Surgery Guide

Fixation of Long Bone (Diaphyseal) Fractures Using Non-Locking Plates and Screws

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Fractures in canine and feline patients are commonly encountered in veterinary practice. It is important for surgeons to understand the principles of fracture management, and to make confident decisions regarding correct fixation methods. This surgery guide offers a detailed insight into the use of non-locking plates and screws in the treatment of diaphyseal fractures.

Contents

Screw Types and Screw Application Explained

Screws are used to secure a plate onto the bone (a plate screw), or to secure two pieces of bone together (a bone screw).

Screws are classified by:

- External diameter of the thread (mm).
- Type of drive e.g. cruciate, hex or star/torx.
- What type of bone the screw is intended for; usually cortical, rarely cancellous.
- Whether the screw locks, or does not lock, into the plate hole (locking, or cortical/non-locking).
- Whether a screw has a thread along its length (fully threaded, common) or only along part of its length (partially threaded, uncommon).
- How the screw is placed by the surgeon e.g. positional, lag, or plate screw.
- Whether the screw is self-tapping or non-self tapping.

Screw glossary:

Cortical (non-locking) screw: Intended for use in cortical bone in a non-locking plate such as a Dynamic Compression plate. Cortical screws are the most commonly used screws. May be either self-tapping or non-self-tapping.

Cancellous screw: Intended for use in cancellous bone, which is soft e.g. metaphyseal bone. In practice, cancellous screws are rarely used. Self-tapping pigtail tip.

Self-tapping screw: Cuts its own thread in the bone using sharp cutting flutes at the tip of the thread (or in the case of cancellous screws, a pigtail tip). Self-tapping screws do not require pre-tapping of the pilot hole and can be screwed into the bone immediately after drilling.

Non self-tapping screw: Cannot cut its own thread in the bone. After the pilot hole is drilled, the thread is prepared in the bone using a tap, then the screw can be placed.

Locking screw: Specifically designed for use in a locking plate, or locking part of a plate e.g. Dynamic Locking Plate, locking TPLO plate, locking arthrodesis plate, locking TPO plate etc. Always self-tapping.

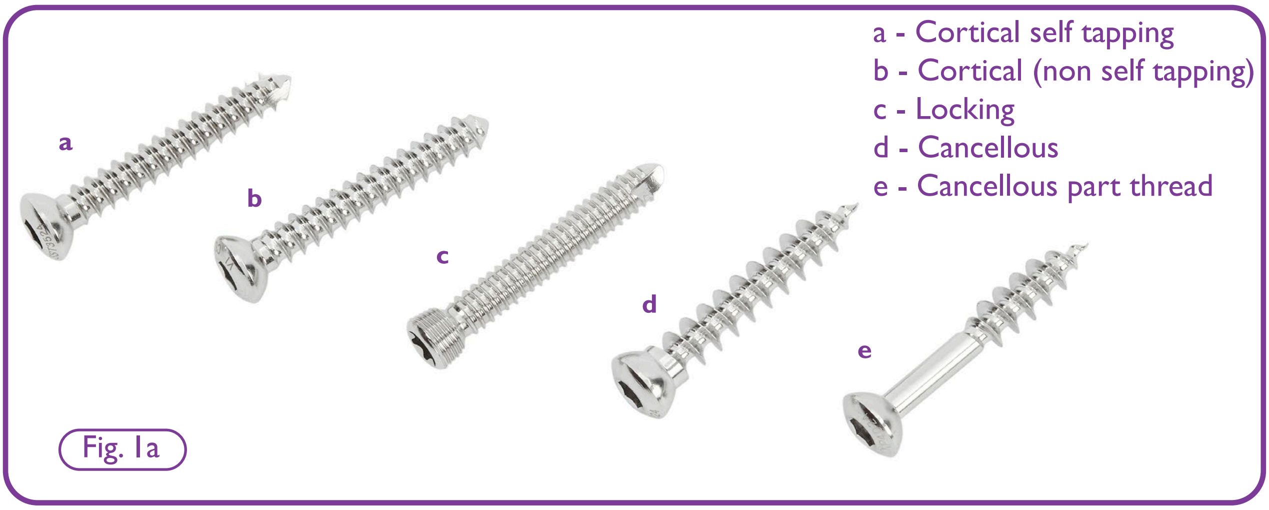


Fig. 1a

Fig. 1a illustrates different screw types.

a b c d

a - Locking (self tapping)
b - Cortical (self tapping)
c - Cancellous Part Threaded (self tapping)
d - Cortical (non self tapping)

Fig. 1b

Fig. 1b illustrates the differences between self tapping and non-self tapping screw tips.

a b c

a - Star drive
b - Hex drive
c - Cruciate drive

Fig. 1c

Fig. 1c illustrates the three different drive types.

a b c

a - Cortical self tapping - low profile cruciate head (selected sizes only)
b - Cortical self tapping - hex head (all sizes)
c - Locking

Fig. 1d

Fig. 1d illustrates the difference in head shape between various screw types.

It is essential to use the correct size of pilot drill (and tap if using non self-tapping screws).

Appendix 1, at the end of this surgery guide, shows the correct size of drill bits and taps for all common sizes of cortical and cancellous screws, for use as positional or lag screws.

Positional Screws

A positional screw (Fig. 2) holds two pieces of bone in position relative to each other. Each section of bone has the hole drilled and the thread tapped into it; the screw is tightened and holds the two pieces of bone in the same position as when the screw was applied. A positional screw gives very secure bone purchase; the chances of the screw stripping or causing bone damage e.g. fracture are much less than for a lag screw.

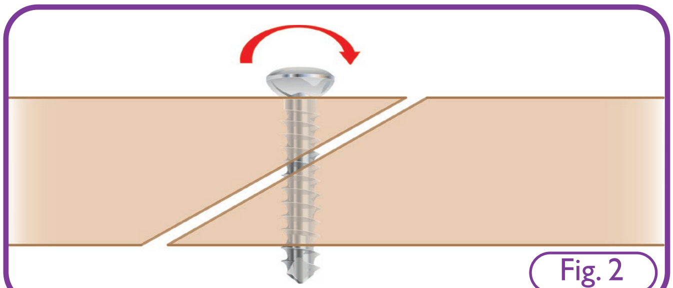


Fig. 2

Fig.2: Schematic diagram of a positional screw. N.B. the gap is for illustrative purposes; a gap should not be left when placing a positional screw.

To place a positional screw:

- Reduce the fracture and hold in position with bone holding forceps.
- Drill the appropriate hole for the shaft of the screw; use a drill guide.
- Measure the depth of the hole using a depth gauge. Refer to Appendix 3 for correct use of the Vi depth gauge.
- If using non-self-tapping screws, tap the thread; use the correct sized tap and drill guide. This step is not necessary for self-tapping screws.
- Use a screw of the appropriate length according to Appendix 3. Place the screw. Take care not to over-tighten the screw.

Tip: A positional screw can be used to hold a fracture in compression: bone holding forceps are squeezed tight across the fracture, and the positional screw is placed, holding the bone in the compressed position. This is safer than placing a lag screw, as a lag screw is at higher risk of either stripping or fracturing the bone.

Lag Screws

A lag screw (Fig. 3) compresses two pieces of bone directly against each other; this creates the mechanical environment for primary (contact) bone healing. One to three lag screws are typically placed along a fissure, oblique or spiral fracture. A lag screw should never be used alone; after lag screw application, a neutralisation plate **must** be placed.

Examples of lag screw application would include:

- Reconstruction, reduction and compression of an oblique or spiral fracture with lag screws (followed by stabilisation with a neutralisation plate).
- Compression or control of a fissure in cortical bone.
- Compression across a transverse condylar fracture e.g. humeral condyle following humeral condylar fissure and fracture.

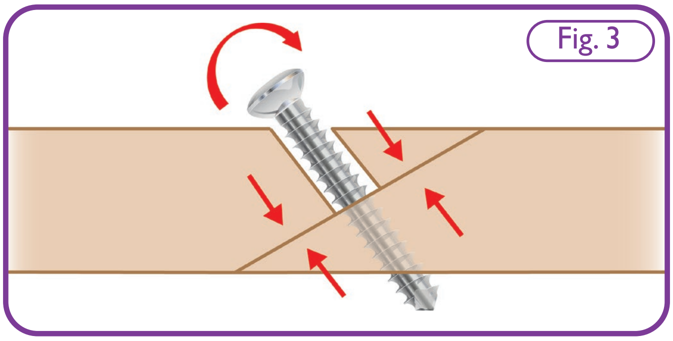


Fig.3: Schematic diagram of a lag screw

Important notes:
A lag screw generates high compressive forces, bringing stability to the fracture which should result in primary bone union. However, these compressive forces can potentially fracture the bone, so lag screws must be applied with great care.

A lag screw may be placed directly in the bone, or through a plate.

It is unknown what happens to the function of a lag screw in the early post-operative period e.g., the function of a lag screw could weaken if the bone under the screw head resorbed, or if the screw loosened secondary to movement. For these reasons, a loaded positional screw (as described above) is probably better and safer than a lag screw.

To place a lag screw:

- The fracture is perfectly reduced and held in position with bone holding forceps.
- The lag screw is directed perpendicular (at 90°) to the fracture line.
- The "glide" hole is prepared in the cis (near) cortex; use the correct sized clearance drill bit (a drill bit with the same outer diameter as the screw) and drill guide.
- An insert sleeve is placed into the glide hole; make sure the correct size is used according to the size of screw being placed.
- The thread hole in the trans (far) cortex is drilled; use the correct sized pilot drill bit and drill guide.
- A countersink is used to prepare the outer surface of the cis (near) cortex to match the shape of the under-side of the screw head. This step is not necessary if placing a lag screw through a plate.
- The hole depth is measured using a depth gauge.
- If using a non-self-tapping screw, the thread in the trans (far) cortex is prepared using a tap.
- The correct length of screw is selected. Refer to Appendix 3 for screw selection guidance when using a Vi Depth Gauge.
- The screw is tightened which generates compression across the fracture. The screw should be tightened until snug. Care should be taken not to over-tighten the screw; this will result in either fracture of the bone or stripping of the thread.

Partially threaded screws can only be used as a lag screw, never as positional screws.

Fully threaded screws can be used either as a lag or a positional screw, depending on how the hole in the bone is prepared (as above).

Plate Screws

A plate screw (Fig. 4) is placed as described for a positional screw above:

- The plate is contoured to the bone.
- The correct drill guide for that specific plate is selected. If using a Dynamic Compression Plate, a Load Neutral Drill Guide or Universal Drill Guide of the appropriate size must be used.
- Through the screw hole in the plate, the hole is drilled into the bone using the drill bit and drill guide.
- Measure the depth of the hole using a depth gauge. Refer to Appendix 1 for correct use of the Vi depth gauge.
- If using non self-tapping screws: the screw hole is tapped in the bone using the correct sized tap and drill guide.
- Use a screw of the appropriate length according to Appendix 3.
- Insert the screw into the pilot hole and tighten.

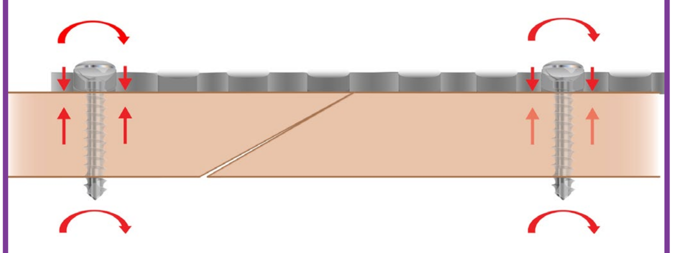


Fig. 4

Fig. 4 illustrates how non-locking plates work: the screw "squeezes" the plate onto the bone which generates friction between the plate and bone, which generates construct stability

The action of tightening the screw squeezes the screw head down into the plate hole, which in turn compresses the plate onto the bone. This generates friction between the plate and the bone, and this provides the construct stability.
If the screw is not tight, or if the plate is not in contact with the bone (for example, due to inadequate contouring, or inadequate removal of soft tissue), inadequate friction is generated, therefore no stability is generated by that screw and it is functionally/mechanically useless.

Plate Screw as a Lag Screw

Occasionally a plate screw can be a lag screw (Fig. 5). If so, this is the first screw(s) in the plate that is placed. The procedure is as described above for placing a lag screw, except that:

- the lag screw pilot hole is prepared through the plate hole.
- the countersink is not used.

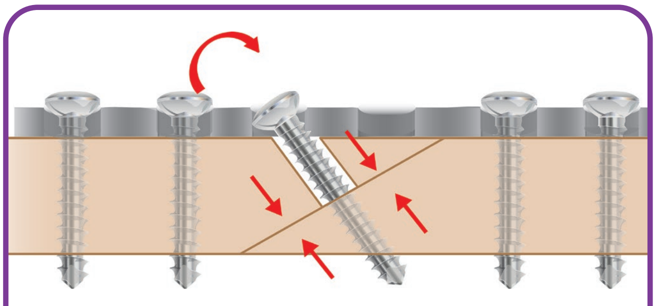


Fig. 5

Fig. 5 shows placement of a lag screw through a plate

It can be technically very challenging to place a plate screw as a lag screw because:

1. The fracture must be perfectly reduced and compressed with bone holding forceps whilst 2. the plate is perfectly contoured to the bone shape and 3.the plate is applied to the fracture and held in situ whilst 4. the lag screw is being placed. Doing all this simultaneously can be very difficult.

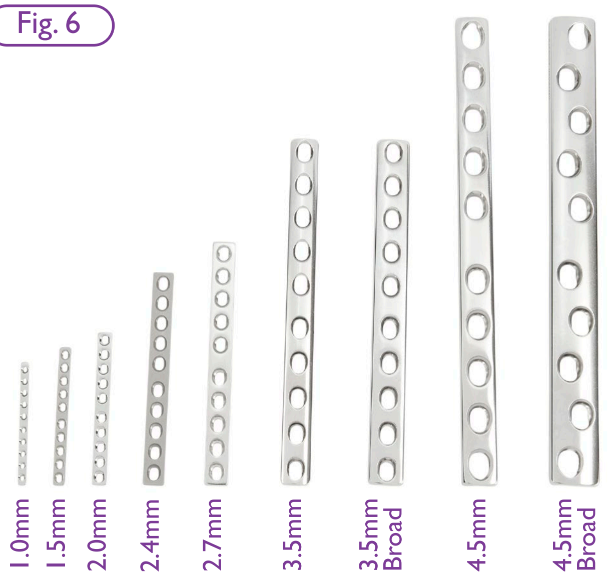
Placing an "independent' lag screw is much easier i.e., the fracture is reduced, the lag screw(s) is/are placed, and then the plate is placed.

Non-Locking Plates Explained

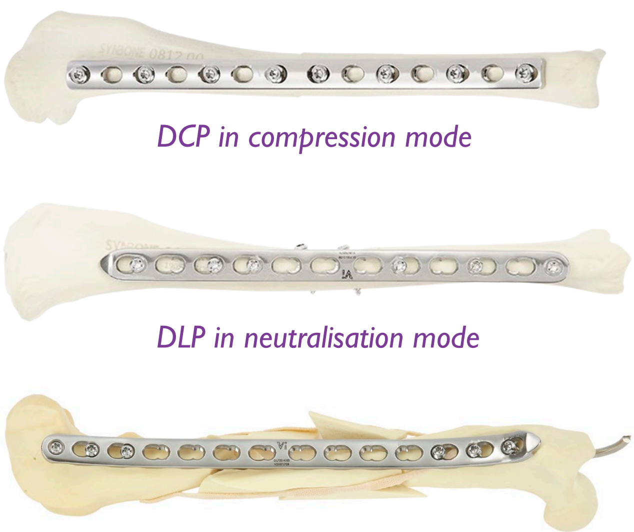
Plates can be classified in a number of different ways:

- **The size of the plate** e.g. 2.7mm or 3.5mm (Fig. 6). Oddly, this does not refer to any direct property of the plate, rather the size of screw the plate is intended for use with i.e. a 2.7mm plate works with, and is designed to accept, 2.7mm screws.

Fig. 6



- **The mechanical function of the plate** e.g. compression plate, neutralisation plate, bridging plate. NB This is the way the surgeon has applied the plate to the bone and does not refer to the type of plate (Fig. 7).



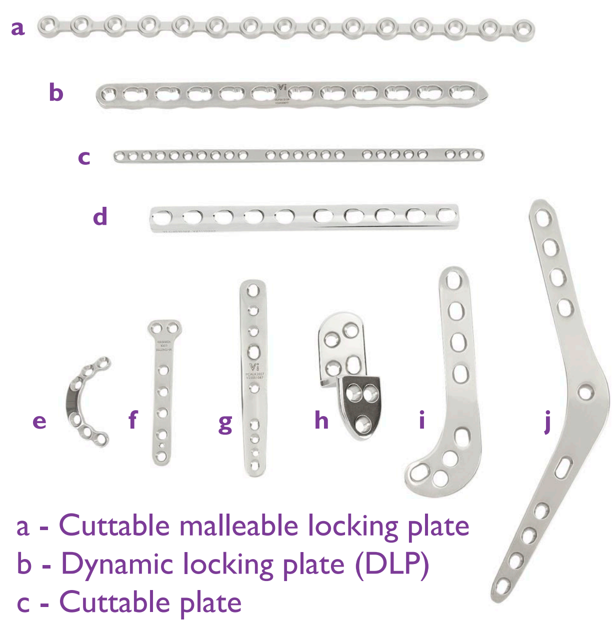
DCP in compression mode

DLP in neutralisation mode

DLP in bridging mode

Fig. 7

- **The features of the plate** as sold by the manufacturer e.g. dynamic compression plate (DCP), dynamic locking plate (DLP), pancarpal arthrodesis plate, cuttable plate etc (Fig. 8).



a - Cuttable malleable locking plate
b - Dynamic locking plate (DLP)
c - Cuttable plate
d - Dynamic compression plate (DCP)
e - Acetabular plate
f - T plate
g - Pancarpal arthrodesis plate
h - TPO/DPO plate
i - Femoral supracondylar plate
j - Pantarsal arthrodesis plate

Fig. 8

Non-Locking Plates and Friction

Non-locking plates stabilise fractures by compression of the plate down onto the bone by the screw head, as the screw is tightened into the plate. This generates a friction force between the plate and the bone. This friction force is what brings stability to the construct and prevents movement (please refer to Fig. 4).

Two important facts derive from this theory:

- All screws must be tight, otherwise friction is not generated.
- The plate must be perfectly contoured to the bone otherwise there is no contact between the plate and bone. If there is no contact, friction cannot be generated.

The screw is secured in the bone through the hole in the plate; the head of the screw engages the plate. A screw can be placed in a plate in several different ways that create different mechanical functions:

- **Compression (axial) screw -** the screw is placed eccentrically in an oval DCP (dynamic compression plate) screw hole using the Load Neutral Drill Guide or Universal Drill Guide. As the screw is tightened, the plate is tightened down onto the bone surface, and the screw travels in the direction of the fracture; this pulls the bone with it and causes compression at the transverse fracture site.

- **Neutral screw** – the screw is placed centrally in an oval DCP plate hole using the Load Neutral Drill Guide or Universal Drill Guide, or in a round-hole plate, placed centrally using an appropriate drill guide. As the screw is tightened, it tightens the plate down onto the bone surface; there is no additional movement of the bone.

- **Lag screw** – the lag screw hole is prepared through the plate hole. As it is tightened, the screw compresses the oblique or spiral fracture. This screw should be placed prior to the other screws in the plate. This is technically challenging to achieve. (see above).

- **Locking screw (locking plates only)** – the hole is prepared using the locking drill guide specific to that plate. When the screw is placed, the screw head locks into the hole in the plate. The locking screw / plate interface is a rigid coupling that behaves completely differently to non-locking screws. The locking screw/plate construct is essentially an "internal" external skeletal fixator and the locking screw/plate mechanism is the equivalent of the ESF clamp. There is no compression of the plate onto the plate, and no generation of friction between the plate and the bone. A separate Vi guide is available which describes the indications for, and use of, locking plates and screws.

General Rules for Application of Non-Locking Plates

- **Number of screws**: Minimum number of recommended screws is 3 bi-cortical screws either side of the fracture.
- For transverse fractures, the plate should be applied to the **tension surfaces of bones**.

The tension surfaces of bones are:

Radius; cranial & cranio-medial surfaces
Humerus; cranial & lateral surfaces
Tibia; medial & cranial surfaces
Femur; lateral surface

- **Use as long a plate as possible**. Too short a plate is at risk of failure due to screw pull-out and/or bone fracturing through the screw holes. The plate should be as close to the full length of the bone as is possible.
- **Contour the plate to the bone**. Accurate contouring is essential for non-locking plates for two reasons:
  - Construct stability depends on plate-bone contact. If the plate is not accurately contoured, plate-bone contact will not occur therefore friction is not generated, so construct stability cannot be achieved.
  - As the screws are tightened, the plate is pulled down onto the bone surface. A poorly contoured plate can pull the bone out of alignment i.e. causing bone malalignment as the screws are tightened.
- **Fill as many screw holes as possible**: minimum 3, maximum 5, bicortical screws per section of bone.
- **Every screw must be tight**. Screws that are not tight are useless as they do not compress the plate onto the bone, therefore they do not create friction and do not create stability.
  - Screws usually become loose if they are over-tightened; this is called a "stripped" screw. This happens either because the surgeon is too keen with tightening the screw, or because the bone is soft or weak. This is an inherent problem of non-locking screws; the surgeon must always be very careful with "terminal tightening" of the screw to avoid over-tightening and stripping.
  - If a screw becomes loose during surgery, it must be removed (leaving an empty plate hole) or replaced with a screw that can be correctly tightened.

- **All screws should engage both cortices**. This is because non-locking screws are not "angle-stable" in the plate hole i.e., they can "rock" or "toggle" in the plate hole; such toggling is much more likely for a uni-cortical screw compared to a bi-cortical screw. (Fig. 8).

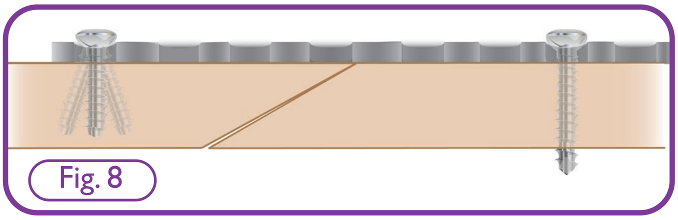


Fig. 8

Fig. 8 shows "toggling" of a uni-cortical non-locking screw that is not angle stable, on the left of the image; therefore bi-cortical application is recommended to avoid this instability, as shown on the right of the image.

- **Reconstructing a fracture means full reconstruction.** This can be likened to a jigsaw puzzle which isn't complete until every piece is in place.
  - Partial (incomplete) reconstruction, leaving a cortical defect, is a weakness in the reconstructed bone. This means less load sharing between the plate and bone. This can result in premature plate failure.
  - This most commonly and easily happens in a transverse fracture that is reconstructed, but with a small gap left at the facture.
- **Only lag screws should cross the fracture line:**
  - A safer alternative to a lag screw is a loaded positional screw.
  - A loaded positional screw is a positional screw that is placed across the fracture whilst the fracture is simultaneously being compressed by bone holding forceps.
- **Be aware of cortical fissures.** Fissures demand care and respect and should be controlled, not exploded.
  - Do **not** place screws directly through fissures as there is a high chance of "exploding" the fissure and making it much worse.
  - Instead, fissures should be stabilised and controlled. This is best achieved using lag or loaded positional screws.
  - Alternatively, cerclage wire can be used, but this is less reliable and causes more biological damage.

Fracture Classification and Plan for Surgery

Classify the diaphyseal (long bone) fracture, and decide on the best form of stabilisation:

Transverse fracture: The fracture is 30 degrees or less to the perpendicular of the long axis of the bone.

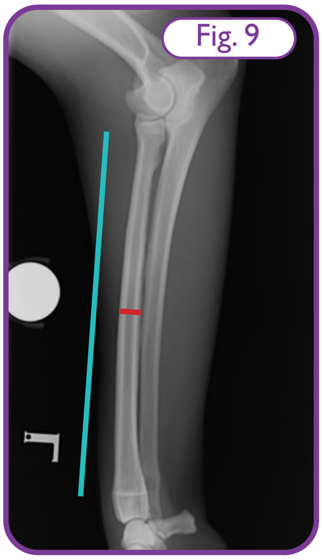


Fig. 9

Fig. 9 shows the axes of the bone; the long axis (light blue) and the perpendicular (red). A transverse fracture is aligned 30 degrees or less from the perpendicular.

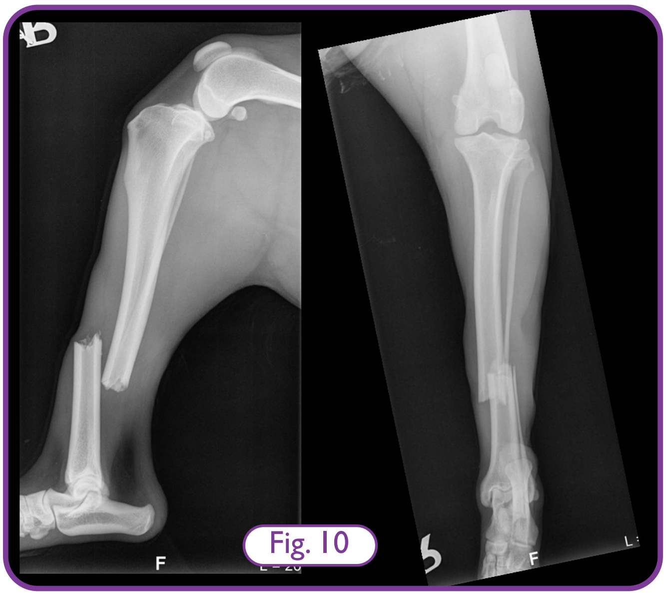


Fig. 10

Fig. 10 shows a transverse fracture of the distal tibial diaphysis.

A transverse fracture is almost always best reconstructed and stabilised by application of a dynamic (axial) compression plate; e.g. a DCP or a DLP. If this is not possible, the transverse fracture should be "bridged".

Oblique or **spiral fracture**: The fracture is 30 degrees or more to the perpendicular of the long axis of the bone.

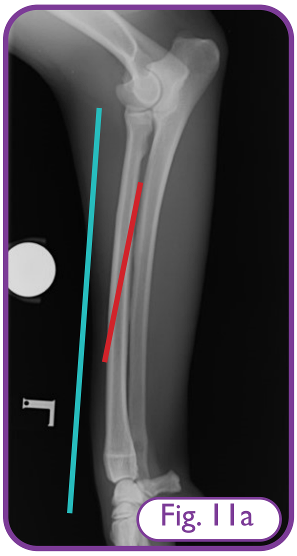


Fig. 11a

Fig 11a shows the long axis of the bone (light blue). An oblique fracture (red) is more than 30 degrees to the perpendicular of the long axis.

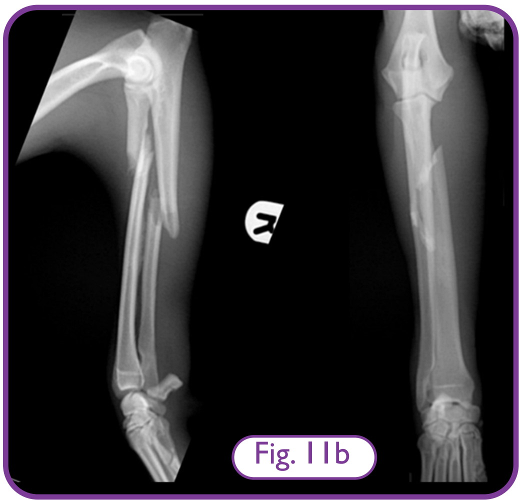


Fig. 11b

Fig. 11b shows oblique fractures of the proximal radius and proximal ulnar diaphysis.

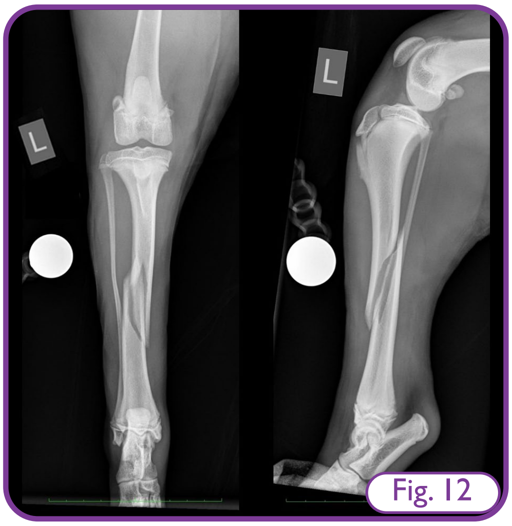


Fig. 12

Fig. 12 shows a spiral fracture of the mid tibial diaphysis; this is seen as an oblique fracture in both views.

Oblique or spiral fractures can be stabilised by:

- **Reconstruction** i.e. Compression of the fracture and application of a neutralisation plate. Compression of the fracture can be achieved by:
  - Application of bone holding forceps and place 1 to 3 positional screws; so called "loaded positional screws"; this is simplest and safest.
  - Application of bone holding forceps and place 1 to 3 lag screws; this is technically more complex and there is a higher risk of complications such as bone fracture or screw strippage.
  - Application of an intramedullary pin and then 2 to 4 cerclage wires OR 2 to 4 cerclage wires and then a neutralisation plate. Warning: cerclage wire can be very difficult to tighten, and difficult to achieve retention of tightness. In addition, placing a cerclage wire requires more dissection than screw placement ie. more bone and soft tissue trauma.
- **Application of a bridging construct** – if reconstruction cannot be achieved.

Comminuted fracture: Two or more fractures with three or more pieces of bone. A fracture can be mildly, moderately, or severely comminuted.

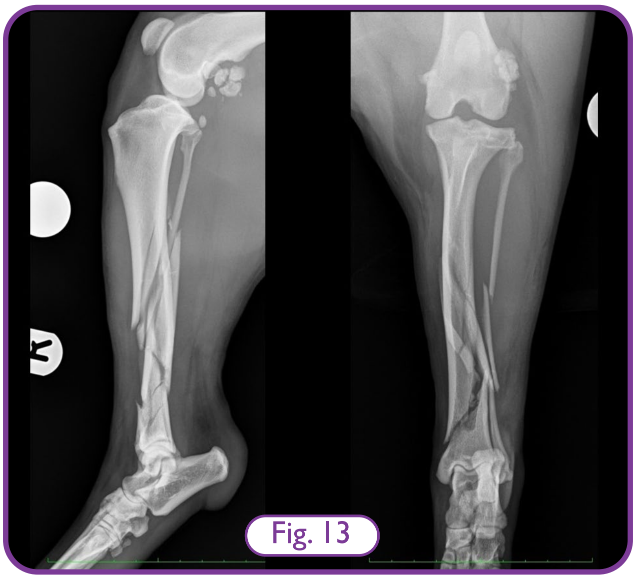


Fig. 13

Fig. 13 shows a moderately comminuted tibial fracture with adjacent segmental fibular fracture.

A critical initial choice with a comminuted fracture is whether the fracture can be reconstructed or not. A reconstructible fracture is stabilised by sub-dividing into a series of transverse, spiral or oblique fractures that are stabilised sequentially, ensuring perfect reduction and compression of each.

It is often not worth attempting reconstruction due to the time, surgical dissection and trauma, which causes devascularisation of the bone, and the risk that reconstruction is not correctly achieved. It is usually better to make the decision early that reconstruction is not possible, than attempt it and fail. As a general rule, a fracture that has more than 3 or 4 large segments of bone is not worth attempting reconstruction.

For non-reconstructable fractures, a "bridging" construct is used. There are a number of different types of bridging constructs that can be used:

- A plate-rod construct; a bone plate combined with an intra-medullary pin.
- Orthogonal plating; two plates at 90 degrees to each other.
- Double plating; plating of 2 adjacent bones i.e. the radius and the ulna.
- An external skeletal fixator; linear or circular.
- Interlocking nail.

Dynamic (Axial) Compression Plating for Transverse Fractures

The Dynamic Compression Plate (DCP) is used to compress the fractured bone ends together, in line with the long axis of the bone. Axial compression can only be applied to a transverse fracture. Axial compression across an oblique fracture will result in shear instead of compression.

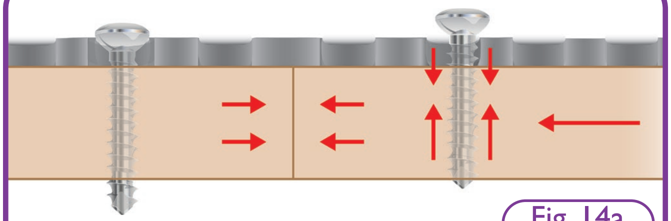


Fig. 14a

Fig. 14a illustrates the principles of axial compression. The DCP achieves axial compression by the unique design of its oval screw holes and the use of the appropriately sized Load Neutral Drill Guide or Universal Drill Guide to achieve positioning of the pilot holes in the correct position. Tightening the screw causes the screw head to engage the plate hole. With the pilot hole for the screw placed in the compression (loaded) position, the screw is forced to move in the direction of the centre of the plate, i.e. towards the fracture.

Fig. 14b

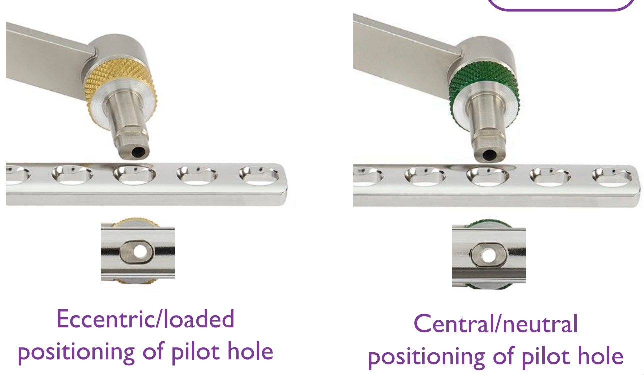


Fig. 14b shows how the compression (gold) guide of the Load Neutral Drill Guide places the screw eccentrically (loaded placement) in the oval DCP plate hole. The neutral (green) guide of the LNDG places the screw centrally (neutral placement) in the oval DCP plate hole.

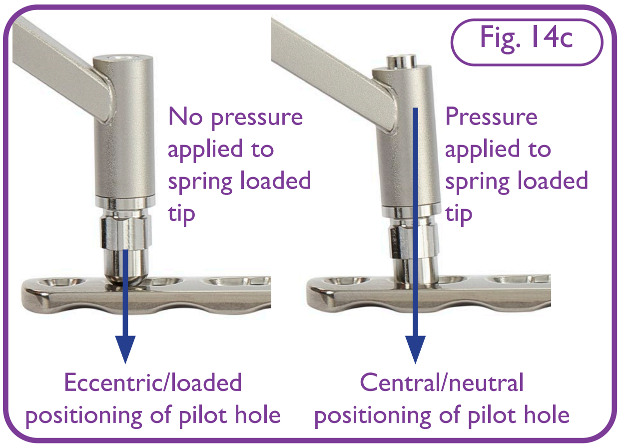


Fig. 14c shows how the Universal Drill Guide (UDG) is used as an alternative to the LNDG. For loaded placement of the screw, the spring-loaded tip of the UDG is held against the far edge of the oval plate hole, with no pressure applied to the tip. This results in eccentric positioning of the pilot hole. For neutral placement of the screw, the spring-loaded tip of the UDG is pressed down, which moves it into the centre of the oval plate hole, resulting in central positioning of the pilot hole.

Application of a Compression Plate

1.

Reduce the fracture & hold in reduction with bone holding forceps.

2.

Select the correct size of plate – see Vi plate selection chart (Appendix 2). The plate should be as long as possible.

3.

Contour the plate to the shape of the bone; consider pre-contouring to a similar sized bone model, or to radiographs of the contralateral bone.

4.

Pre-stress the plate; this means applying a mild over-contour of the plate over the fracture so that the plate sits proud of the bone by 1-3mm in this central region.

5.

Apply the first screw using the neutral drill guide; the screw should be tight.

6.

Apply the second screw to the other end of the bone; use the compression drill guide. Note that as the screw is tightened, the fracture will be compressed.

7.

Apply a maximum of one further compression screw per end of the bone. Just before each compression screw is fully tightened, the previously placed screw on the same end of the bone should be slightly loosened by half a turn; this is to reduce friction to allow the compression movement. Fully tighten the compression screw. Then fully tighten the previously loosened screw.

8.

Then apply all remaining screws as neutral screws; minimum 3, maximum 5 screws per segment of bone.

It can be helpful to start at the centre of the plate and gradually work "outwards " i.e. working proximally and distally. But be careful; make sure the proximal and distal ends of the plate are overlying the bone otherwise the plate can "over-hang" the bone meaning screws will not engage the bone.

Scan the QR code to view our video demonstrating the application of a DCP to a transverse fracture.

Specific Rules for (Axial) Compression Plating of Transverse Fractures

Pre-stress the plate: When a plate is applied to bone and the screws are tightened, as the screws pull the bone towards the plate, the cis cortex immediately under the plate is reduced, but a small gap often opens at the trans-cortex. This is a problem as it means the trans-cortex loses the mechanical property of being the compression side of the bone, therefore the cis cortex no longer acts as the tension surface. Consequently, the mechanical advantage of placing the plate on the tension side is lost; the plate is in bending mode and could fail prematurely.

In order to overcome this, the plate should be 'pre-stressed' (Fig. 15a). Once the plate has been contoured to the shape of the bone, the plate is slightly over-contoured in such a way that when placed on the surface of the reconstructed bone, the centre of the plate sits just 1-3mm proud of the surface of the bone.

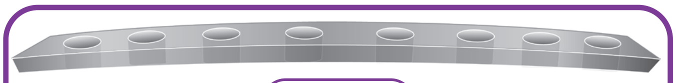


Fig. 15a

The effect of this is that when the screws are tightened, the trans-cortex is pulled into tight apposition first. This generates compression at the trans-cortex and thus ensures that the trans-cortex is intact and acting as the mechanical compression surface. The cis-cortex is therefore maintained as the tension surface, thus ensuring optimal mechanical loading of the plate.

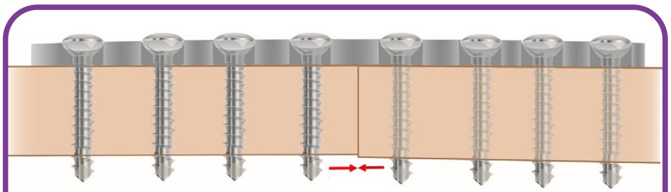


Fig. 15b

Fig 15b shows pre-stress: the plate is pre-stressed (slightly over-contoured); this ensures that, as the screws are tightened, the trans-cortex is in contact, ensuring the plate is in tension mode. If a plate is applied to a transverse fracture without pre-stress, a small gap is created at the trans(far) cortex; this means that the plate is in bending mode, not tension mode; the plate could fail prematurely.

Do not leave one single screw hole empty over the fracture as this leaves an exposed single stress concentrator; this increases the possibility of plate failure at this location (Fig. 16a). If you must leave an empty screw hole over a transverse fracture, it is better to leave multiple empty screw holes as this dissipates the stress concentration effect - in other words, the same bending force is divided between multiple plate holes rather than concentrated over just one (Fig. 16b).

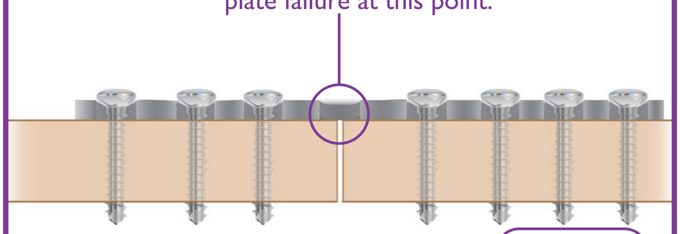


Fig. 16a

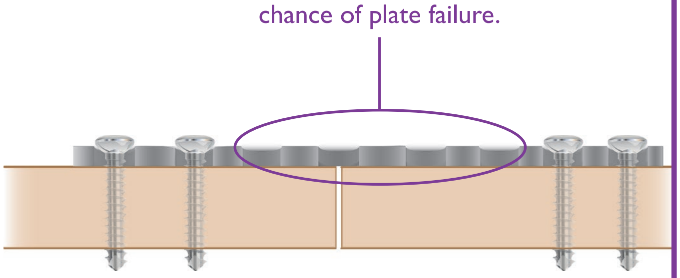


Fig. 16b

Make sure you apply the plate to the tension surface of the bone so that the plate acts in tension mode where it is strong. If you do not, the plate is on the bending or compression side of the bone; the plate is then in bending mode and is at high risk of premature failure.

The tension surfaces of bones are:

Radius; cranial & cranio-medial surfaces
Humerus; cranial & lateral surfaces
Tibia; medial & cranial surfaces
Femur; lateral surface

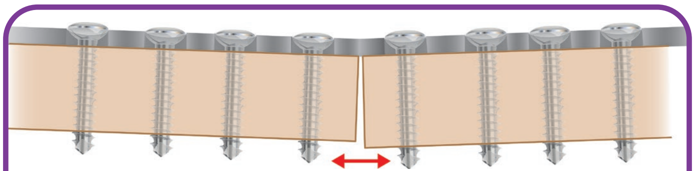


Fig. 17

Fig. 17 shows a plate applied to the bending surface of the bone; plates are weak to bending and could fail prematurely. The plate should always be applied to the tension side of the bone.

Neutralisation Plating for Oblique and Spiral Fractures

Neutralisation plate; the fracture is reduced using adjunctive fixation devices such as lag screws, positional screws, cerclage wires or K wires. This reconstructs and stabilises the bone to some, but not all, biomechanical forces. The neutralisation plate neutralises the remaining forces to which the reconstructed bone is weak or relatively unstable. The plate and bone share the load (forces) of weight bearing. Common methods to compress the fracture would be (in decreasing order of preference):

- Reduce the fracture, compress using bone holding forceps, apply 1 to 3 positional screws perpendicular to the fracture. These are called "loaded" positional screws; this is relatively straightforward and safe to place.
- Reduce the fracture, stabilise using bone holding forceps, apply 1 to 3 lag screws perpendicular to the fracture. Lag screws are technically more difficulty and fiddly to place, as described above, and there is a higher risk of bone fracture or screw stripping.
- Reduce the fracture, stabilise and compress using 2 to 4 cerclage wires. Cerclage wire can be very difficult to get tight (double loop cerclage wire is best), stay tight, and placing it involves more dissection than screw placement resulting in more trauma and disruption of blood supply to the bone. This is the least advisable option.

Application of a neutralisation plate: Once the fracture is stabilised and compressed with one of the methods above, the neutralisation plate is applied:

1.

Select the correct size of plate – see Vi plate selection chart. (Appendix 2). The plate should be as long as possible.

2.

Contour the plate to the shape of the bone; consider pre-contouring to a similar sized bone model, or to radiographs of the contra-lateral bone.

3.

Apply all screws using the neutral end of the Load Neutral Drill Guide, or the Universal Drill Guide in neutral mode. Loaded (compression) screws must not be used.

4.

Place the screws at the ends of the bone. No screws should be placed over the fracture i.e. group 3 to 4 screws over the proximal and distal intact sections of the bone.

5.

Screws can be placed in any order; it is often helpful to work inwards from the proximal and distal ends of the bone.

Remember:

Any plate can be used as a neutralisation plate.

If a DCP or DLP is used as neutralisation plate, the screws must be placed in the neutral position using the appropriate end of the Load Neutral Drill Guide, or the Universal Drill Guide in neutral mode.

It is possible to place lag or loaded positional screws through a neutralisation plate, but this is technically challenging because several things must be achieved simultaneously:

- Reduction of the fracture using bone holding forceps.
- Compression of the fracture using bone holding forceps.
- Contouring of the plate to the bone.
- Application of the plate to the bone & held in correct position.
- Placement of the lag or loaded positional screws (without causing slippage of the bone or plate).

Bridging Plating for Comminuted/ Non-Reconstructable Fractures

Bridging plate; the fracture is not reconstructed; therefore the bone cannot take any load. This means that the plate must take all the forces of weight bearing. The bridging plate spans the fracture gap and is responsible for all load bearing during the healing period.

The bridging plate can be likened to a bridge that spans a river (Fig. 18); the plate is the bridge and is secured to the land (bone) either side of the river. The fracture is the river under the bridge. Compared to a normal road, a bridge must be reinforced to avoid collapse; the same principle is true of a bridging plate.

Fig. 18

A bridging plate can be reinforced by:

- **Combination with an intramedullary pin;** so-called plate-rod construct; this is very commonly done. Use of an intramedullary pin has the added advantage of distracting the fracture and holding it at the correct length and alignment whilst the plate is contoured and applied to the bone.

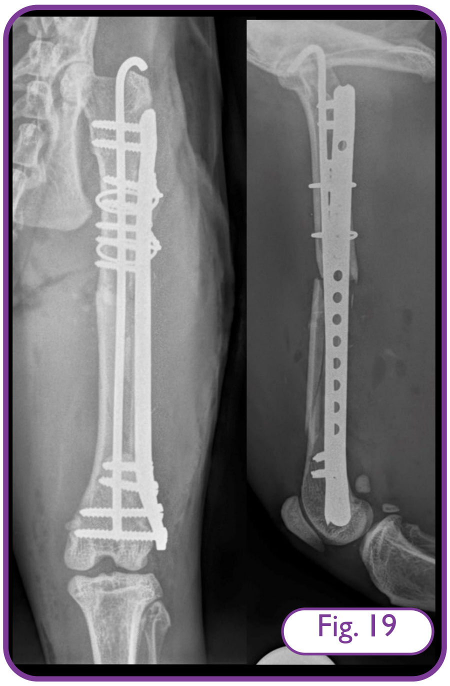


Fig. 19

Fig. 19 illustrates a bridging plate for a comminuted mid-diaphyseal femoral fracture. The bridging plate is combined with an intra-medullary pin; this is called a plate-rod construct.

- **Orthogonal plating** i.e. two plates at 90 degrees to each other e.g. a plate on the cranial **and** the medial aspect of the tibia or radius. This is less frequently done.

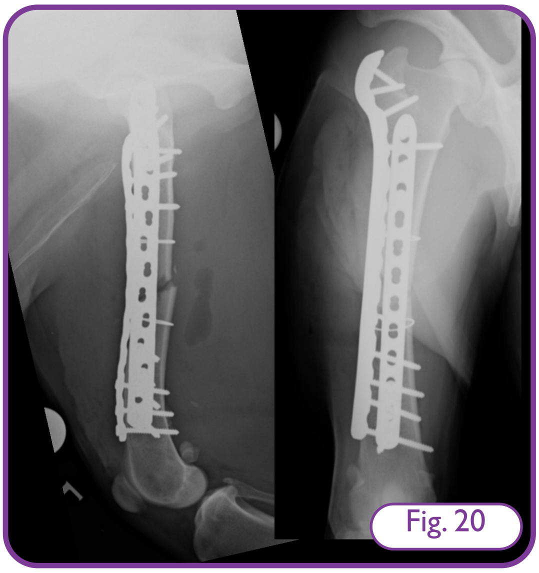


Fig. 20

Fig. 20 shows orthogonal (bridging) plating of a non-reconstructable femoral fracture.

- **Double plating** i.e. applying one plate each to adjacent bones; this is only possible for the radius and ulna.

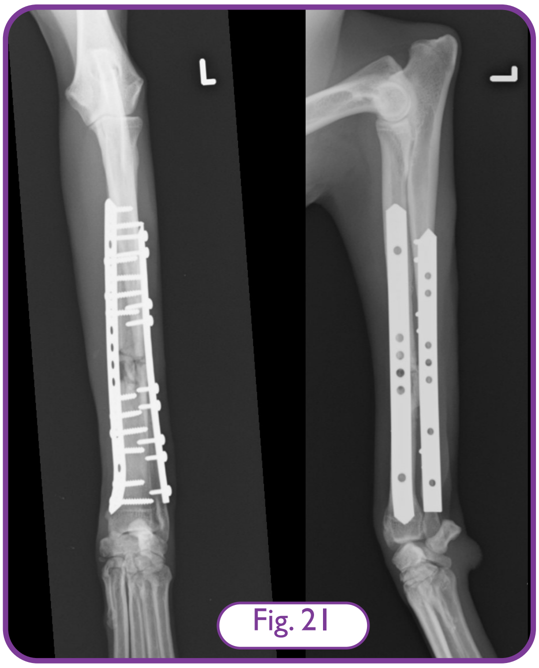
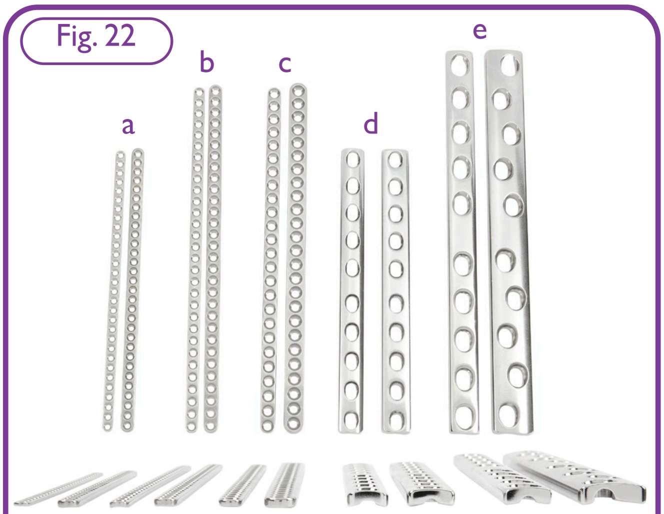


Fig. 21

Fig. 21 showing double (bridging) plate fixation of comminuted radius and ulnar fractures; a plate has been placed medially on the radius, and laterally on the ulna.

- **Increasing the size of the plate**; this is sometimes a practical alternative, particularly when broad versions of plates are available i.e. the plates are thicker and therefore stronger. Broad versions of 3.5mm DCPs, 4.5mm DCPs and cuttable plates are available. However, increasing the size of the plate can sometimes be impractical because the plate or screws become too large for the bone to which they are applied.

Fig. 22



a - 1.5mm cuttable plate (standard and broad)
b - 2.0mm cuttable plate (standard and broad)
c - 2.7mm cuttable plate (standard and broad)
d - 3.5mm DCP (standard and broad)
e - 4.5mm DCP (standard and broad)

Fig. 22 shows the difference in thickness between standard and broad plate versions.

- **Use of a "biological" or "lengthening" plate**; these plates are designed with no holes over the central section, hence are stronger in the middle. However, the weakest point then becomes the screw hole next to the mid-section of solid metal.

Fig. 23

Fig. 23 shows examples of Biological Healing Plates (on the left) and LokRod plates (on the right). NB. LokRod plates are only for use with locking screws but are included here for visual comparison.

Application of a Bridging Plate (Plate-Rod) Construct:

1.

Apply an intramedullary pin, ideally normograde. The pin will hold the fracture at the correct length and alignment. The diameter of pin should be chosen to fill about 30-40% the internal medullary canal at the mid diaphysis of the fractured bone.

2.

Select the correct size of plate– see Vi plate selection chart. (Appendix 2).

- As the plate is in bridging mode, if there is an overlap of suggested plate sizes, choose the bigger (stronger) size of plate, or consider "upsizing" the plate from the recommended size.
- The plate should be as long as possible = near equal to the length of the bone.

3.

Contour the plate to the shape of the bone; consider pre-contouring to a similar sized bone model, or to radiographs of the contra-lateral bone.

4.

Apply all screws using the neutral end of the Load Neutral Drill Guide, or the Universal Drill Guide in neutral mode.

5.

Place 3 to 4 screws in each of the proximal and distal segments of bone. Plate screws should not be placed in or close to the fracture. If in doubt, group the screws towards the most proximal and distal aspects of the bone.

6.

Screws can be placed in any order; it is often helpful to work inwards from the proximal and distal ends of the bone.

7.

Remember:

- Any plate can be used as a bridging plate.
- If a DCP or DLP is used as bridging plate, the screws must be placed in the neutral position using the appropriate end of the Load Neutral Drill Guide, or the Universal Drill Guide in neutral mode.

Decision making summary:

Transverse fracture; reduce and hold in perfect apposition using compression forceps. Apply a Dynamic Compression Plate using axial compression to compress the fracture. Primary (contact) bone healing is expected.

Oblique/spiral fracture; reduce and hold in perfect apposition using compression forceps. Apply loaded positional or lag screws to compress and stabilise the fracture. Then apply a neutralisation plate to neutralize the remaining forces. Primary (contact) bone healing is expected.

Comminuted/non reconstructable fracture: Bridge the fracture using a bridging construct:

- Plate rod: i.e. intramedullary pin & bridging plate.
- Orthogonal plates.
- External Skeletal Fixator +/- intramedullary pin.
- Interlocking nail.

Secondary bone healing (callus) is expected.

Plate Choices

Plate selection according to the Vi Implant Selection Chart (Appendix 2) assumes that the fracture is reconstructable. For non-reconstructable/comminuted fractures where the plate is being used in bridging mode, the plate selection needs to be 'upgraded' to account for the fact that the plate is carrying more load and is therefore more exposed to the chance of premature failure. Other 'upgrades' that can be considered include:

- Use of plate-rod technique.
- Double or orthogonal plating.
- Plate size upgrade i.e. using the next larger size of plate available e.g. 2.7mm to 3.5mm, or 3.5mm to 3.5mm broad.

Reconstruction & Malleable Plates

These plates have less metalwork in-between the screw holes so that they are more easily contoured.

- The advantage of this type of plate is that it can be easily contoured in all 3 dimensions. They are particularly useful for bone surfaces that are not flat or smooth and where substantial plate contouring is necessary e.g. fractures of the pelvis, acetabulum, distal humerus, distal femur or mandible.
- However, because there is less metal, the plates are weaker than equivalent plates e.g. DCPs. This must be taken into consideration when the plate is applied. Reconstruction and malleable plates are generally not suitable for diaphyseal fracture repair, as they are not strong enough.

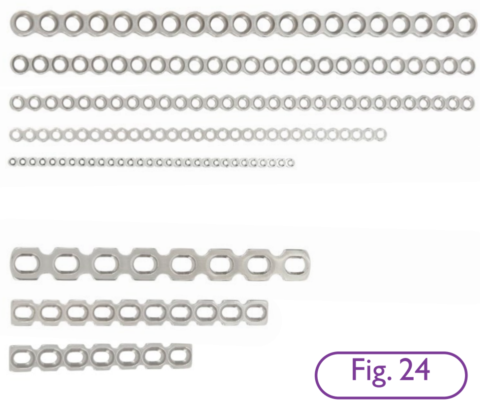


Fig. 24

Fig. 24 shows a selection of cuttable malleable plates (at the top x5) and reconstruction plates (at the bottom x3).

Veterinary Cuttable Plates (VCP) and Cuttable Plates

VCPs are supplied in a standard length of 300mm with 50 round holes. Vi's range of Cuttable Plates are between 120mm and 150mm in length and are available with a variety of hole spacings/configurations, including DCP holes. Cuttable plates can be very useful to repair small bones or bones for which there is no perfect length of DCP, for example some long bone fractures in cats, and metacarpal fractures in cats and dogs. Other advantages include:

- The plates can be cut to the required length using implant cutters; this removes the need to stock multiple plate lengths.
- All sizes are available from 1mm up to 3.5mm.
- Different plate thicknesses are available; the broad versions are thicker and therefore stronger.
- Cuttable plates are relatively weak, but the strength can be increased by 'stacking' the plates (placing one plate on top of the other).

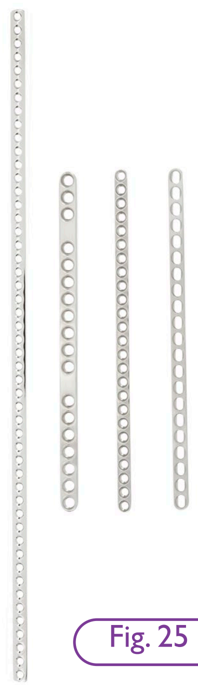


Fig. 25

Fig. 25 shows a VCP on the left. The three plates on the right are some of the range of cuttable plates, demonstrating differing sizes and hole configurations as described.

Anatomic Specific Plates

A range of specialised plates for specific purposes are available in a variety of shapes and sizes. Many of these specialised plates now incorporate locking technology.

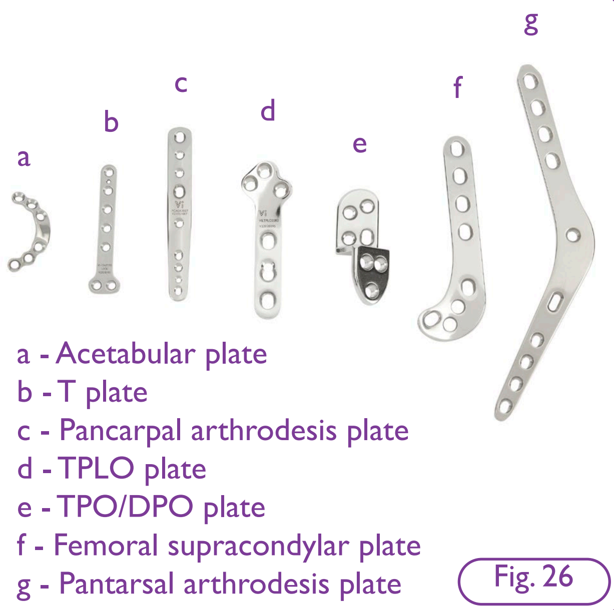


Fig. 26

Fig. 26 shows various anatomic-specific plates.

Other reading material:

- Surgery Guide - The Essentials of Fracture Management.
- Surgery Guide - Fixation of Long Bone (Diaphyseal) Fractures Using Locking Plates and Screws.
- Surgery Guide - Linear External Skeletal Fixation.

With thanks to Gareth Arthurs PGCertMedEd MA VetMB CertVR CertSAS DSAS(Orth) FHEA FRCVS RCVS Recognised Specialist in Small Animal Surgery (Orthopaedics) for his invaluable assistance with this Surgery Guide, new for 2023.

Appendix I

Appendix I shows the correct size of drill bits and taps for all common sizes of cortical and cancellous screws, for use as positional or lag screws.

Pilot and Clearance Drill Data for Cortical Self Tapping Screws

	Cortical Self Tapping (1.0mm)	Cortical Self Tapping (1.5mm)	Cortical Self Tapping (2.0mm)	Cortical Self Tapping (2.4mm)	Cortical Self Tapping (2.7mm)	Cortical Self Tapping (3.5mm)	Cortical Self Tapping (4.5mm)
Pilot Drill	0.7mm	1.1mm	1.5mm	1.8mm	2.0mm	2.5mm	3.2mm
Round Shank	N/A	H090100	H090101	H090208	H090102	H090112	H090105S
AO Quick Fit	10MDB07-A (Dental Fit)	S090100S	S090101S	S090208	S090102SS090102S	S090112S	S090105S
Clearance Drill	1.0mm	1.5mm	2.0mm	2.4mm	2.7mm	3.5mm	4.5mm
Round Shank	N/A	H090101	H090102	H090209	H090104	H090106S	H090108S
AO Quick Fit	10MDB10-A (Dental Fit)	S090101S	S090102S	S090209	S090104S	S090106S	S090108S

Pilot Drill, Clearance Drill and Tap Data for Cortical Non Self Tapping Screws

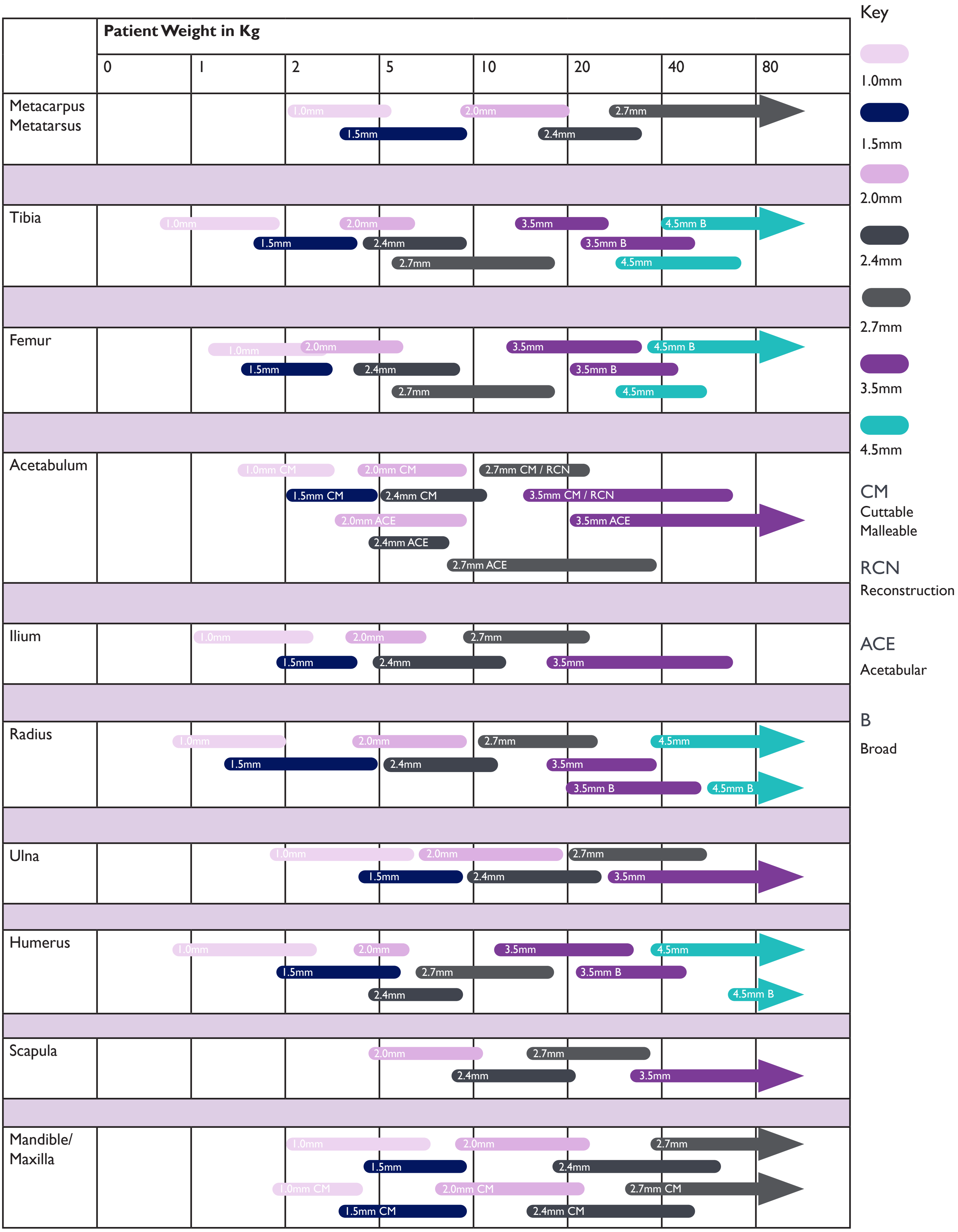
	Cortical Non Self Tapping (1.5mm)	Cortical Non Self Tapping (2.0mm)	Cortical Non Self Tapping (2.7mm)	Cortical Non Self Tapping (3.5mm)	Cortical Non Self Tapping (4.5mm)	Cortical Non Self Tapping (5.5mm)
Pilot Drill	1.1mm	1.5mm	2.0mm	2.5mm	3.2mm	4.0mm
Round Shank	H090100	H090101	H090102	H090112	H090205S	H090107
AO Quick Fit	S0901022S	S090101S	S090102S	S090112S	S090105S	S090107
Clearance Drill	1.5mm	2.0mm	2.7mm	3.5mm	4.5mm	5.5mm
Round Shank	H090101	H090102	H090104	H090106S	S090108S	H090109
AO Quick Fit	S090101S	S090102S	S090104S	S090106S	S090108S	S090109
Tap - AO Quick Fit	TD0015	TD0020	TS0027	TS12535	TS00045	TS00055
Tap - 'T' Bar	TBT015	TBT020	TBT027	TBT12535	N/A	N/A

Pilot Drill, Clearance Drill and Tap Data for Cancellous Screws

	Small Cancellous (2.2mm)	Small Cancellous (3.0mm)	Small Cancellous (3.5mm)	Cancellous (4.0mm)	Cancellous (6.5mm)
Pilot Drill	1.5mm	2.0mm	2.0mm	2.5mm	3.2mm
Round Shank	H090101	H090102	H090102	H090112	H090105S
AO Quick Fit	S090101S	S090102S	S090102S	S090112S	S090105S
Clearance Drill	2.0mm	3.0mm	3.5mm	4.0mm	6.5mm
Round Shank	H090102	H090205	H090106S	H090107	N/A
AO Quick Fit	S090102S	N/A	S090106S	S090107	N/A
Tap - AO Quick Fit	N/A	N/A	TS17535	TS17535	TS00065
Tap - 'T' Bar	N/A	N/A	TBT17535	TBT17535	TBT065

Appendix 2

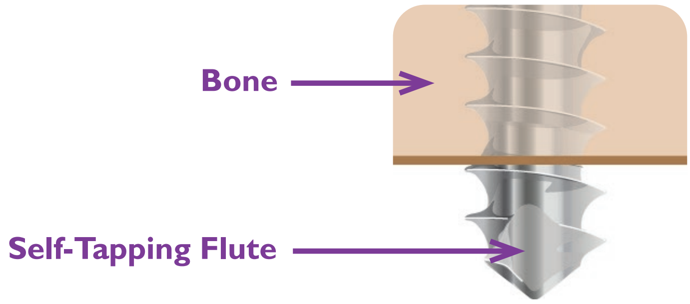
Appendix 2: The Vi implant selection chart is for guidance only. Precise implant selection depends on a number of factors which are to be considered when assessing the fracture healing score & the mechanical behaviour of implants. Unless otherwise stated, values apply to Vi compression, limited contact compression, ASYM®, round hole & biological healing plates. Scaled plate profiles are available in the catalogue or download the profiles from our website www.vetinst.com



Appendix 3

Depth Gauges are used to give a guide for selection of correct screw length required during orthopaedic surgery. A visual guide to how these are used in principle can be found by scanning the QR code below.

Screw length for bicortical screws should be selected such that there are full rings of thread engaged in both cortices of the bone. So self-tapping flutes should be clear of the bone, and the blunt tip of traditional non self-tapping screws should protrude far enough that the thread is fully engaged. This maximises pull-out resistance.



Vi-designed Depth Gauges measure the distance between the hook location on the trans cortex to the tip of the body of the Depth Gauge. So, if the scale measures 12mm, that is the length of probe which extends from the tip of the instrument.

When the correct Depth Gauge is used for any given size of cortical screw, with the matching non-locking plate size, the blunt end of the Depth Gauge is designed to sit into the plate hole so the probe emerges where the neck of the screw would be. If the Depth Gauge does not locate correctly, the measurement obtained will be affected. Depth Gauges in the table below are all designed for use with plates accepting cortical screws. **Locking holes may fractionally increase the measurements obtained, as the tip of the gauge may not sit down as far. This is due to the conical shape of the plate hole.**

Cortical screws and locking screws are measured complete end to end, including the screw head. Therefore, to select the correct length of screw for any given type/diameter of screw, the user will need to add the appropriate number of millimetres for the screw head and self-tapping flutes, to the length shown on the instrument scale.

Failure to do so will result in selection of screws which are too short, resulting in only monocortical engagement, therefore potentially reducing effectiveness and security of the final repair.

Table 1 below gives the recommended additional length required for each type of screw. If the Depth Gauge measurement plus the additional length results in a "between sizes" length, then round up to the next screw size.

NB. The 4.5 Depth Gauge is not a Vi designed instrument. When the probe is fully retracted, the scale reads 5mm. There is therefore no need to add an allowance for the screw head.

Table 1

		Cortical Self-Tapping			Standard Cortical			Locking (All Self-Tapping)		
Screw Diameter	**Depth Gauge Code**	Head Depth (mm)	Flute Length (mm)	**Length To Add To Depth Gauge Measurement**	Head Depth (mm)	Tip Length (mm)	**Length To Add To Depth Gauge Measurement**	Head Depth (mm)	Flute Length (mm)	**Length To Add To Depth Gauge Measurement**
1.5mm	DGP15	1.8	1.7	**3.5mm**	1.8	1	**3mm**	1.7	1.7	**3.5mm**
2.0mm	DGP2024 DG2027	2.2	2	**4mm**	2.2	1.2	**3.5mm**	1.3	1.2	**3mm**
2.4mm	DGP2024	1.8	3	**5mm**	1.8	2	**4mm**	2.6	3.5	**6mm**
2.7mm	DG2027 DGP2735	2.4	3	**5.5mm**	2.4	2	**4.5mm**	2.7	3.5	**6mm**
3.5mm	DGP2735 DG2735	2.8	4	**7mm**	2.8	2.5	**5mm**	3.2	4.5	**7.5mm**
4.5mm	*DG4565 (non-Vi design)*	*Scale includes 5mm for head*	*4mm*	***4mm***	*Scale includes 5mm for head*	*3.5mm*	***3mm***	*n/a*	*n/a*	*n/a*

Featured Products

Vi supply a full range of equipment for application of non-locking plates. The kits listed below represent the most clinically-current full plating kits available, but all components (plates, screws and associated equipment) are available to purchase separately.

Cortical Self Tapping Kits In MPB

CORTSTKIT1.5/2MPB	1.5mm/2.0mm Self Tapping Cortical Kit in MPB
CORTSTKIT1.5MPB	1.5mm Self Tapping Cortical Kit in MPB
CORTSTKIT2.0MPB	2.0mm Self Tapping Cortical Kit in MPB
CORTSTKIT24MPB	2.4mm Self Tapping Cortical Kit in MPB
CORTSTP152024MPB	1.5/2.0/2.4mm Self Tapping Cortical Kit in MPB
CORTSTP2735MPB	2.7/3.5mm Self Tapping Cortical Kit in MPB
CORTSTKIT4.5MPB	4.5mm Self Tapping Cortical Kit in MPB
CORTSTPKITSTAR152024MPB	1.5/2.0/2.4mm Self Tapping Cortical Kit in MPB
CORTSTPKITSTAR2.7/3.5MPB	2.7/3,5mm Self Tapping Cortical Kit in MPB .
CORTSXTP152024MPB	1.5/2.0/2.4mm Cortical Self Tapping Cruciate Head Kit in MPB

Cortical Self Tapping Kits In Premium Boxes

CORTSTP152024 1.5mm/2.0mm/2.4mm Cortical Self Tapping Kit in Premium Box
CORTSTP2735 2.7mm/3.5mm Cortical Self Tapping Kit in Premium Box

1.0mm Plating Kit

CORTSTP10 1.0mm Plating Set in Premium Box

Please contact a member of the Vi team for a list of the contents of these kits.

Vi

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