are complete.

Frequently asked questions (FAQs)

STATION K

How do you prevent coupling problems when removing a screw?
The main way to prevent destroying the coupling mechanism of a screw is ensuring adequate screwdriver-screw coupling when placing and removing the implant. The surgeon must feel and see that the screwdriver has fully attached to the screw and has a good grip. When removing the implant, care should be taken to check that all tissue has been removed from the coupling hole to allow perfect matching between driver and screw. Turn the driver slowly with your hands while pushing it against the screw head. Feel if there is a good catch between the screwdriver and the screw. If it feels loose, recheck its position.

Ensure the adequate tools for removing the implant are available; that is, having a screwdriver that is the right size and shape. Do not use damaged screwdrivers. Finally, do not underestimate any surgical procedure. Always use a careful surgical technique and pay attention to every detail.

What should be done if a coupling problem develops or if a head breaks (or is broken)?
Ensure all the necessary instruments are available for difficult implant removal. If no instruments are available, consider rescheduling the surgery or reconsider the necessity of implant removal. Always remember that the first rule of medical action is do no harm, so always carefully consider a harm/benefit analysis when faced with failed implant removal.

Finally, remember to explain to your patient before the removal surgery that there is a possibility of failure to remove the implant. That way he/she will know there is always a slight chance that, even after the procedure, the implant may not have been successfully removed.

Why not use a power drill with the hollow reamer?
Be aware of the fact that a lot of heat is produced (see station "Heat generation during drilling") when drilling or reaming. The benefit in time you might gain when using a power drill will be devoured by the damage created to the bone by heat necrosis.