

Participant Booklet

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Topic: using a screwdriver

What is coupling?

Coupling means insertion of the screwdriver into the screw head. 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).





screw head

2 Tighten the screw until you feel you have reached optimal torque

Test your surgical skill

- 3 Press the marked button on the screen
- **4** When the red hexagon is visible on the screen, further tighten the screw so that screw thread in bone is stripped
- **5** Press again the marked button on the screen and analyze result
- 6 Repeat steps using different screws and different bone models

Practice over- and undertightening of screws
Investigate potential problems when inserting the screwdriver into the

Take-home message

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

Optimal tightening of screws

Screws need to be tightened between ~60% and ~85% of their maximum torque

- If torque is too high, the interface between screw and bone is destroyed and purchase is lost
- If torque is too low, the screw cannot transmit forces applied



IATION

B

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.

Why do the tips of 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).

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.





Tasks

- 1 Observe the difference between a sharp and a blunt drill bit
- 2 Drill hole through both bone cortices using sharp or blunt drill bits, or a K-wire; try to minimize soft-tissue penetration
- **3** Check degree of damage done by soft-tissue penetration

Learning objectives

- Learn to differentiate between sharp and blunt drill bits
- Develop feeling for penetration of opposite bone cortex and compare results using blunt and sharp drill bits or K-wires
- 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

Observe the surface of the very tip of the drill bit



Sharp: no reflection of light on the tip



Blunt: light is reflected on the tip

Method



Measurement of depth of penetration



STATION

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 a greater surface area will be subjected to friction. The same thing happens with speed and feed rates: the sharpness of the instrument and the amount of pressure applied affect 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 influence on the heat production on the near cortex, irrigation 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.

Test your surgical skill Heat generation during drilling

Tasks

- 1 Observe the difference between a sharp and a blunt drill bit
- 2 Drill hole through both bone cortices using blunt or sharp drill bits, or a K-wire, with the assistance of the appropriate drill sleeve
- 3 Leave drill bit in place with tip sticking out
- 4 Observe on the screen, how the temperature develops
- **5** Repeat steps 1–4 with different drill bits or K-wires and compare results

Learning objectives

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

Take-home message

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

Observe the surface of the very tip of the drill bit



Sharp: no reflection of light on the tip



Blunt: light is reflected on the tip

Heat generated during drilling causes conically shaped volume of damage to the cortex

TATION



Cell necrosis as a function of temperature and duration of heat exposure



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.

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 the risk of soft-tissue damage, among other things.

Please check the back of all three cards for station D for a complete set of FAQs for this station.

Mechanics of bone fractures Deformation and fracture pattern under torque

Tasks

- 1 Insert artificial tibia into fracture machine; tibia plateau goes to the right
- 2 Pull on the left lever to break the tibia under torque
- 3 Examine the fracture pattern created

Learning objectives

- Describe deformation of material under torque
- Discuss typical fracture pattern under torque
- Describe orientation of
 compressive stress and tensile stress
- Discuss possible implications on 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 torque

- Compressive stress inclined 45°
- Tensile stress inclined 45°



Fracture under torque

- Failure occurs first on the side under tension resulting in a spiral fracture inclined 45° with respect to long-bone axis, **then**
- Longitudinal split on the side under compression





D STATION

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).

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 the risk of soft-tissue damage, among other things.

Please check the back of all three cards for station D for a complete set of FAQs for this station.

Mechanics of bone fractures **Deformation and fracture pattern under bending**

zone

Tasks

- 1 Insert generic bone tube into fracture machine with the smilev face visible
- 2 Pull on the lever to break generic bone under bending
- 3 Examine the fracture pattern created

Learning objectives

- Describe deformation of material under bending
- Discuss typical fracture pattern under bending
- Compare compression and distraction sides
- Discuss possible implications on soft-tissue envelope

Take-home message

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

Deformation under bending

- Shortening on the side under compression
- Lengthening on the side under tension
- Neutral zone in between





Tension side

Fracture under bending

- Failure occurs first on the side under tension resulting in a transverse distraction fracture. then
- Failure on the side under compression results in an oblique fracture with or without a bending wedge











What is axial compression?

It is a load that is applied along the main axis of the bone. 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 applied 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 the risk of soft-tissue damage, among other things.

Please check the back of all three cards for station D for a complete set of FAQs for this station.

Mechanics of bone fractures Deformation and fracture pattern under axial load

Tasks

- 1 Place artificial cancellous bone in vice and apply axial load until it fractures
- 2 Remove material from vice and examine fracture pattern

Learning objectives

- Describe deformation of material under axial load
- Discuss typical fracture patterns under axial load
- Distinguish between compressive, tensile, and shear stresses
- Discuss possible implications on soft-tissue envelope

Take-home message

The resultant stress of compressive and tensile stress is **shear**, which is the main reason for failure of bone in compression

Deformation under axial compression

creates not only compressive but also tensile stress, where the resultant of these is shear stress

unloaded

Orientation of compressive, tensile, and shear loaded stresses

Fracture under axial load

- Short bone: obligue fracture or double oblique fracture with longitudinal split (see illustration)
- Long bone: buckling, similar to failure under bending (without illustration)











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.

Please check the back of both cards for station E for a complete set of FAQs for this station.

Techniques of reduction (1) **Direct and indirect reduction**

Tasks

Examine bone models; reduce fractures directly or indirectly, according to fracture pattern, location, and surgical approach

Learning objectives

- Differentiate between direct and indirect reduction
- Relate both techniques to specific indications and bone segments

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

Metadiaphyseal segment

Indirect reduction to obtain

- Lenath
- Axial alignment
- Rotational alignment

A diaphyseal fracture is a black box

- No visualization
- No direct contact

Articular segment

Anatomical reconstruction of the joint surface

Direct reduction





Indirect reduction. ligamentotaxis



STATION

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 reductionaiding 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.

Please check the back of both cards for station E for a complete set of FAQs for this station.



Techniques of reduction (1) **Use of reduction clamps**

Tasks

- 1 Examine a variety of reduction clamps/ forceps, including different locking mechanisms
- 2 Apply different tools at different anatomical sites

Learning objectives

- 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

Use proper tools according to the anatomical and technical conditions The term clamps and forceps are sometimes used interchangeably

Pointed reduction clamps

Pointed reduction clamp (Weber clamp)



Plate holding clamp



Standard reduction clamp



Other reduction tools

Collinear reduction clamp

through a

minimally invasive

surgical

approach

Lamina spreader









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.

Techniques of reduction (2) **Distraction**

STATION

Tasks

- 1 Connect the femoral distractor to the Schanz screws
- **2** Use alternative Schanz screws as joy sticks
- **3** Explore various functions of the femoral distractors, also in combination with joy sticks
- 4 Combine femoral distractor use with joy stick function

Learning objectives

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

Femoral distractor



External fixator as reduction tool



How does an intramedullary (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 locking the nail.

Please check the back of all three cards for station G for a complete set of FAQs for this station.

Mechanics of intramedullary fixation Nail design

STATION

Tasks

Examine various nail designs; discuss the advantages and disadvantages of each

Learning objectives

- Describe different nail designs and their mechanical characteristics
- Explain radial preload and corresponding concept of stabilization

Take-home message

Slotted nail with cloverleaf section

Cannulated nail

Elastic nails

Solid nail

Nail designs



Connection of nail to bone with radial preload needs Slotted nail

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A slotted nail increases the radial preload

Reaming

Mechanics Cylindrical medullary cavity Long-distance contact between bone and nail



Biology

Necrosis of the inner two thirds of bone cortex





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

Please check the back of all three cards for station G for a complete set of FAQs for this station.

Mechanics of intramedullary fixation Conventional nailing

G

Tasks

Examine stability of different nail constructs

Learning objectives

- Describe indications for nailing without interlocking
- Identify common problems using nails that are too short or too thin
- Describe possible problems of nailing without interlocking

Take-home message

Nailing without interlocking

Needs

 Nail with proper length and diameter

Prerequisites

- Fractures in middle third of diaphysis
- Partial contact between main fragments

Be aware of the need for adequate rotational stability



Residual instability

Nail too short

- Nail does not engage in the distal metaphysis
- Distal fragment
 unstable



Nail too thin

- No contact between nail and bone in fracture zone
- No radial preload
- Instability at fracture site



What is static and dynamic locking 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 locking allows more movement than static locking. 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 locking 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 locking is needed in such cases.

Please check the back of all three cards for station G for a complete set of FAQs for this station.

Mechanics of intramedullary fixation **Interlocked** nailing

Tasks

Examine stability of different nail constructs

Learning objectives

- Describe different nail locking options and possible influences on stability of fixation (dynamic locking, static locking)
- Explain elastic stable intramedullary nailing

Take-home message

Dynamic interlocking

Requires partial contact between main fragments

Static interlocking

In case of no contact between main fragments

Dynamic interlocking

Only distal bolts Nail can stick out proximally

proximal bolts Nail can perforate knee joint

Only

Distal and proximal bolts Proximal bolt through

dynamic hole allows controlled dymanization

Static interlocking **Distal and proximal bolts**

- Control of length Control of axis
- Control of torsion

Elastic stable intramedullary nailing

- For diaphyseal and metaphyseal fractures in children
- · Minimally invasive
- Flastic nail
- Different diameters
- Precontouring needed









STATION

How does plate length influence screw loading?

Plates work on screws as a first-class lever. A short lever arm leads to a high pull-out force on the screw. Increasing the lever arm reduces the pull-out force. Thus, screws far from the fracture need a very high pullout force to fail.

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, for example, monocortical screws in thick cortical walls or bicortical screws in normal cortical walls, whereas low working lengths are present with monocortical screws in a thin (osteoporotic) cortex.

Please check the back of all three cards for station H for a complete set of FAQs for this station.

Mechanics of plate fixation Loading of the plate screws

Tasks

- 1 Compare screw holding force by weighting each plate model
- 2 Compare effect of working length of screws by rotating handles on the three bone-plate constructs

Learning objectives

- Explain how the lever arm influences screw loading
- Define the term "screw working length"

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

Lever arm and pull-out force Long lever arms decrease screw loading

A short lever arm leads to a high pull-out force on the screw. Increasing the lever arm reduces the pull-out force. Thus, screws far from the fracture need a very high pullout force to fail.



Working length of screw

A **short working length** exists when there is thin bone cortex or monocortical screw insertion. This results in **high stress** at the interface.



A **long working length** exists when there is thick bone cortex or bicortical screw insertion. This results in **low stress** at the interface.



Length of screw thread in contact with bone influences stress at screw-bone interface



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 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.

Please check the back of all three cards for station H for a complete set of FAQs for this station.

STATION

Mechanics of plate fixation Stiffness of plate fixation



Test bending stiffness of plate-bone models under different bending directions or plate positions

- 1 Plate on tension side
- 2 Plate in lateral position
- 3 Plate on compression side

Learning objectives

- Explain principle of load sharing between implant and bone
- Identify influence of a fracture gap on stiffness of fixation and on plate loading
- Explain the influence of the bending direction on the load sharing of the plate-bone composite construct

Take-home message

To share load, an implant must be attached to the **tension side** of the bone

Internal fixation without gap Internal fix Bending of plate-bone construct; different Internal fix bending directions 1 No load shate 1 Load 1 No load sharing Internal fix 2 Partial load Internal fix sharing Internal fix Internal fix No load shate 2 No load Sharing

Internal fixation with large gap

No load sharing for all bending directions















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.

Please check the back of all three cards for station H for a complete set of FAQs for this station.

STATION

Mechanics of plate fixation Loading of the plate

Tasks

- 1 Test bending stiffness of plated bone models by loading each with your hands
- 2 Compare and discuss

Learning objectives

- List reasons for plate failure
- Identify actions to avoid plate failure
- Explain importance of overspan width and screw position on plate loading

Take-home message

- Short segments of a plate will break under repetitive stress
- Incarcerated bone fragments lead to load sharing

Plate loading and overspan width

Small gap with screws inserted close to gap

- Short segment of plate loaded
- Stress concentration



Small gap with screws inserted at a distance from gap

- Long segment of plate loaded
- Stress distribution



Gap width and plate deformation

A large gap leads to high angulation and thus a high deformation of the plate under load



Incarcerated bone fragments, even with relatively loose connection to soft tissues, reduce maximum angulation and thus plate deformation







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, vou 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 highstress 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.

Please check the back of both cards for station J for a complete set of FAQs for this station.

Fracture healing and plate fixation Mechanics of interfragmentary tissues

Tasks

- **1a** Slowly pull granulation model horizontally from one side
- **1b** Note degree of cell deformation as a function of initial gap width
- 2 Use foam model to demonstrate how deforming forces produce different strain levels between gaps in various fracture configurations.

Learning objectives

- 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

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)

Model

Granulation tissue with cells between two bone fragments



Cell deformation under traction

- Numbers indicate cell diameter units
- In each step, the gap is increased by 1 unit
- Relative deformation of the cells is shown



Cell deformation under bending

- Compression or distraction of cells in the gap under bending
- Cell destruction when elongation exceeds
 one cell unit

Cell destruction







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.

Please check the back of both cards for station J for a complete set of FAQs for this station.

Fracture healing and plate fixation Stiffness of composite beam systems under load

can be axially loaded



² strength = the ability of a material to withstand destruction

STATION



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 screw 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 when drilling or reaming (see station "Heat generation during drilling"). 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.

Damaged implant removal Challenges and solutions (Option 1)

Tasks

1 Destroyed coupling mechanism

Insert conical extraction bolt (a) in screw head and try to remove screw

2 Broken screw removal procedure

Remove bone around screw with appropriate sized hollow reamer (b)

Use extraction tube (c) to remove screw shaft

Learning objectives

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

Take-home message

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

Problem 1

Destroyed hexagonal coupling mechanism of screw head



Problem 2

Broken screw, screw shaft stuck inside bone











Intact

Destroyed



Damaged implant removal Challenges and solutions (Option 2)

Tasks

1 Destroyed coupling mechanism

Insert conical extraction bolt (a) in screw head and try to remove screw

2 Broken screw removal procedure

Remove bone around screw with appropriate sized hollow reamer (b)

Learning objectives

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

Take-home message

- Use undamaged screwdriver
- Clean hexagonal coupling mechanism of screw head

Destroyed

• Do not use a power drill

Problem 1

Destroyed hexagonal coupling mechanism of screw head



Intact



Problem 2

Broken screw, screw shaft stuck inside bone





TATION

This option is available in Europe and the Middle East only.

Hazards and legal restrictions

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Hazards

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