

# AO Skills Lab

for orthopedic  
trauma surgeons



Version 1.1

# Frequently asked questions (FAQs)

## 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).

Test your surgical skill

## Torque measurement of bone screws

### Tasks

- 1 Insert electronic screwdriver into screw head so that it is properly engaged; leave screwdriver engaged in the same screw for the whole session
- 2 Tighten the screw until you feel you have reached optimal torque
- 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

### Learning outcomes

- 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

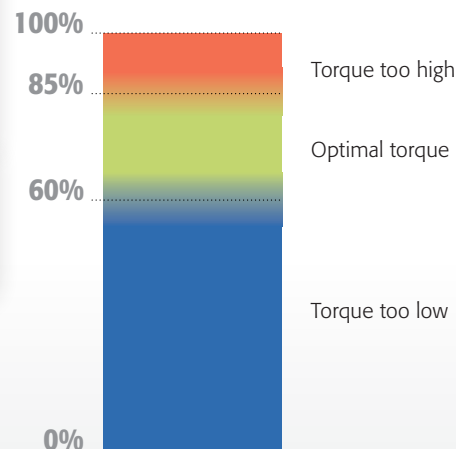
Optimal torque should be between 60% and 85% of maximum torque

#### 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

### Torque measured



## Frequently asked questions (FAQs)

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### **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.



Test your surgical skill

## Soft-tissue penetration during drilling

### 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

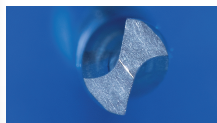
### Learning outcomes

- 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

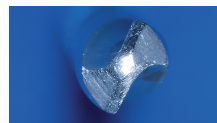
### Take-home message

- 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

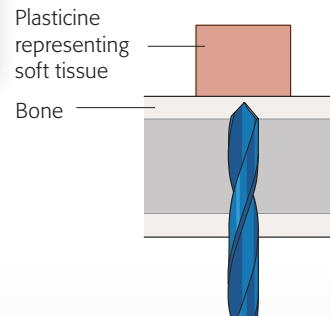


Sharp: no reflection of light on the tip

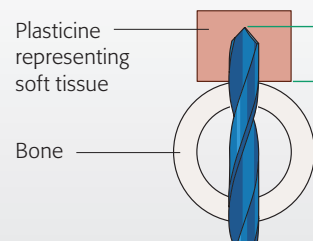


Blunt: light is reflected on the tip

### Method



### Measurement of depth of penetration



## Frequently asked questions (FAQs)

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### **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

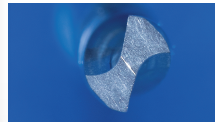
### Learning outcomes

- 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

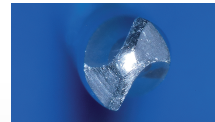
### Take-home message

- 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

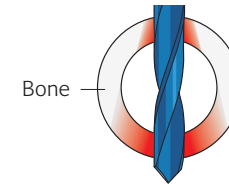


Sharp: no reflection of light on the tip

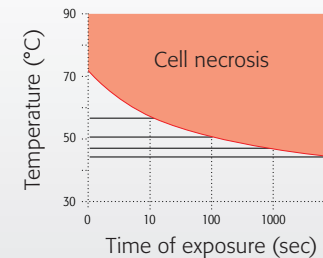


Blunt: light is reflected on the tip

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



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



## Frequently asked questions (FAQs)

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### **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.

## 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 outcomes**

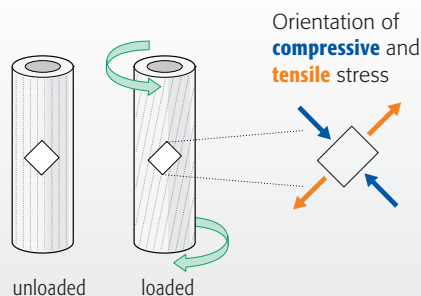
- Describe deformation of material under torque
- Discuss typical fracture pattern under torque
- Describe orientation of compressive stress and tensile stress
- Discuss possible implications on soft-tissue envelope

**Take-home message**

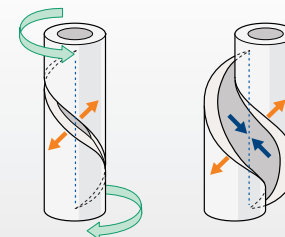
Deformation under torque first creates a spiral fracture inclined  $45^\circ$  on the side under tension, then a longitudinal split on the side under compression

**Deformation under torque**

- **Compressive stress** inclined  $45^\circ$
- **Tensile stress** inclined  $45^\circ$

**Fracture under torque**

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



## Frequently asked questions (FAQs)

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### **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.

## Mechanics of bone fractures

# Deformation and fracture pattern under bending

### Tasks

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

### Learning outcomes

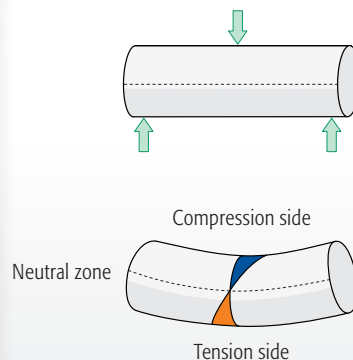
- Describe deformation of material under bending
- Discuss typical fracture pattern under bending
- Compare compression and distraction sides
- Discuss possible implications on soft-tissue envelope

### 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

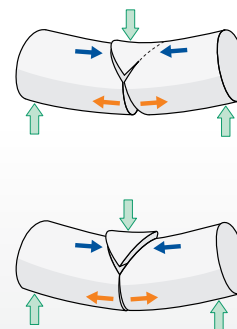
#### Deformation under bending

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



#### 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



## Frequently asked questions (FAQs)

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### **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.



## 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 outcomes

- 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

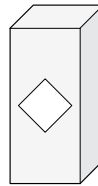
### Take-home message

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

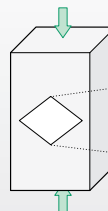
#### Deformation under axial compression

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

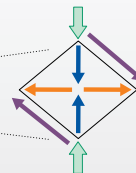
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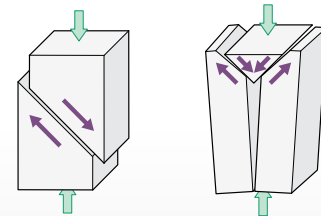


Orientation of  
**compressive**, **tensile**,  
and **shear** stresses



#### Fracture under axial load

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



## Frequently asked questions (FAQs)

### What is callus and how does it make a fracture stable?

Callus is the scar the bone creates to heal itself. It is the *classical* means by which a fracture consolidates. It has been called indirect bone healing and it comprises four phases: inflammation, soft callus, hard callus, and remodeling.

The body produces a mass of tissue surrounding the fracture (granulation tissue) that slowly becomes more rigid. Granulation tissue has a high tolerance against deformation but is not very rigid. A certain amount of movement is necessary for granulation tissue to form. It then differentiates into fibrous tissue, which is more rigid, then into cartilage, woven bone, and finally it becomes laminar bone, which is the most rigid and least flexible (stiffest) of all. As the callus forms and matures, its cross section expands and it becomes more rigid, thus fostering stability.

As tissue differentiates, the amount of motion possible at the fracture site diminishes. This works as a cycle, since a more rigid construct promotes tissue differentiation into bone. However, if there is no motion, there is also no stimulus for the tissue to differentiate. The exact amount of motion, introduced by a certain amount of load (external forces onto a structure), by which bone formation is promoted, is unknown. Too much or too little motion can produce nonunion, unless there is no motion from the beginning, in which case the fracture heals by different means, ie, direct bone healing.

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

# Fracture healing

## Mechanics of callus (1/2)

STATION E

### Tasks

- 1 Bend the two ends of the model, which represent bone fragments; note low stiffness
- 2 To simulate soft callus formation, inject beads into the flexible middle portion of the model; note increase in stiffness
- 3 To simulate tissue transformation, extend the other end of the model to extract air; note increase in stiffness

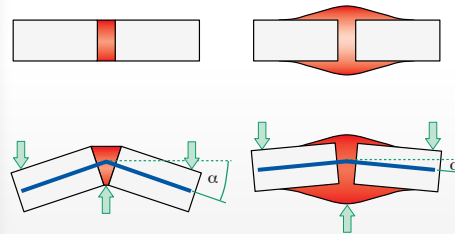
### Learning outcomes

- Identify the importance of the increasing cross section
- Identify the importance of tissue transformation between fragments

### Take-home message

- Apposition of callus leads to an increase of cross section and thus of stiffness in the fracture zone
- Callus transforms over time

#### Increase of cross section of callus



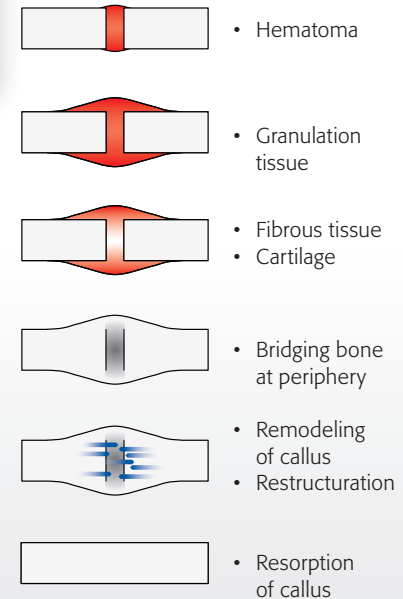
#### No callus

High angulation under external load  
 → High tissue strain, low stiffness

#### Callus

Low angulation under external load  
 → Low tissue strain, high stiffness

#### Transformation of callus



From flexible to rigid

## Frequently asked questions (FAQs)

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### What is direct and indirect bone healing?

There are two paths a fracture can take to heal. In direct healing the bone heals without or almost without any callus formation. That means that the osteons (bone forming units) cross the fracture site as if there was no fracture at all. It is as if the bone 'forgets' there was a fracture. For this to happen there must be no motion at the fracture site (absolute stability).

In indirect healing a callus develops as explained in the answer to the first FAQ. Some motion (introduced by a certain load) must be present in order for indirect healing to develop (relative stability). However, the exact amount of motion required is unknown.

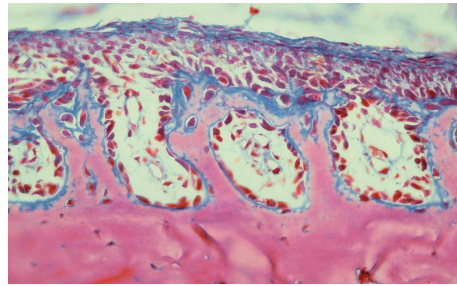
### What other factors are involved in direct/indirect healing?

Besides the *motion* condition (ie, absolute stability for direct healing and relative stability for indirect healing) both direct and indirect healing needs an adequate blood supply. This cannot be overemphasized. Preserving blood supply is one of the most (if not the most) important factors for achieving union. In the past, operative techniques called "biologic osteosynthesis" were developed that maximized blood supply preservation. This kind of technique should be used every time a fracture is treated, either by open, minimally invasive, percutaneous, or closed means.

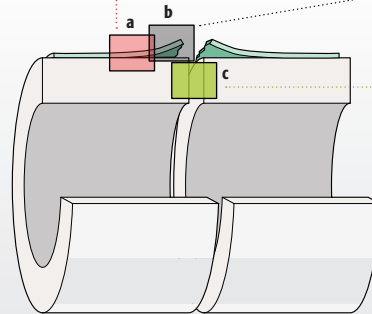
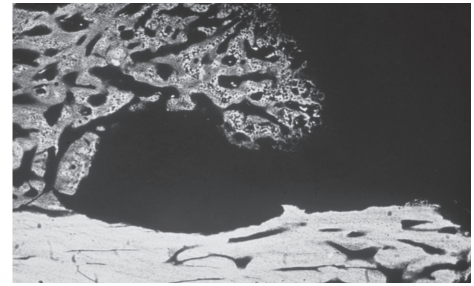
**Please check the back of all three cards for station E for a complete set of FAQs for this station.**

### Histological callus formation

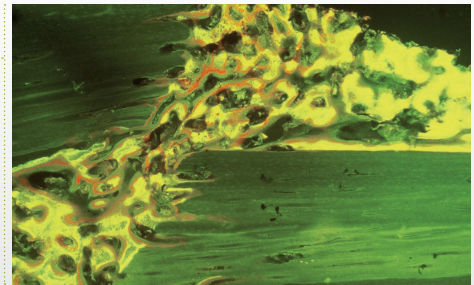
**a** Periosteal and primary angiogenic bone formation



**b** Bone formation far from fragment end in vascularized zone



**c** Interfragmentary callus formation



## 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. To put it simply, 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 three-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.

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

## Fracture healing

**Mechanics of interfragmentary tissues****Tasks**

- 1 Slowly pull granulation model horizontally from one side
- 2 Note degree of cell deformation as a function of initial gap width

**Learning outcomes**

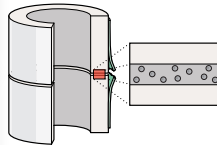
- Define absolute and relative stability
- Define the importance of initial gap width onto cell deformation under the condition of relative stability
- Define the effect of tissue differentiation on deformation

**Take-home message**

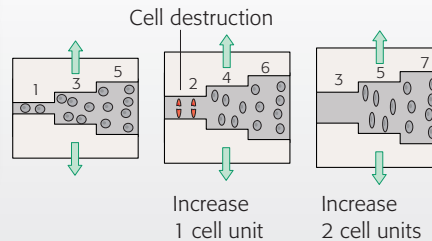
Under **relative stability** the cells in a small fracture gap can be destroyed because of too high strain

**Model**

Granulation tissue with cells between two bone fragments

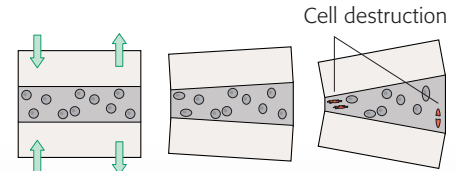
**Cell deformation under traction**

- 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**

(not shown in granulation model)

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



## Frequently asked questions (FAQs)

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### **Why do we have different reduction techniques?**

In order to understand reduction one must also take into account what kind of fixation and stability is going to be used. In that order there will be some discussion on the difference between anatomical reduction and anatomical alignment (see next FAQ) and between absolute and relative stability (a topic discussed at station E: Fracture healing).

### **What is anatomical reduction and anatomical alignment?**

Anatomical reduction is a technique where you put back together all the fracture fragments in their original anatomical positions to reestablish the original shape and form of the fractured bone. Anatomical reduction is used to reduce articular fractures.

Anatomical alignment refers to reestablishing the original axis of the bone without as much regard to the exact position of every fragment. It is used in metaphyseal and diaphyseal fractures.

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



# Techniques of reduction

## Direct and indirect reduction

STATION F

### Tasks

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

### Learning outcomes

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

### Take-home message

#### Direct reduction

- Fracture site is exposed, hands or instruments directly manipulate fracture fragments
- Reduction achieved is directly visible

#### Indirect reduction

- Fracture site is not exposed, reduction is performed by applying corrective forces and moments at a distance from the fracture
- Reduction is checked clinically or using image intensifier, x-rays

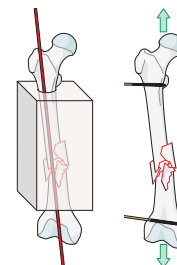
#### Metadiaphyseal segment

Indirect reduction to obtain

- Length
- Axial alignment
- Rotational alignment

A diaphyseal fracture is a black box

- No visualization
- No direct contact



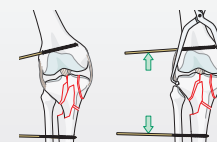
#### Articular segment

Anatomical reconstruction of the joint surface

Direct reduction



Indirect reduction, ligamentotaxis



## Frequently asked questions (FAQs)

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### How is all this clinically relevant?

The surgical treatment of a fracture comprises three main steps that ought to be included in a complete preoperative plan: surgical approach, fracture reduction, and fracture fixation. Reducing the fracture is one of the difficult steps in this surgical process and is often underestimated. Since there are many reduction techniques and reduction-aiding devices, getting to know and adding them to your surgical arsenal is important if you want to successfully reduce any kind of fracture. Developing a refined 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 F for a complete set of FAQs for this station.**

## Techniques of reduction

# 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 outcomes

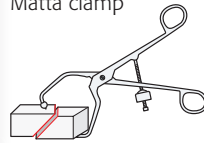
- Identify the degrees of freedom for each clamp
- Recognize difficulties in the application of the different devices
- Analyze biological advantages and shortcomings of different clamps

### Take-home message

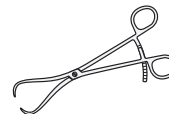
Use proper tools according to the anatomical and technical conditions

#### Pointed reduction clamps

Matta clamp

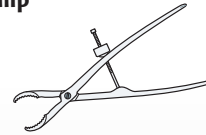


Weber clamp



#### Toothed reduction clamp

Spanier clamp



#### Bone holding clamp

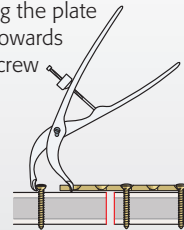
Verbrugge

Reduction onto the plate

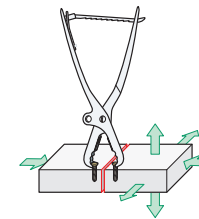


Compression

Pulling the plate end towards the screw

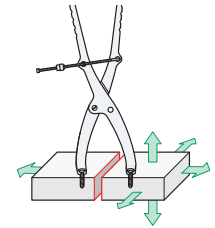


#### Pelvic reduction clamps



Farabeuf clamp

- Compression
- Shear
- Pull and push

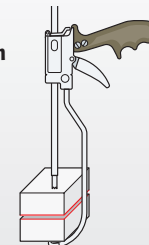


Jungbluth clamp

- Compression and distraction
- Shear
- Pull and push

#### Collinear reduction clamp

Allows minimally invasive direct reduction



## Frequently asked questions (FAQs)

### 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, then you would expect healing by callus formation.

### Why should I interlock the nail?

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

### How do the shape and the size of a nail affect its mechanics?

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

### Tasks

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

### Learning outcomes

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

### Take-home message

#### Nail designs



Slotted nail with cloverleaf section



Solid nail



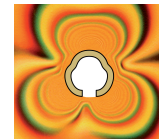
Cannulated nail



Elastic nails

### Connection of nail to bone with radial preload needs

#### Slotted nail

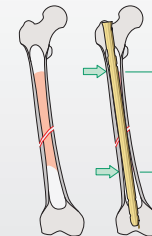


A slotted nail increases the radial preload

#### Reaming

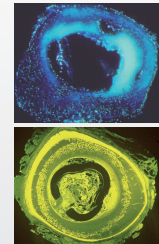
##### Mechanics

Cylindrical medullary cavity  
Long-distance contact between bone and nail



##### Biology

Necrosis of the inner two thirds of bone cortex



## Frequently asked questions (FAQs)

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### **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

### Tasks

Examine stability of different nail constructs

### Learning outcomes

- 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

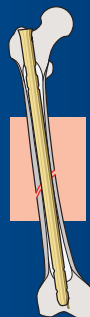
##### Needs

- Nail with proper length and diameter

##### Prerequisites

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

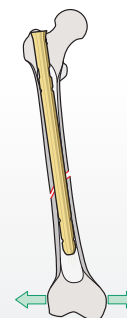
Be aware of the need for adequate rotational stability



#### Residual instability

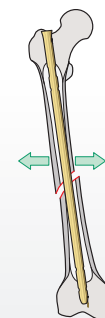
##### Nail too short

- 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



## Frequently asked questions (FAQs)

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### **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. As seen in Station E: Fracture healing, for a callus to be formed some micromovement at the fracture site should be present.

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

STATION  
G

### Tasks

Examine stability of different nail constructs

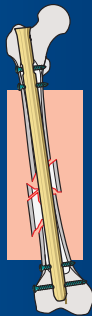
### Learning outcomes

- 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



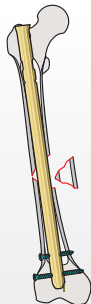
#### Static interlocking

In case of no contact between main fragments

#### Dynamic interlocking

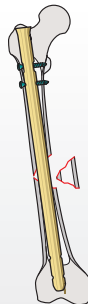
##### Only distal bolts

Nail can stick out proximally



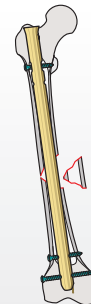
##### Only proximal bolts

Nail can perforate knee joint



##### Distal and proximal bolts

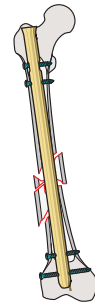
Proximal bolt through dynamic hole allows controlled dymanization



#### 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
- Elastic nail
- Different diameters
- Precontouring needed



## Frequently asked questions (FAQs)

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### **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 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.

**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

STATION H

### 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 outcomes

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

### Take-home message

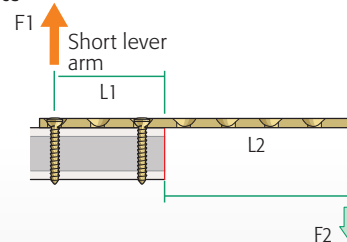
- Short lever arm = high pull-out force on the screw
- Long working length = low stress on the screw

#### Lever arm and pull-out force

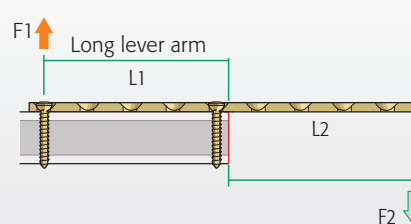
##### Long lever arms decrease screw loading

A short lever arm leads to a high pull-out force on the screw. Increasing the lever arm reduces the pull-out force.

##### High force

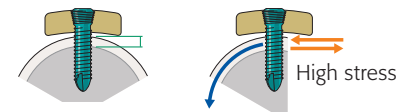


##### Low force

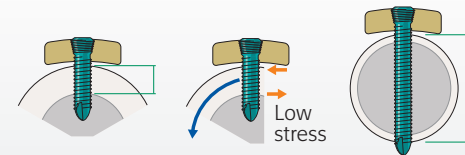


#### Working length of screw

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

## Frequently asked questions (FAQs)

### How does a gap influence plate fixation?

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

### What is load sharing? Is there any load sharing with plate fixation and if so, under what condition?

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

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

# Mechanics of plate fixation

## Stiffness of plate fixation

STATION H

### Tasks

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 outcomes

- 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

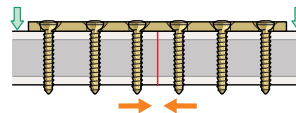
### Take-home message

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

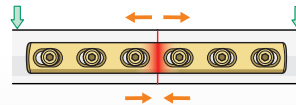
#### Internal fixation without gap

Bending of plate-bone construct; different bending directions

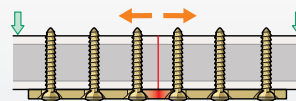
1 Load sharing



2 Partial load sharing



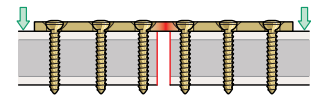
3 No load sharing



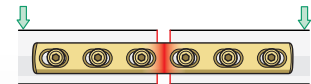
#### Internal fixation with large gap

No load sharing for all bending directions

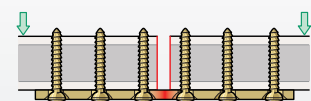
1 No load sharing



2 No load sharing



3 No load sharing



## Frequently asked questions (FAQs)

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### **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.**

# Mechanics of plate fixation

## Loading of the plate

STATION H

### Tasks

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

### Learning outcomes

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

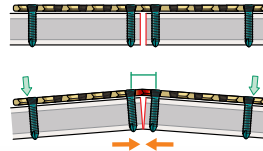
### Take-home message

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

#### Plate loading and overspan width

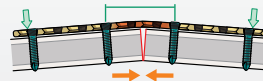
**Small gap** with screws inserted **close** to gap

- Short segment of plate loaded
- Stress **concentration**



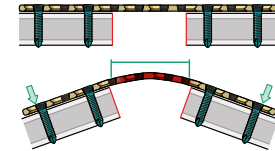
**Small gap** with screws inserted **at a distance** from gap

- Long segment of plate loaded
- Stress **distribution**

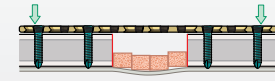


#### Gap width and plate deformation

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



# Frequently asked questions (FAQs)

## 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.



## Mechanics of plate fixation

# Stiffness of composite beam systems

### Tasks

Compare stiffness of beam models

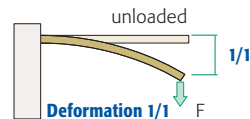
### Learning outcomes

- 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

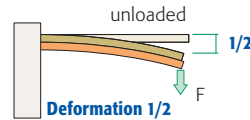
### Take-home message

- 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

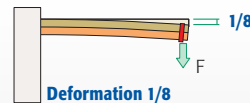
Bending of an isolated beam



Bending of two isolated beams



Bending of two connected beams



### In plate osteosynthesis stiffness<sup>1</sup> and strength<sup>2</sup> depend on these elements

<b>Bone</b>	- Cross section
	- Quality of bone
<b>Fracture</b>	- Simple versus comminuted fracture
	- Contact versus noncontact situation
<b>Plate</b>	- Cross section
	- Material
	- Bending direction
<b>Screws</b>	- Anchorage
	- Number and position
	- Length of the plate
<b>Fixation</b>	- Splinting
	- Compression

<sup>1</sup>) stiffness = the ability of a material to withstand deformation

<sup>2</sup>) strength = the ability of a material to withstand destruction

## 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 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 outcomes

- 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

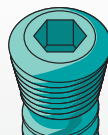


#### Problem 1

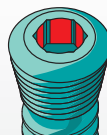
Destroyed hexagonal coupling mechanism of screw head



a



Intact



Destroyed

#### Problem 2

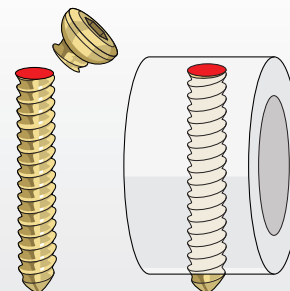
Broken screw, screw shaft stuck inside bone



b



c



# 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)

Use extraction tube (c) to remove screw shaft

### Learning outcomes

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

**In 2015 this option is available in Europe and the Middle East only.**

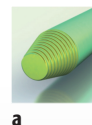
### Take-home message

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

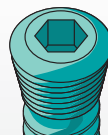


#### Problem 1

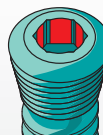
Destroyed hexagonal coupling mechanism of screw head



a



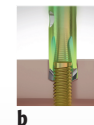
Intact



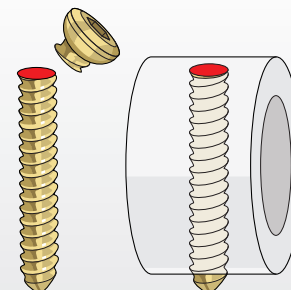
Destroyed

#### Problem 2

Broken screw, screw shaft stuck inside bone



b



## Notes

## Notes

## Notes

# Hazards and legal restrictions

Check hazards and legal restrictions on [www.aofoundation.org/legal](http://www.aofoundation.org/legal)

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## Hazards

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