AO TRAUMA

Plates and Screws—form and function

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Presenter‘s name Arial 24 pt

Presenter‘s title Arial 20 pt

Meeting Arial 24 pt

City, Month, Year Arial 20 pt

This lecture is a combination of the lectures «Screws-form and function» and «Plates-form and function» created by Chris Colton and Judy Orson. It was adapted by the AO Trauma ORP Educational Taskforce so that it can be used as shortened version for in the blended learning program for ORP.

This presentation can only be used for the blended learning course for ORP!

Learning outcomes

- At the end of this lecture you will be able to:
  - Describe the function of compression holes
  - List different functions of plates
  - Discuss the different functions of screws

At the end of this lecture you will be able to:

- Outline the evolution of plates
- Describe the function of compression holes
- List different functions of plates

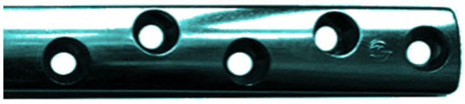
Historical introduction

- First record of plates for long bones:
  - 1886 by Hansmann, Germany
- Original plate set

- Plates for fixation of long-bone fractures were first recorded by Hansmann, Heidelberg University, Germany, in 1886.
- One of his original plate sets is seen below
- White label says: Attention! Do not lose anything
- Instruments were listed in set.

Hansmann's plates were of "German silver" and were bent up at one end to protrude (stick out) through the integuments (skin).
The long shanked screws also protruded.
The implants were removed at about 6 weeks and external splintage was then applied.

Plates—forms: evolution



- Round hole plate 1960

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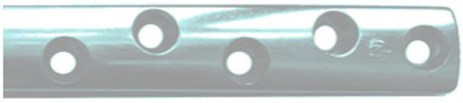
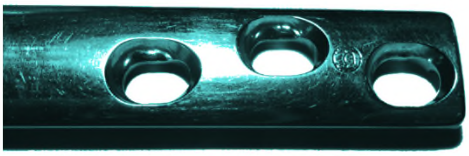
Since 1958, AO has devised a family of plates for long-bone fractures, starting with a round-holed plate (to be used with an external compression device), then the dynamic compression plate (DCP).

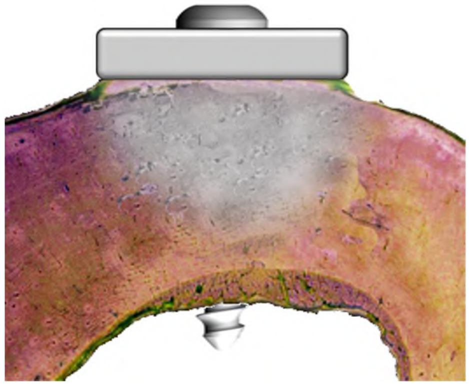
Experimental work showed that the flat undersurface of the DCP interfered with the blood supply of the underlying cortex onto which it was compressed by the screws. The concept of the “footprint” of a plate emerged–that area of the undersurface of the plate in contact with the underlying bony cortex.

Plates—forms: evolution





- Round hole plate 1960
- DCP 1969



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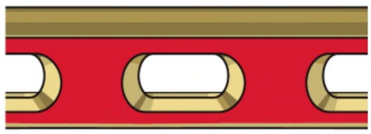
Plates—forms: evolution

- Round hole plate 1960
- DCP 1969



- LC DCP 1994
  - “footprint”

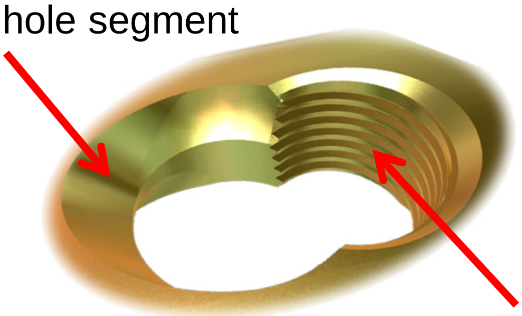
The need to preserve the blood supply of the underlying cortex led to considerations of reducing the footprints of plates, and the limited contact dynamic compression plate (LC DCP) was created. Note its fluted undersurface. Note the difference–the red color on undersurface indicates the size of footprint on the underlying bone.

Latterly, since 2001 the locking compression plate (LCP) with combination holes has come into use.

Plates—forms: LCP

- Features of LCP
  - Combi hole:
    - Locking head screws (LHS)
    - Conventional screws

Standard hole segment



Threaded hole segment

The holes permit the insertion of standard head screws and of threaded locking head screws.
This means that the LCP can be used for conventional plating functions, and also with locking head screws to produce angular stability.

Plates—forms: LCP

- Features of LCP
  - Combi hole:
    - Locking head screws (LHS)
    - Conventional screws
  - Minimal footprint

The LCP is also designed with a minimal footprint.

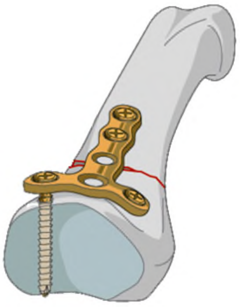
Plates—forms: reconstruction

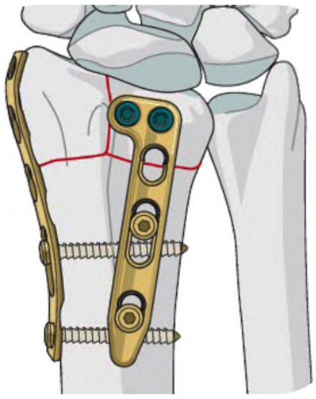
- Reconstruction plates
- Have notched edges
- Can be bent in multiple planes

Reconstruction plates have notched edges to permit bending “on the flat” as well as conventional bending.
These plates are very adaptable, using the correct tools, …

Plates—forms: anatomical plates

- Anatomical preformed plates

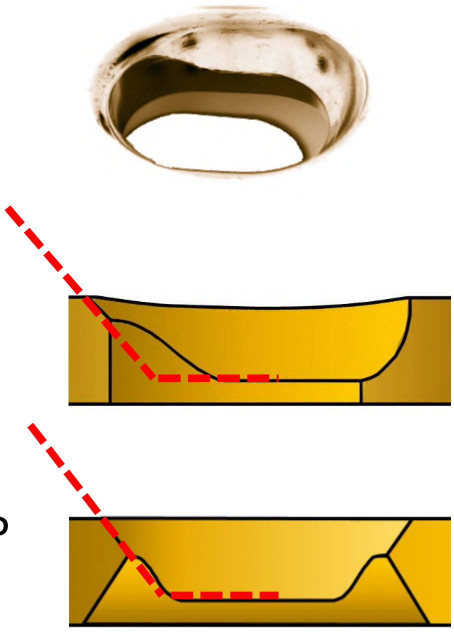




Here are some examples of other anatomically preformed plates:

- T-plate for phalanges
- L and LCP contoured plate for distal radius
- Ulna plates and distal humerus plates

Plates—forms: DCP principle



DCP

LC DCP

- Oval shape
- “Sloping form”

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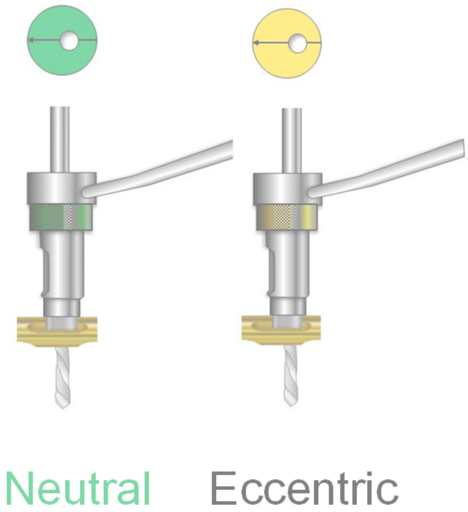
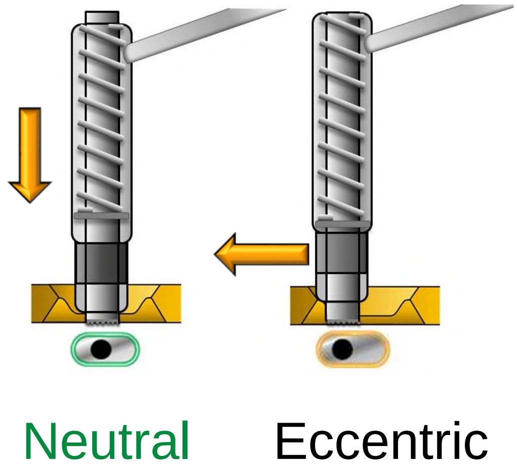
Dynamic compression plates are designed with screw holes of a particular form, as illustrated.
The holes are oblong and the portion of each hole distant from the fracture has a sloping form, or “shoulder.”
Note that the DCP and LC DCP have different forms.

Plates—forms: Drill guides

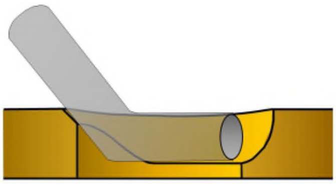
- Universal drill guide

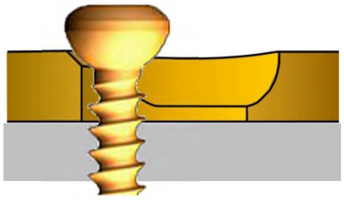




There is also a spring-loaded universal drill guide, which can be used for insertion of conventional screws through all plates (but not for the locking head screws), and which can serve both functions: if the barrel is depressed toward the plate, the end of the barrel slides down the slope of the plate hole and takes up a neutral relationship. If there is no downward pressure on the barrel but it is drawn to the edge of the plate hole away from the fracture, an eccentric load hole can be drilled.
The initial green/yellow drill guides are to be used for DCP or LC-DCP plates. These cannot be used for the LCP.

Plates—forms: DCP principle





- Head forced to slide down shoulder
- Moving the bony fragment
- Compressing the fracture

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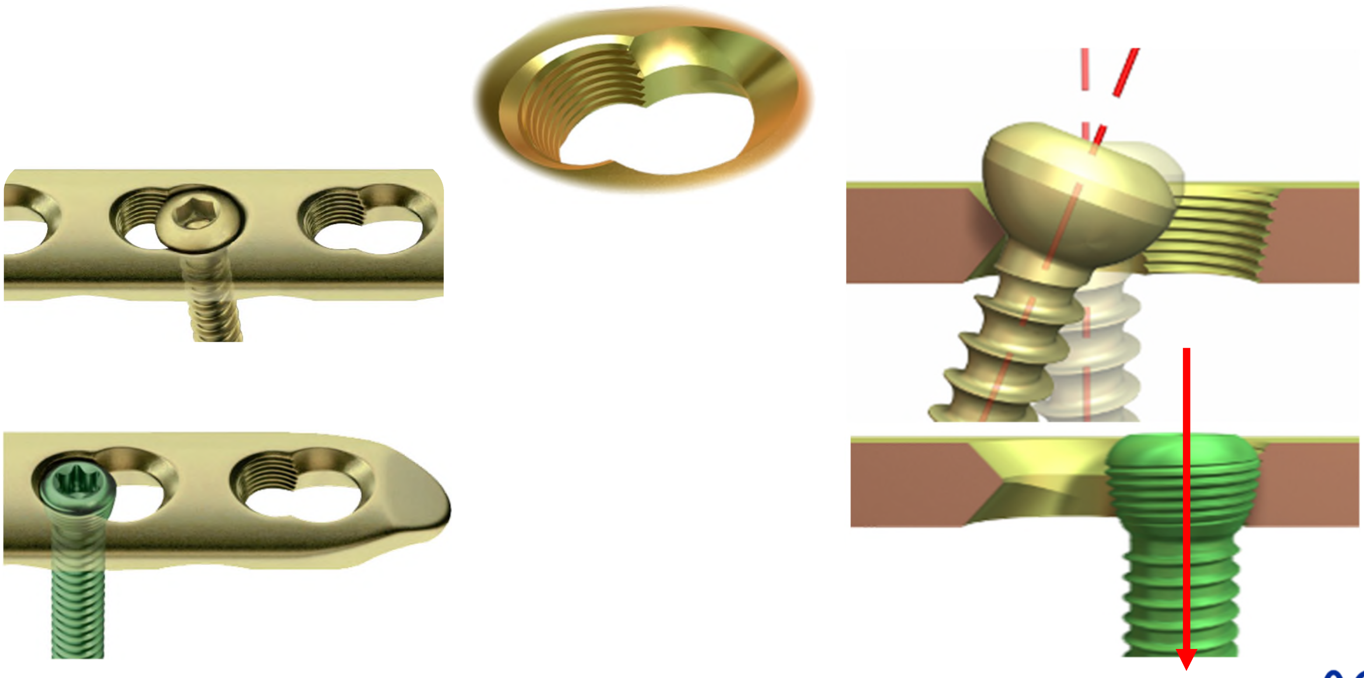
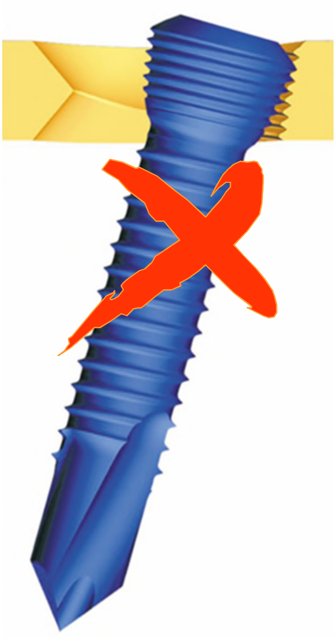
… so that its head, on final tightening, slides down the sloping profile of the hole, the screw/bone unit will be shifted toward the fracture and the fracture plane will thereby be compressed.
Such a screw is often referred to as a load screw.

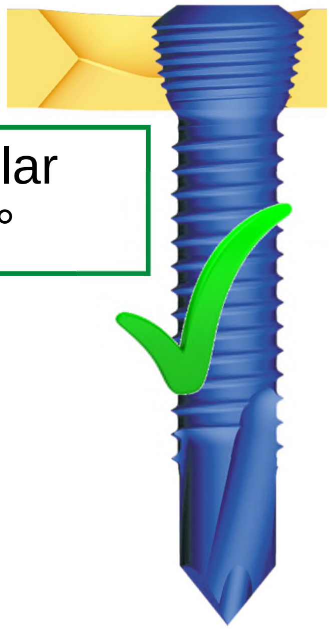
Plates—holes: LCP



The combination hole of the LCP accepts conventional screws for conventional plating techniques, but also accepts locking head screws to create angularly stable fixations.
Conventional screws can be tilted in the non-threaded portions of the combination holes, but locking head screws must not be angled in the threaded portions of the holes.

Plates—holes: LCP



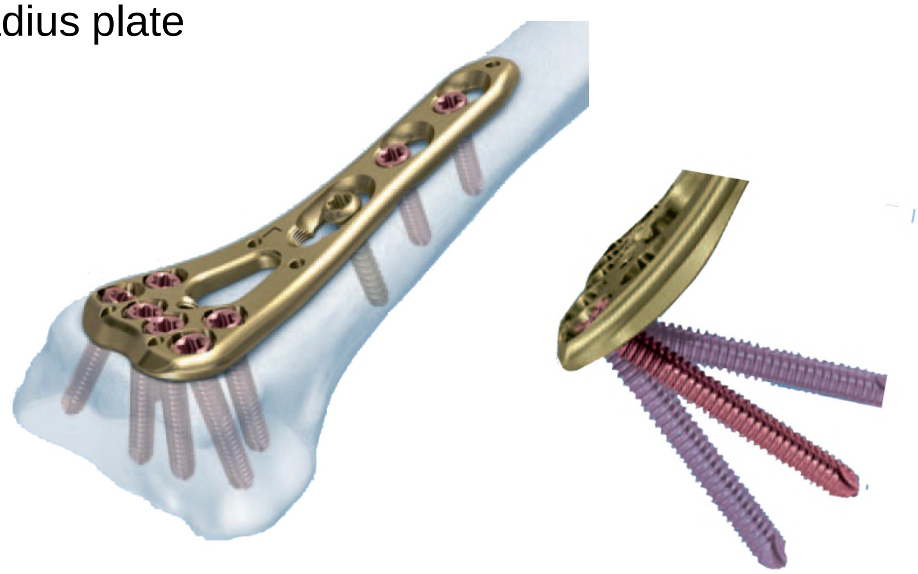


Locking head screws must be inserted carefully: The threads of the screw and the plate must match. Optimal angular stability is gained when the screw is inserted at 90° to the plate, using a special guide. Hence, the importance of the correct use of the LCP drill guide.

Angular stability is greatly reduced if the LHS is not inserted at 90°.

Plates—holes: LCP

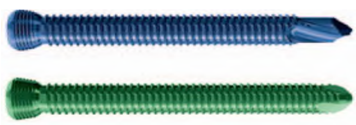
- Threaded holes with range of angulation
  - Variable angles
  - Distal radius plate

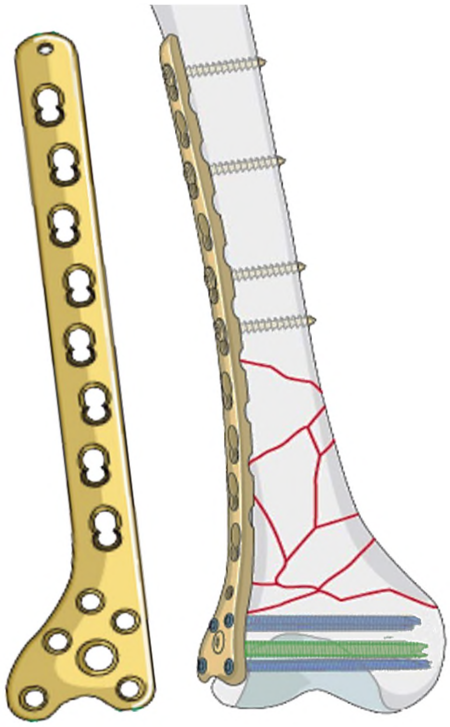


Exceptions
Some locking plates have threaded holes that are designed to permit a small range of angulation of the screw until it is tightened and then locks home.
A distal radial variable-angle locking plate is illustrated.

Plates—angular stability

- Threaded LCP holes with locking head screws
  - Achieve angular stability
  - Hold better in osteoporotic bone





Condylar LCP

Screws that lock into threaded plate holes now provide an alternative method of achieving angular stability, as illustrated here.

Because the screws in the metaphyseal fragment purchase in the bone, and also lock into the plate holes, the mechanical equivalent of a fixed angle device can be constructed.

One great advantage is that locking plate/screw systems are more stable in the osteoporotic bone of the elderly.

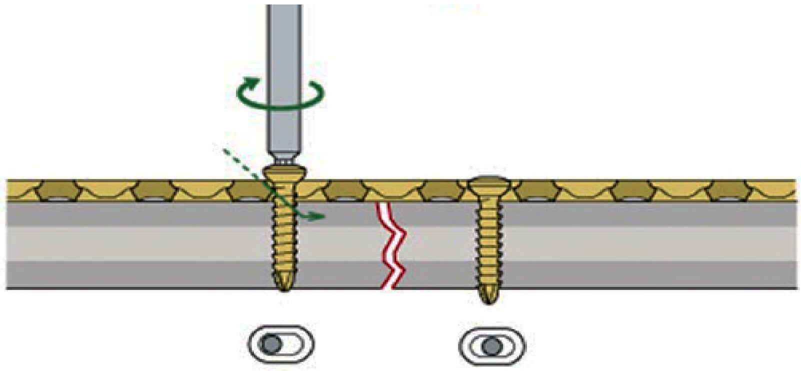
Plates—functions

- Compression
- Neutralization/protection
- Buttress
- Bridging/internal fixator
- Tension band

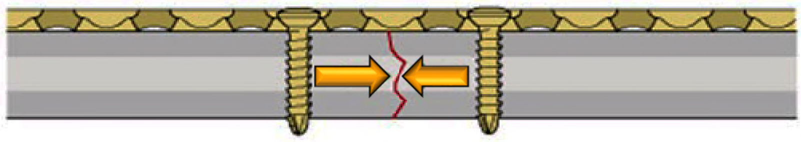
Plates perform several different functions, which will now be considered.
Note: the name of a plate and a plate's function should not be confused. Eg, a DCP can also be applied as a bridging plate.

Plates—functions: compression

- Neutral screw
- Eccentric screw



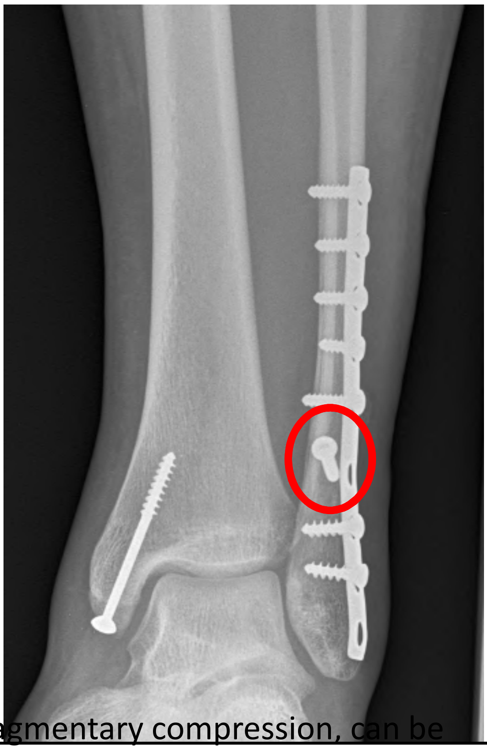
- Eccentric screw fully tightened



As the load screw is fully inserted, it engages and slides down the sloping surface of the plate hole, and the screw and bone move toward the fracture, compressing it.

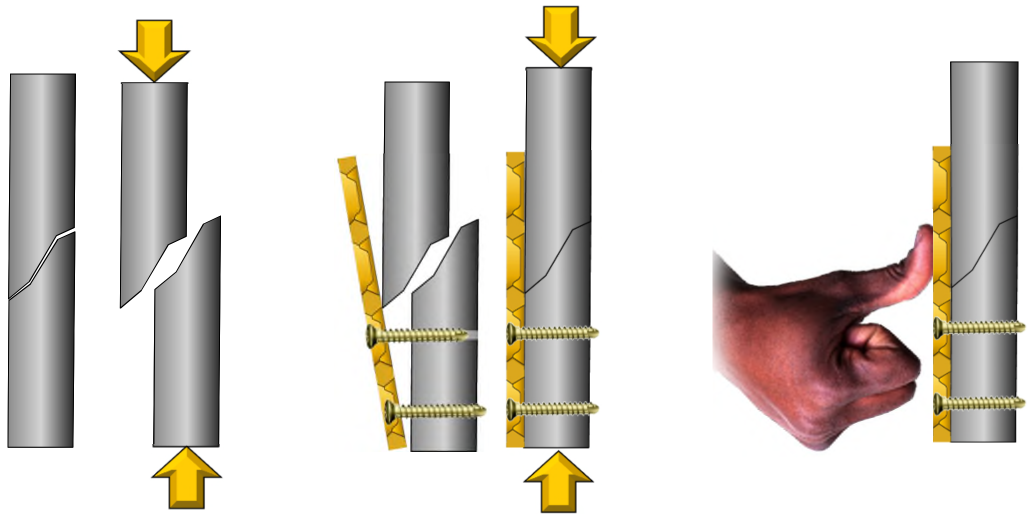
Plates—functions: neutralization

- 1/3 tubular plate protects lag screw



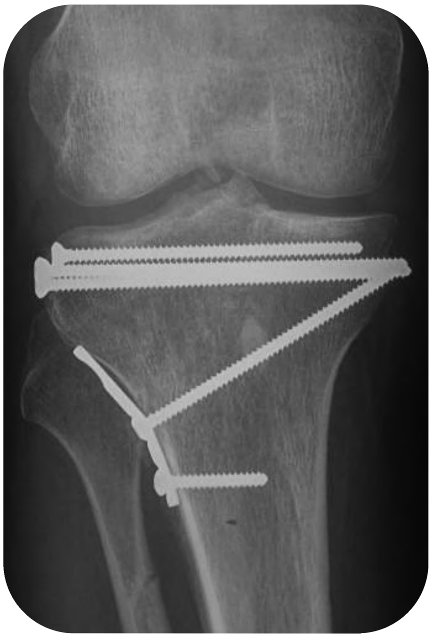
A primary lag screw fixation, exerting interfragmentary compression, can be vulnerable to disruption by physiological bending and/or rotational forces.
Such a primary fixation is usually protected by the use of a plate, spanning from one main fragment to the other – this "neutralizes" the disruptive forces.
All such forces are then transmitted via the plate, and by-pass the primary lag screw fixation.
On the left, a long spiral fracture has been treated by interfragmentary compression using two lag screws. The vulnerable screw fixation has been protected by a spanning plate. The plate does not apply axial compression – all the plate screws are inserted in neutral mode.
Here is an example of a 1/3 tubular plate protecting the lag screw fixation of the distal fibula in an ankle injury.

Plates—functions: buttressing

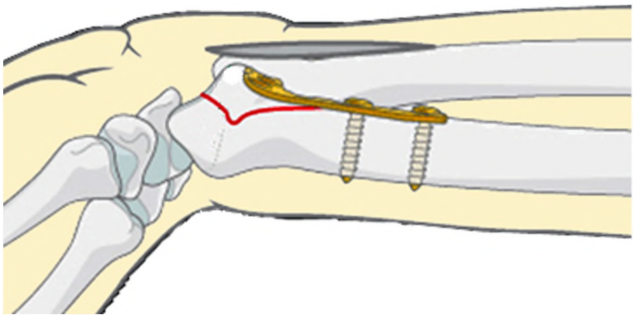


The buttressing plate acts like a thumb that is pressing the other fragment into a reduced position.

Plates—functions: buttressing



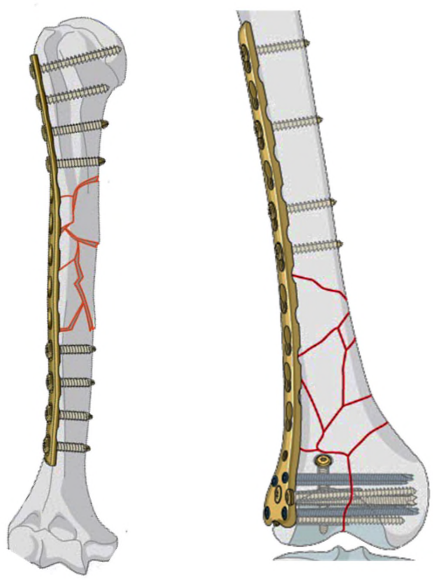
- Indications (examples)
  - Tibial head fracture
  - Distal radius fracture

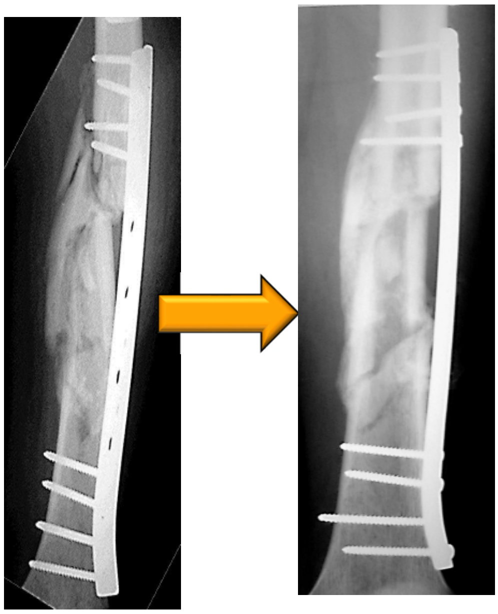


Here are two examples of a buttressing plate holding reduced a tibia head and an anterior marginal distal radial fracture (Barton’s fracture).

Plates—functions: bridging

- Diaphyseal fractures





In comminuted diaphyseal fractures, a plate is often applied, spanning the multifragmentary zone, and attached only to the main fragments. This is used to restore length, axial alignment, and rotational alignment.
This preserves the biology of the multifragmentary zone, which heals by external and interfragmentary callus.

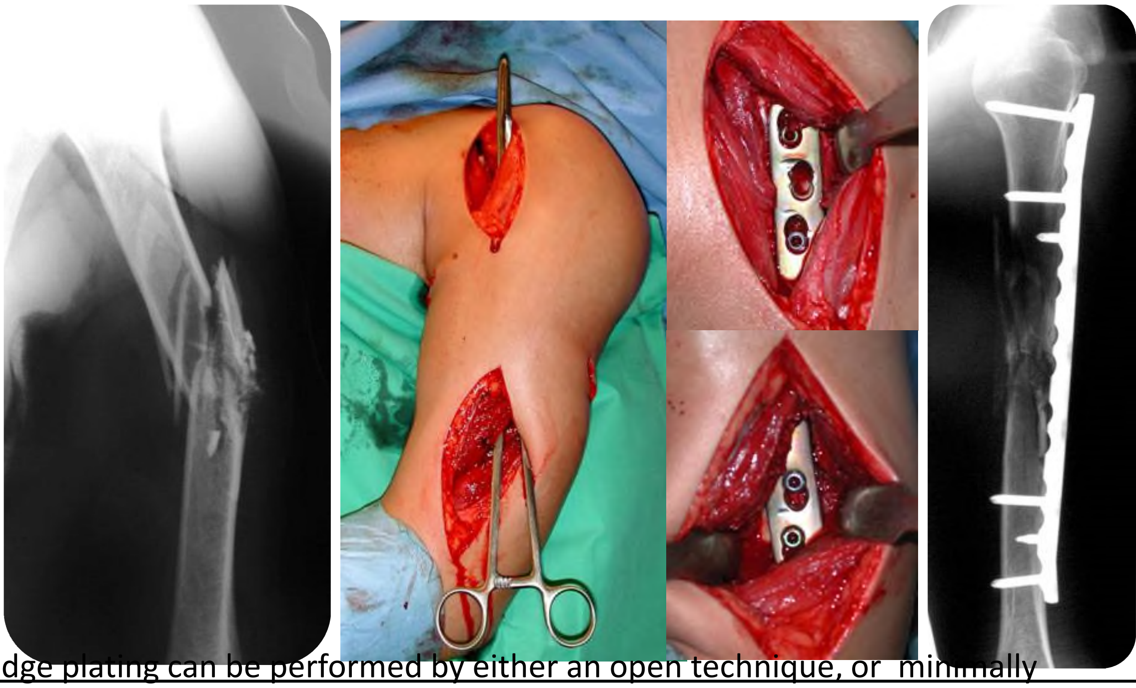
This comminuted femoral shaft fracture was bridged with a plate. After 9 months, healing by callus formation is evident on x-ray.

Here are three examples of multifragmentary diaphyseal fractures:

- Humerus
- Femur
- Phalanges

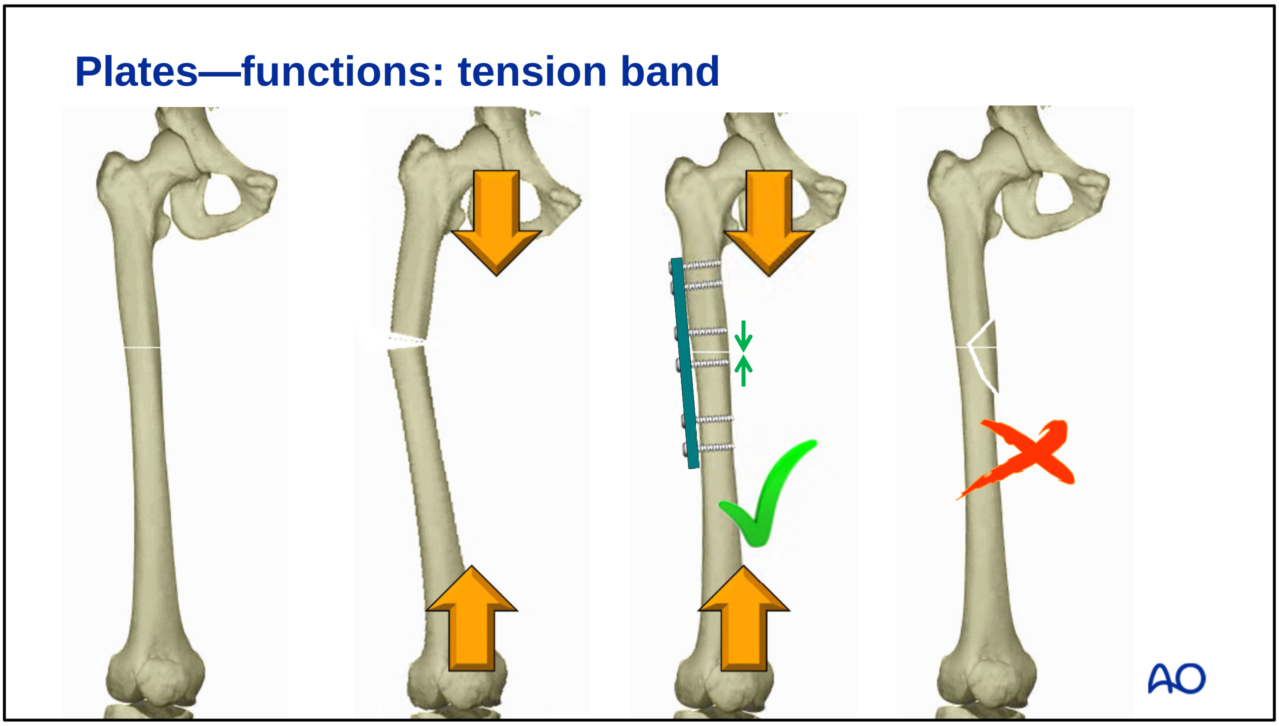
Plates—functions: bridging

LCP used with locking head screw as “internal fixator”



Bridge plating can be performed by either an open technique, or minimally invasively.
In this example, with minimally invasive surgery (MIS) the plate was applied to bridge this gunshot injury.

As locking head screws are used, the plate does not need to be contoured exactly to the bone, the cortical vascularity is not compromised as the plate stands off the bone, and there is angular stability in the metaphyseal zone.



If a body with a fracture is loaded at each end, over a bending point (fulcrum), tension (distraction) forces are generated, maximal on the side opposite the fulcrum, and angulation occurs.

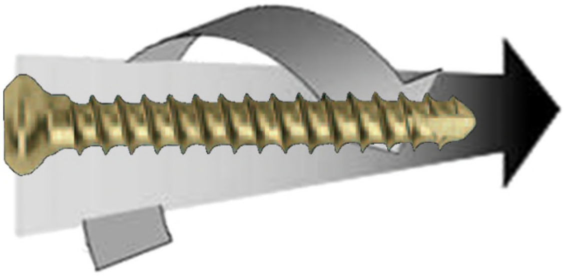
The femur is an eccentrically loaded bone. When axially loaded, the lateral cortex is under tension and the medial cortex bears compressive forces.

However, if an inelastic band, such as a plate, is anchored to the tension side of the body, the same load will generate compression across the fracture interface.
This is known as the tension band principle

A plate fixed to the lateral cortex will function as a tension band and the eccentric physiological load will cause compressive forces in the medial cortex.
If the medial cortex is fragmented and cannot resist compressive forces, a tension band fixation will not prevent plate bending and angulation.

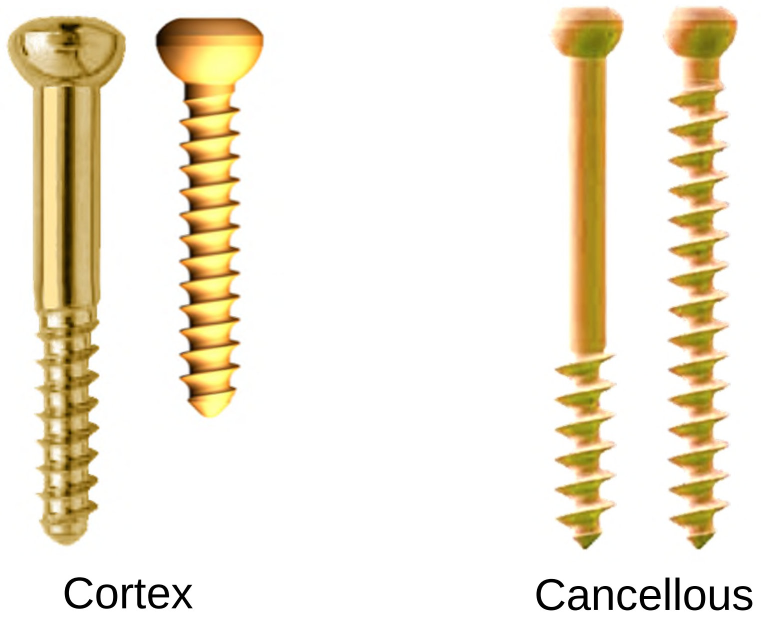
What is a screw?

- A device
  - for converting rotational forces
  - into linear motion
  - rotates by 360º each full turn



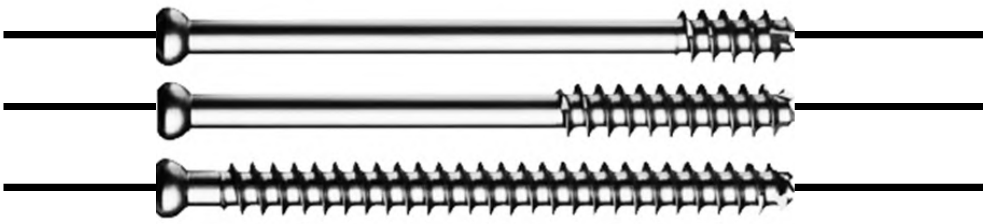
All screws convert rotation into linear motion.

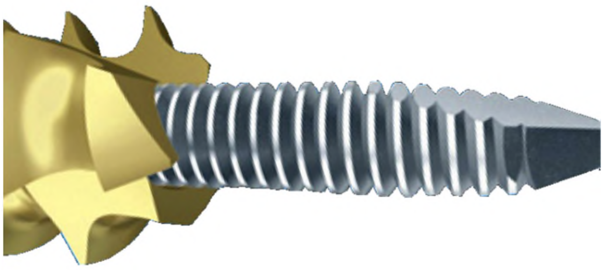
A screw has a particular design



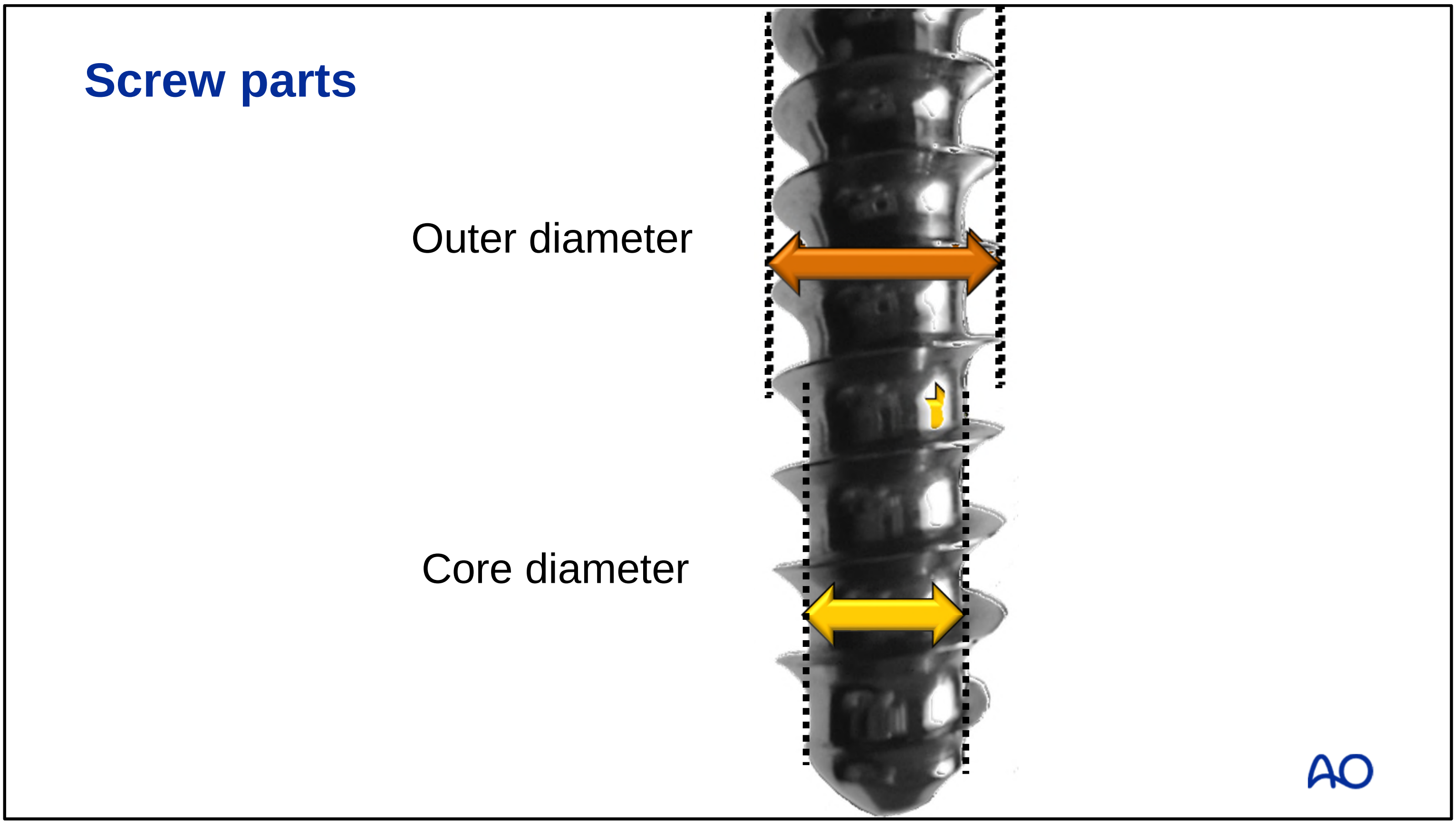
Thread design may vary according to the physical characteristics of the bone in which the screw is intended to gain purchase.
The two main thread types of surgical screws are for cortical bone and for cancellous bone.
Each screw type is available in fully threaded and partially threaded format.

A screw can be cannulated





Screws are also available with central cannulae.
Such a screw can be introduced over a threaded-tip guide wire.
The guide wire is inserted preliminarily, partly as temporary fracture stabilization, and partly so that the final orientation can be checked radiologically, prior to screw insertion.
These screws are self-tapping. There is no need to use the tap.



Here is an example of the thread of a cortex screw.

A surgical screw is a device manufactured to high specifications, and is to be used with great care and precision.

In order to select the correct instruments and technique for insertion of any screw, the surgeon needs to be familiar with its dimensions.

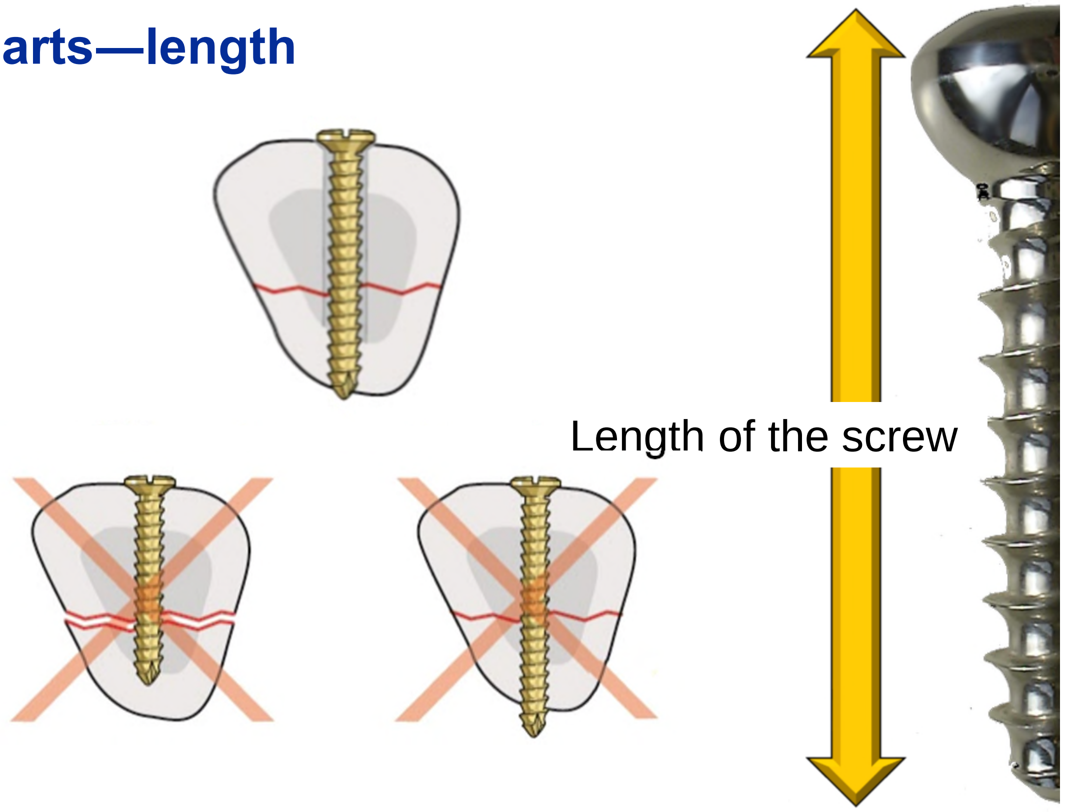
The diameter of the core determines the minimal hole size for the screw to be accommodated in the bone and determines the drill used to create the pilot hole for the screw. In other words the drill to be used will be the same (approximately the same) diameter as the core of the screw.

The outside diameter (or thread diameter) determines the minimal size of any hole through which the screw will glide without its threads' purchasing in the bone.

This is sometimes known as the "nominal" diameter of the screw, as the screws are often categorised by this dimension.

For example, the standard large fragment cortex screw has an outside diameter of 4.5 mm, and is called a 4.5 cortex screw.

Screw parts—length



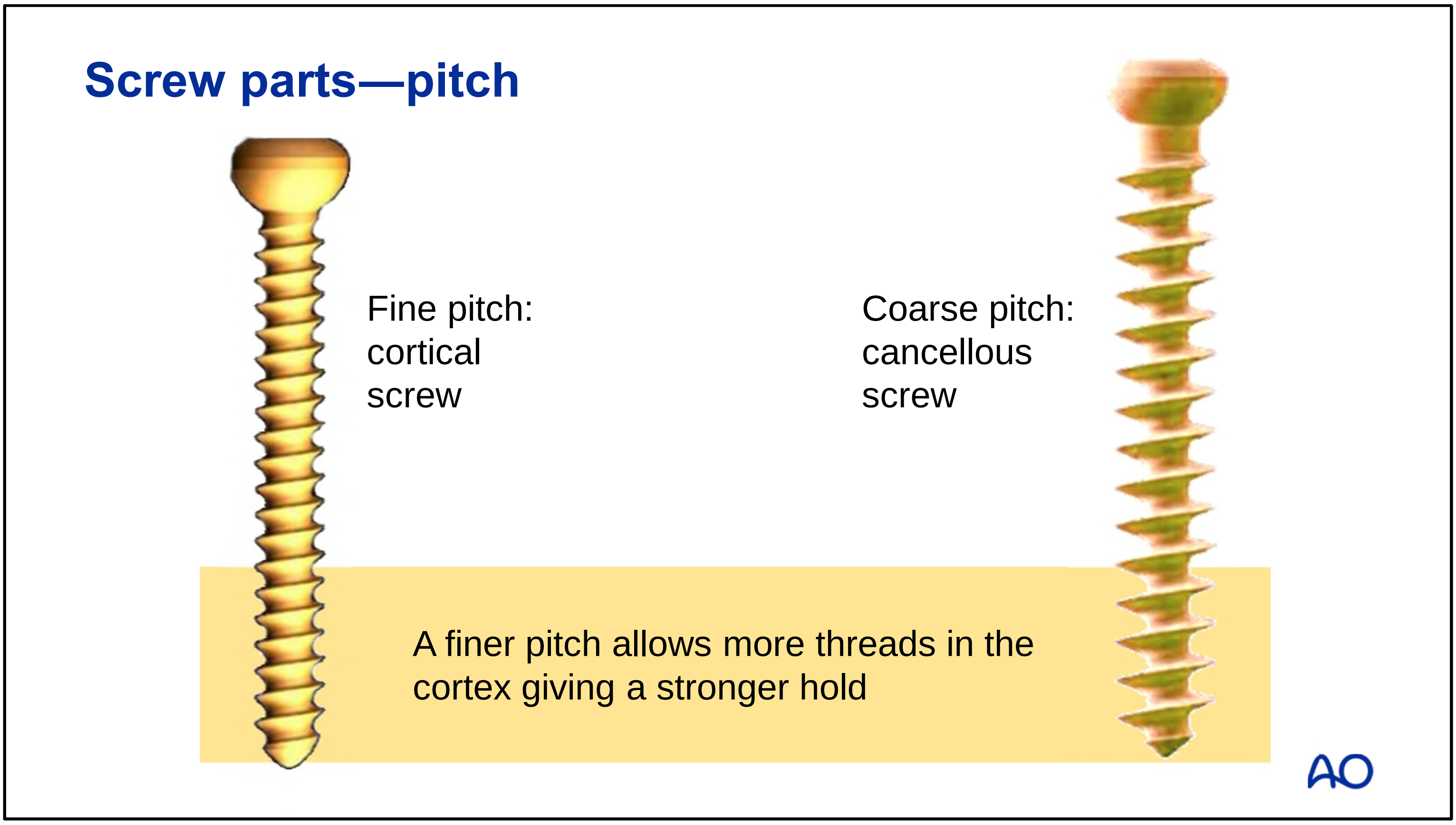
An appropriate length of screw needs to be chosen.

The nominal length of the screw is from the top of the head to the screw tip. As most of the AO screws do sink into the plate, these screws are measured in total length. This is the case for all cortical, cancellous and locking head screws

Too short–it will not gain full purchase in the bone.

Too long–it may cause problems by irritating the soft tissues, or protruding subcutaneously.

The techniques of measuring the correct screw length are discussed later on.

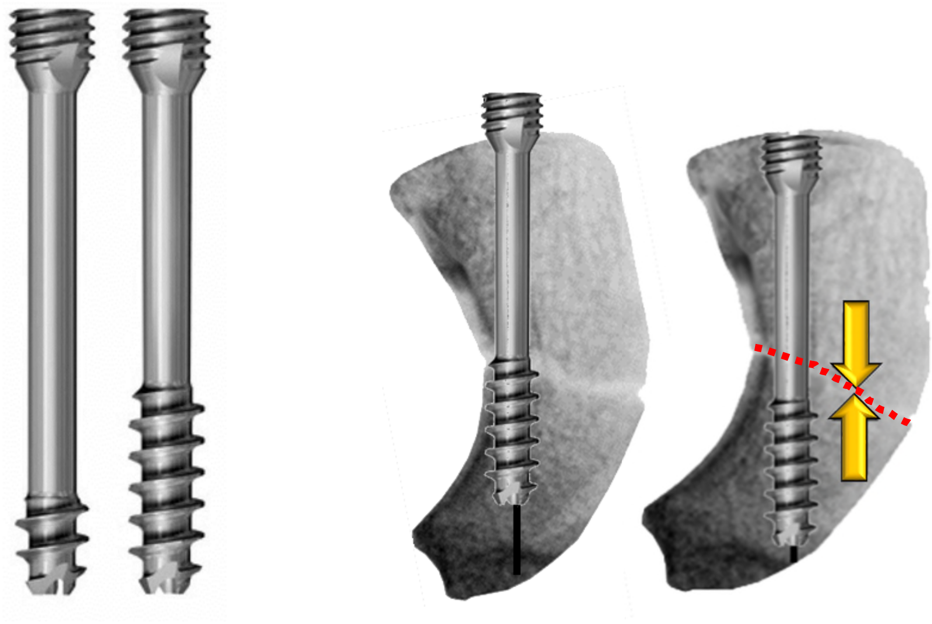


The pitch of the screw is the length travelled by the screw with each 360° turn of the spiral.

The shorter that distance, the “finer” the pitch; the longer that distance, the “coarser” the pitch. Cortical bone screws have a fine pitch, cancellous bone screws have a coarse pitch.

The finer the pitch, the more turns the surgeon will have to make to insert the screw and the more turns of the spiral thread engage in a given depth of cortex.
The more threads engaged in the cortex, the greater the pull-out resistance.

Screw parts—double pitch

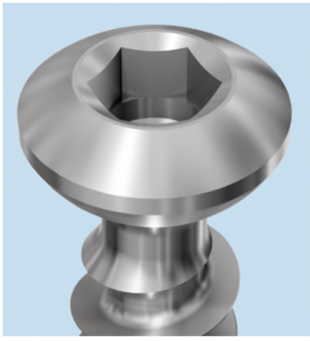
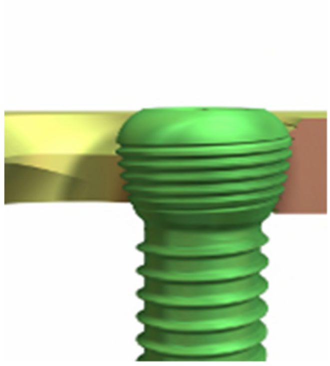


In small bones, such as the scaphoid, self-compressing, double pitch screws can be used.
These are usually cannulated.

As the fine pitch of the thread on the head engages the bone, it travels less far on turning than the coarse-pitched tip and so compression is applied across the fracture plane.

Screw parts—head

- Functions of screw head
    1. to attach a rotational screwdriver
    2. to stop the screw when the head touches bone
    3. to lock the screw head into its plate hole

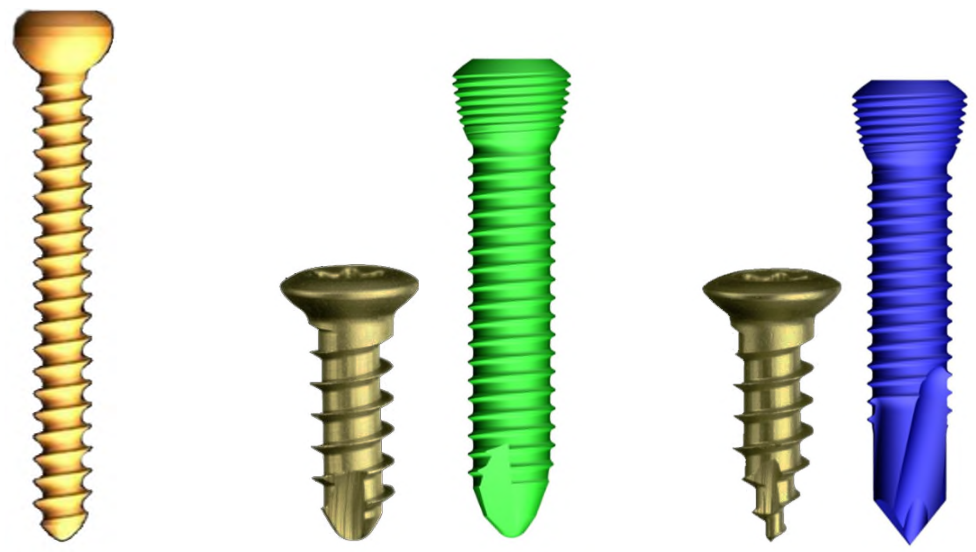
  

The screw head has two basic functions.
One is to permit the attachment of a screwdriver in order to produce the rotation necessary to insert the screw.
This is achieved by producing a shaped recess; this is usually star-shaped, or hexagonal: some very small screws, used in metacarpal and phalangeal surgery, have cross-shaped recesses.

The second one is to arrest forward

There is a third function of some screw heads.
The development of the threaded, or locking, head has allowed screws to lock into threaded plate holes and by creating an angularly stable construct. This is explained in greater detail at a later stage.

Screw tips—cortical bone screws

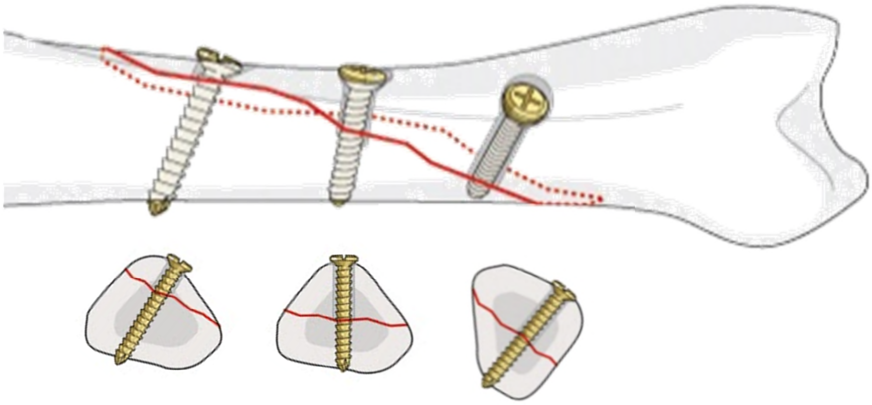


Standard-rounded tip | Self-tapping tip | Self-drilling tip

Screw tips are of three major types.
The standard, round-tipped screw needs pre-drilling of a pilot hole and then tapping (the creation of a thread in the bone by the use of a separate thread-cutting tool - a tap).
The self-tapping screw needs pre-drilling of a pilot hole, but creates its own thread in the cortical bone by virtue of cutting flutes at the tip.
The self-drilling screw requires no preparation of the bone before insertion. It is also self-tapping.

Screws—what are they used for?

1. To produce interfragmentary compression

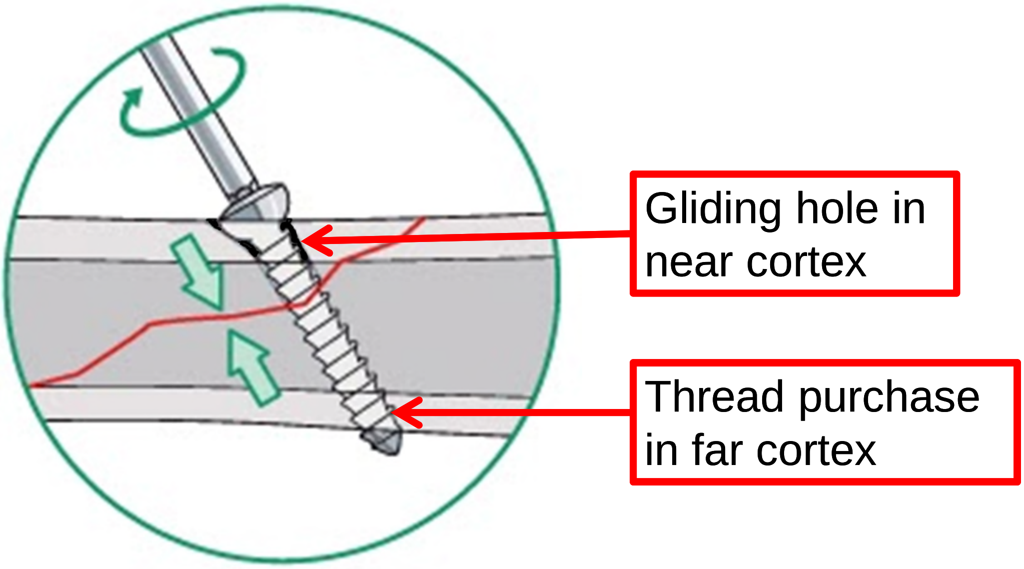


Screws are often inserted across a fracture plane to produce interfragmentary compression, as in this spiral metacarpal fracture.

Note how, because of the spiral nature of the fracture and the need to insert the screws perpendicular to the fracture plane, they vary in direction.

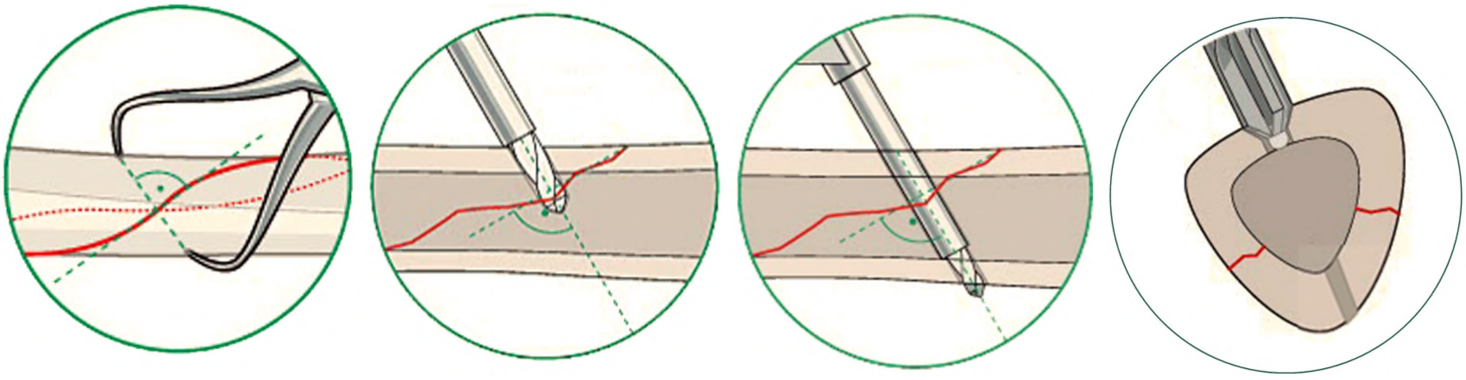
Screws—what are they used for?

1. To produce interfragmentary compression with lag screw principle



For a screw that crosses a fracture plane to produce interfragmentary compression, the thread must purchase in only the far cortex and there must be a gliding hole in the near cortex.
This is known as the “lag screw” principle.
Special partially threaded cortical, or shaft-screws are available for this purpose.
The drilling procedure is the same, except in softer bone, no gliding hole needs to be drilled.
If the screw that crosses the fracture plane purchases in both cortices, it cannot produce interfragmentary compression.
This would be the case if the screw hole has been drilled with 3.2 mm through both cortices. No gliding hole has been drilled.

Lag screw technique



1. Reduction 2. Gliding hole 3. Thread hole 4. Countersink

The steps of the lag screw technique in cortical bone should be followed in a logical order.
Normally, after holding the fracture fragments in a position of anatomical reduction (1)…

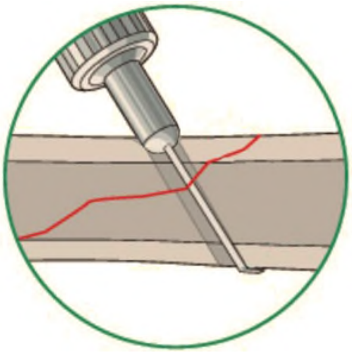
… the near cortex is drilled to produce a gliding hole (2).
The chosen drill for the gliding hole is that of the outside (or nominal) diameter of the selected screw. For example, if a conventional 4.5 mm cortex screw is selected, then the gliding hole drill will be of 4.5 mm diameter.

NB. In this series of illustrations the pointed reduction forceps is omitted, for the sake of clarity.

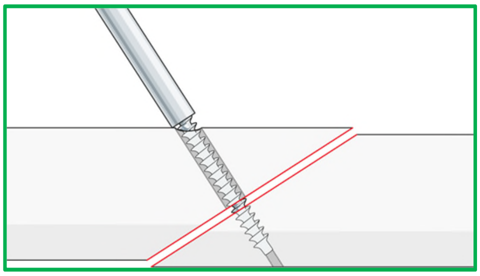
The drill sleeve for the core diameter drill bit is then inserted into the gliding hole, and through it the pilot hole is drilled in the far cortex (for a conventional cortex screw this is 3.2 mm diameter) (3).

The near cortex is then countersunk…

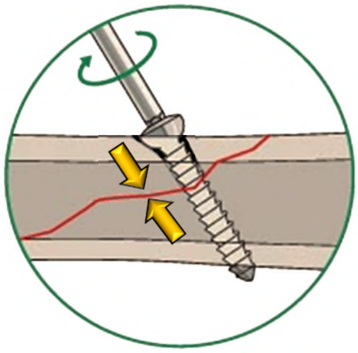
Lag screw technique



5. Measure



6. Tap



7. Insert

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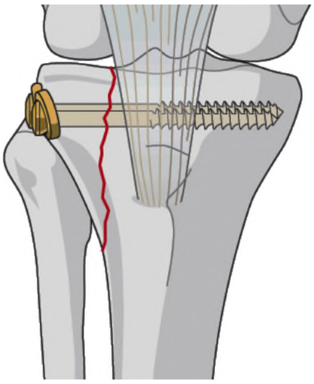
The depth of the screw track is then measured, taking care to engage the hook of the depth gauge against the obtuse edge of the exit hole, not the acute angled edge (5). It is important to follow this order of steps of technique to make sure that the correct length of the screw is measured. If measuring takes place before countersinking then the length of the screw will be too long.
The far cortex is then tapped by hand, using the drill sleeve in the gliding hole (6) – this step is omitted when using self-tapping screws.

The selected screw is then carefully inserted, tightening it to produce interfragmentary compression.

Screws—what are they used for?

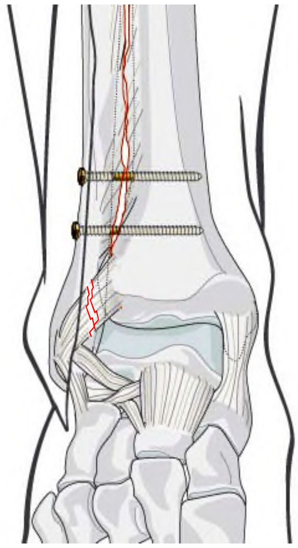
2. To produce interfragmentary compression with partial-threaded cancellous screw (with washer)



Partially threaded cancellous bone screws, inserted across a fracture to produce interfragmentary compression, are used in joint areas, as in this tibia head fracture.
Washers spread the load applied by the head on the underlying cortex.
Washers are used to prevent the screw head from breaking through the thin cortex .

Screws—what are they used for?

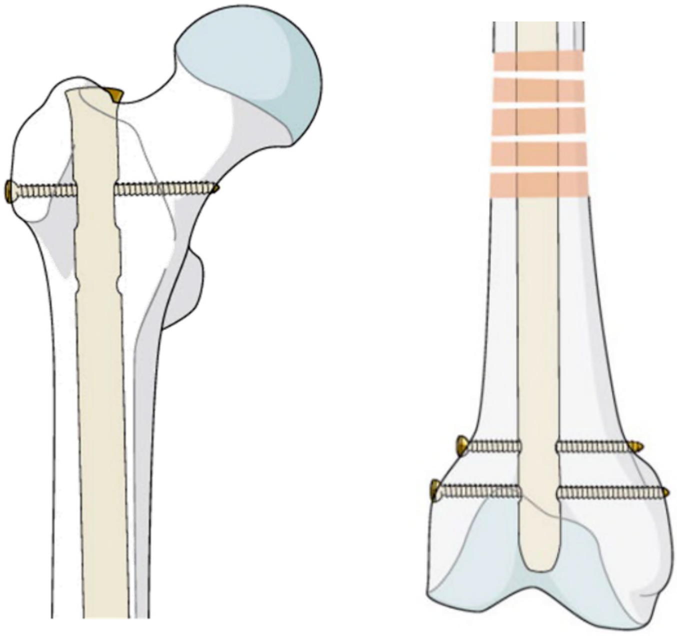
3. To hold two bones in correct anatomical relationship using ‘position screws’



Screws are sometimes used to hold a relationship between two bones: these are called “position” screws. Their threads purchase in both bones and the screws do not compress the bones together.
In this example, the fibula is fractured high up at its neck and the interosseous ligaments are torn: the fibula has been pulled into its normal anatomical relationship to the tibia, and held in position with two screws, each purchasing in two fibular and two tibial cortices.
In this instance, where the screws are being used to stabilize the tibio-fibular syndesmosis, they are sometimes referred to as “syndesmosis” screws.

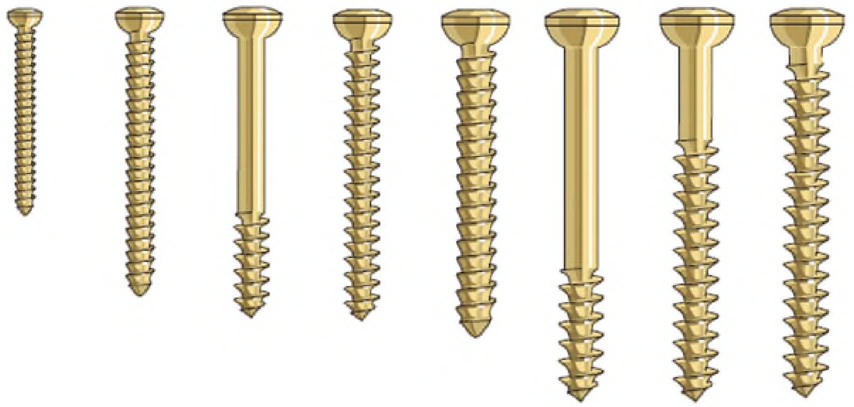
Screws—what are they used for?

4. To lock an intramedullary nail to the cortices



Screws passed through the cortices and through holes in IM nails increase stability by resisting deformation in rotation and shortening. These are referred to as interlocking screws.

Screw—what size?

Screw type	Cortex screw	Cortex screw	Cancellous bone screw, partial thread	Cancellous bone screw	Cortex screw	Cancellous bone screw, short thread	Cancellous bone screw, long thread	Cancellous bone screw, full thread
Screw size, mm	2.7	3.5	4.0	4.0	4.5	6.5	6.5	6.5
								
Drill bit for gliding hole, mm	2.7	3.5	–	–	4.5	4.5	4.5	4.5
Drill bit for pilot hole, mm	2.0	2.5	2.5	2.5	3.2	3.2	3.2	3.2
Tap size, mm	2.7	3.5	4.0	4.0	4.5	6.5	6.5	6.5

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Screw size charts are readily available, indicating associated drill and tap sizes.

Which drill guide should be used for conventional screws in an LCP ?

1. LCP drill sleeve

2. LCP drill guide

3. Universal drill guide

Optional
Insert questions to check learning

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Locking head screws:

1. Provide dynamic compression
2. Provide angular stability
3. Can be applied as lag screws

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The locking compression plate can be applied as a

1. Buttress plate

2. Internal fixator

3. Compression plate

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1. Buttress plate
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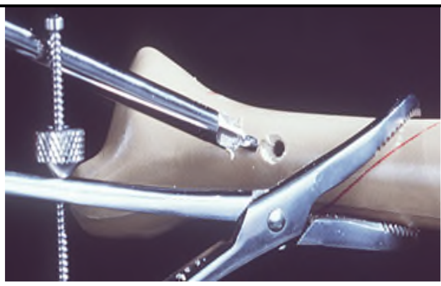
When to countersink?



1. Before measuring screw length

2. After measuring screw length

3. After tapping

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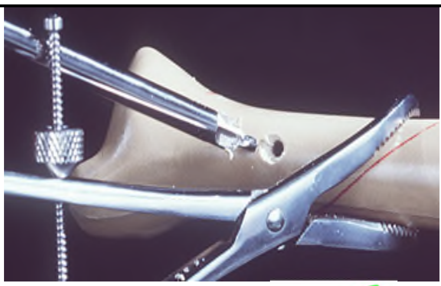
Optional
Insert questions to check learning

When to countersink?



1. Before measuring screw length

2. After measuring screw length

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Optional
Insert questions to check learning

Summary

You should now be able to:

- List different functions of plates
- The different types of screws
- Describe the lag screw technique