eLearning modules for the AO Principles Courses

Plate Fixation

AOUK | Prepared by Professor Christopher L Colton, England

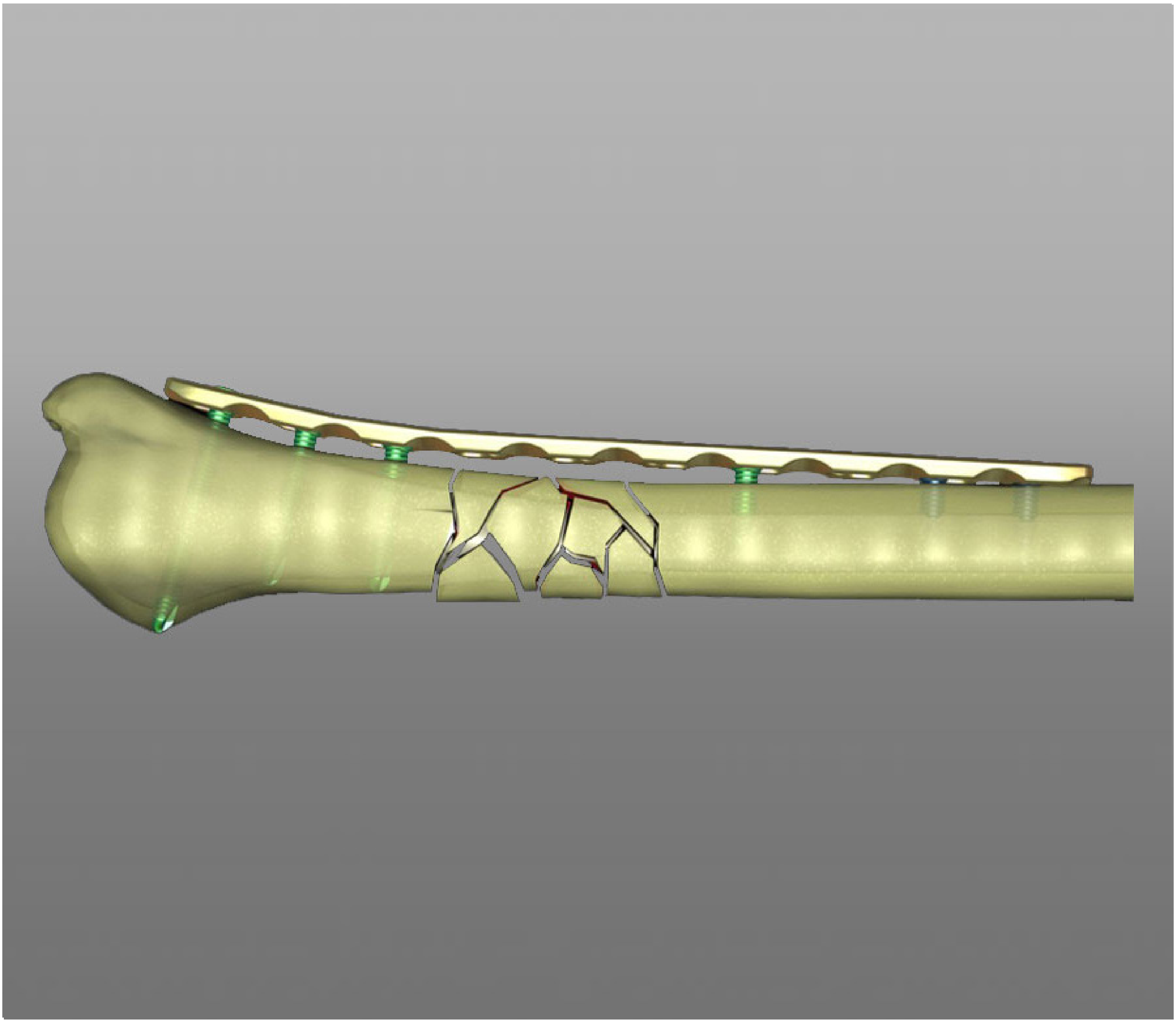
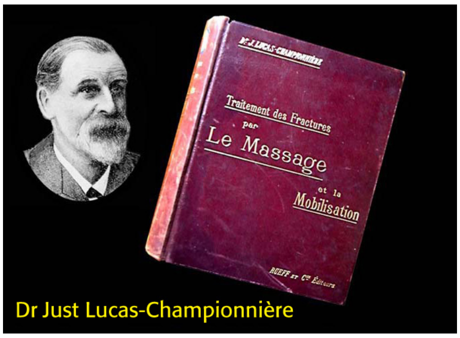


Plate fixation Introduction

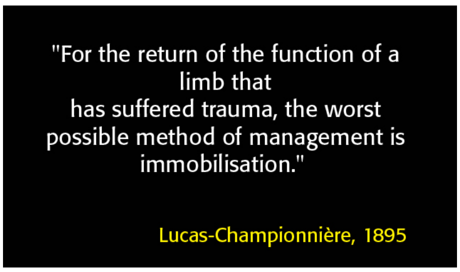
Fixation of fractures by the application of plates to the surface of the bone is one of the longest established techniques of osteosynthesis.
This study guide will discuss the influence of plating on patterns of bone healing, the impact of the implant on the biology of the fracture locus, and how this has influenced plate design and development.
The inter-relationship between the bone and the implants is considered and different plating techniques will be linked to varying fracture patterns.
Current concepts of minimally invasive plating will also be discussed.

Bone is genetically programmed to heal after fracture. No treatment is necessary.
Callus is the natural response of living bone to interfragmentary movement.

Rib fractures, which cannot be immobilised, invariably unite.



Lucas-Championnière published a book in 1895, entitled “Treatment of Fractures by Massage and Mobilisation…



….in which he advocated movement of the injured limb rather than immobilisation, stating “For the return of function of a limb that has suffered trauma, the worst possible method of management is immobilisation.”
He was not popular with his contemporary traditionalists, such as Seutin, who advocated prolonged and uninterrupted splinting.
However, he influenced many, including George Perkins of London (see later).

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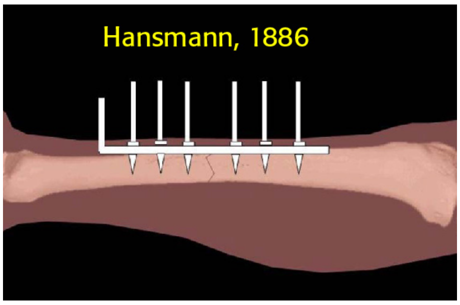
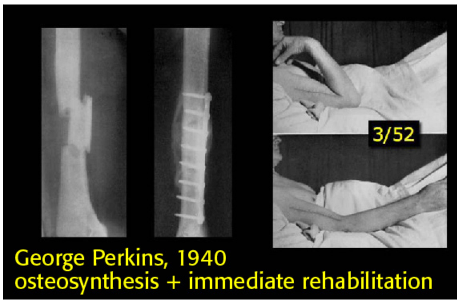
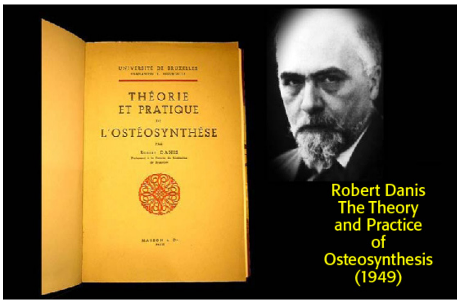
The first plates reported (in 1886) were used by Hansmann of Germany and were made of so-called German silver – an alloy of nickel, copper and tin.



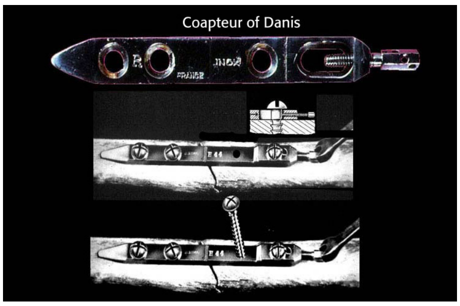
Hansmann's plates were bent up at the end to protrude through the skin, and were attached to bone by screws with long shanks that also projected outside the soft tissues.
His infection rate is not known!



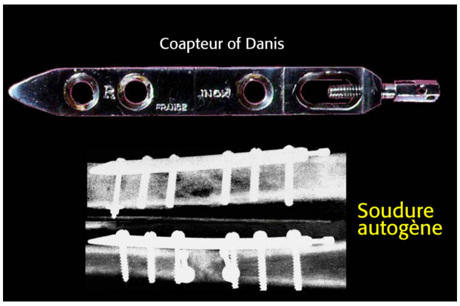
George Perkins, of London, was profoundly influenced by Lucas-Championnière, and did much to popularise early movement, with non-surgical treatment of fractures. His split-bed, simple traction for femoral fractures, with early knee motion, is a classical example of his approach.
Perkins saw the benefit of internal fixation, not solely in terms of bone morphology, but as a means of securing early mobilisation, as well as restoring anatomy.
Here, a humeral fracture, plated by Perkins in 1940, has an excellent range of elbow movement a mere 3 weeks after surgery.



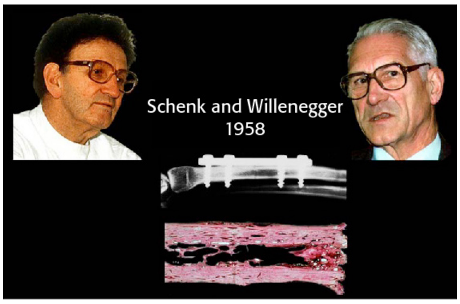
In 1949, a Belgian surgeon, Robert Danis, published a book on osteosynthesis (a term coined in 1907 by Albin Lambotte, also of Belgium).
His thesis was that the fracture should be fixed rigidly in order to permit early functional rehabilitation – sharing the same philosophy with Perkins.



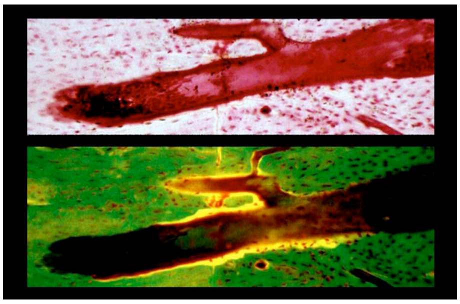
To serve this goal, Danis devised his "coapteur".
This was a plate device that permitted compression to be applied across the fracture plane, greatly increasing the rigidity of the fixation. Using this technique, the fractures rapidly became pain-free and early range of motion exercises became possible.



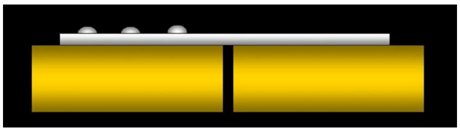
Danis observed that, when a fracture was reduced anatomically and compressed with his coapteur to provide rigid fixation, the bone often healed without external callus formation, as illustrated here.
This he termed "soudure autogène", or welding.



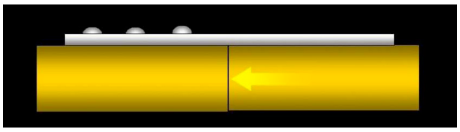
This phenomenon of "direct bone healing" was investigated by the young AO group in Switzerland in the late 1950s. The work of Schenk and Willenegger on compression plating of canine radial shaft osteotomies is now classical.
They were able reliably to produce direct bone healing by anatomical reduction and rigid fixation.



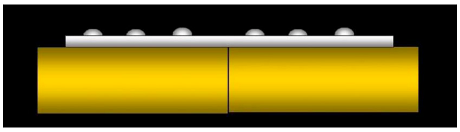
Their experimental work showed elegantly how the bone, with motion abolished at the "fracture", produced a response of augmented osteonal remodelling, as it were skipping the intermediate phase of callus formation to stop interfragmentary movement



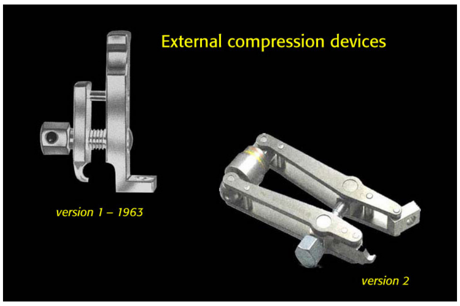
The simplest compression plating is illustrated by a uniplanar, transverse fracture.
The plate is first fixed to one main fragment….



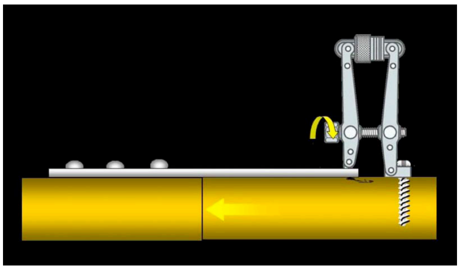
…the fragments are then compressed by a mechanical device.



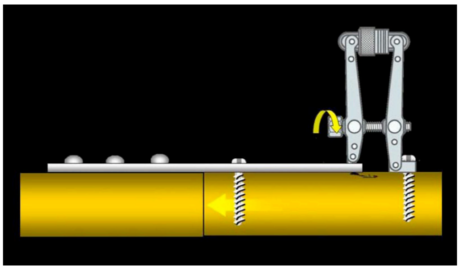
Following this, with the compression maintained, the plate is fixed to the other main fragment.



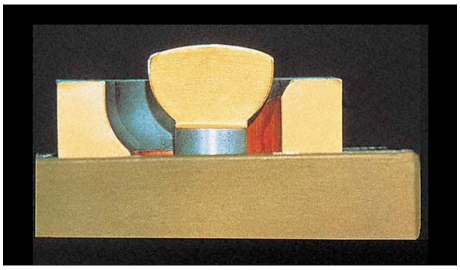
The first AO compression device was external to the plate…



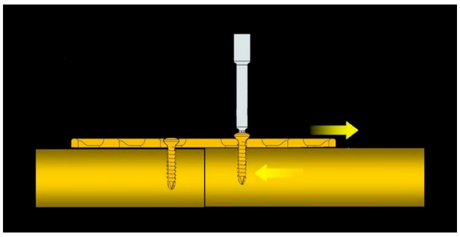
…and was applied as illustrated, with its hook engaging the end hole of the plate and its ”eye” being screw into the cortex at a set distance from the plate (using a small jig).
Turning the nut of the external compression device then compressed the fracture site.



With the device in situ, the remaining screws were inserted, then the device removed.
It extended the surgical approach in order to mount the device, and also left a hole where the anchoring screw had been inserted, then removed.



The next development, in the 1960s was the Dynamic Compression Plate. This had a hole configuration with a sloping surface on the side of the screw hole distant from the fracture.
The principle here was that an eccentrically placed screw would shift the plate in relation to the bone, as the head travelled down the slope, and this was exploited to compress the fracture site.



In this illustration, it can be seen that, as the right hand screw (the load screw) is driven home, its head will cause the plate to move to the right in relation to the right hand bony fragment, thereby applying compression at the fracture plane.
The remaining screws would then be inserted in a neutral position in the screw holes of the plate, not eccentrically, as the load screw was placed. Special drill guides permitted the drilling of either neutral or load holes.

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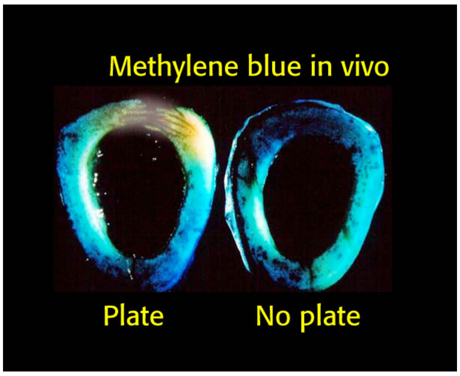
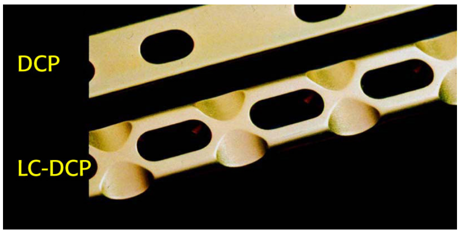
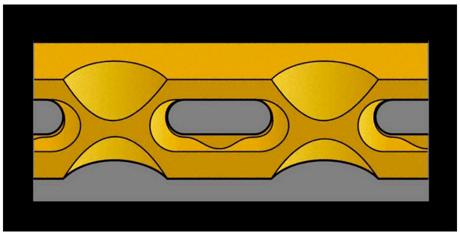


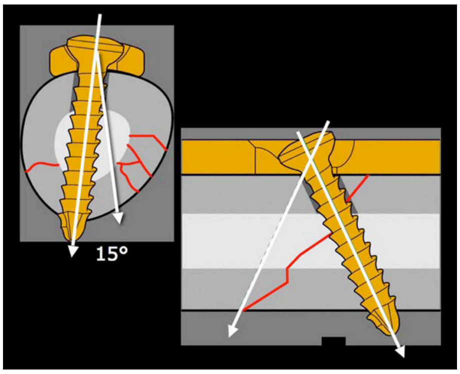
With traditional plate designs and fixation techniques, the bone paid a high biological price. These specimens are of animal long bones, one plated in vivo, and the other pristine. The animals were then given IV methylene blue immediately prior to sacrifice.
Beneath the plate is an avascular area. Such bone dies and, in the absence of infection, will be intensely remodelled by creeping substitution. This will delay the healing deep to the plate; if infection occurs, then a sequestrum may form, separating this dead bone and perpetuating the osteitis.



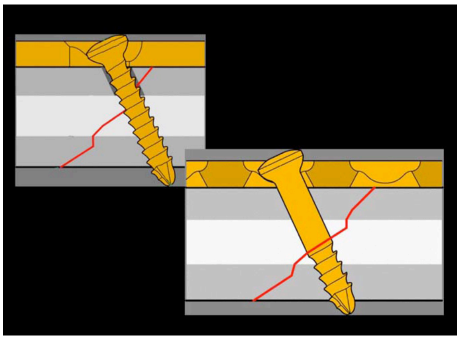
In order to minimise this biological impact of the plate, the Low Contact dynamic compression plate (DCP) was designed. This not only reduced the “footprint” of the plate on the bone, but the sculpturing of the under surface of the plate achieved the same amount of metal at any transverse section of the plate, whether at, or between, the screw holes. This allowed perfect contouring of the plate to the bone, without preferential bending at the screw holes.



Furthermore, this even distribution of strength of the locking compression dynamic compression plate (LC-DCP) meant that the holes do not act as stress concentration points, and reduced the likelihood of plate fatigue at an empty screw hole.
Note that the under surfaces of the screw holes are undercut at an angle….



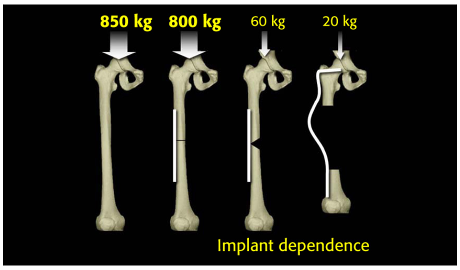
…which permits a greater freedom of angulation of the screws, both longitudinally and transversely.



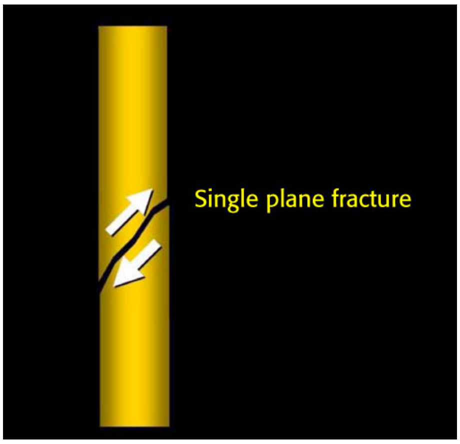
The use of a lag screw through a plate is a standard technique for producing absolute stability. With the introduction of the greater potential for angulation of such lag screws, used in combination with the LCDCP, it became advisable to use cortical screws with a smooth portion to the shaft – so-called “shaft screws”, rather than the standard fully threaded cortical screws..

Bone-implant composite

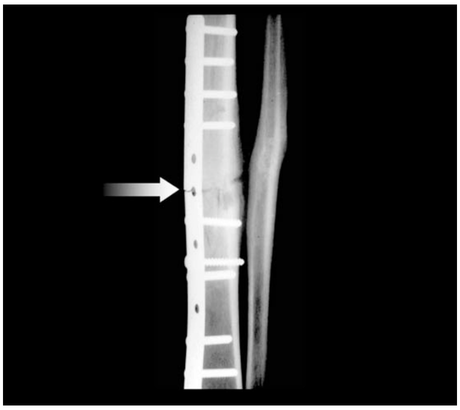
A particularly important consideration in internal fixation, and especially plating, is the interdependence of the bone and the implant in contributing to stability – the bone-implant composite.



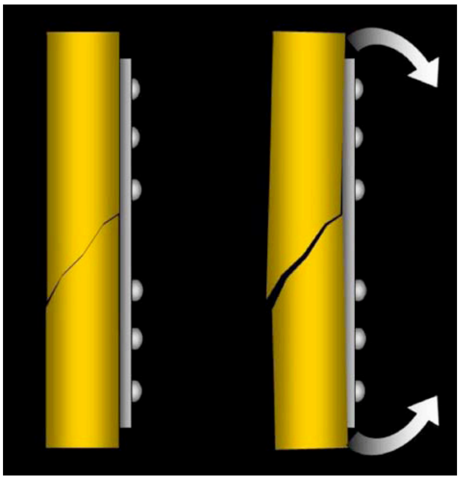
An intact femur will support an axial load of the order of 850 kg.
A transverse fracture of the mid-shaft, with a plate on the lateral, tension, cortex, will withstand up to about 800 kg.
A similar fixation, but with a gap in the medial (compression) cortex will fail under a load of about 60 kg. and a plated gap in the shaft – a totally implant dependent fixation, will buckle under a 20kg load.



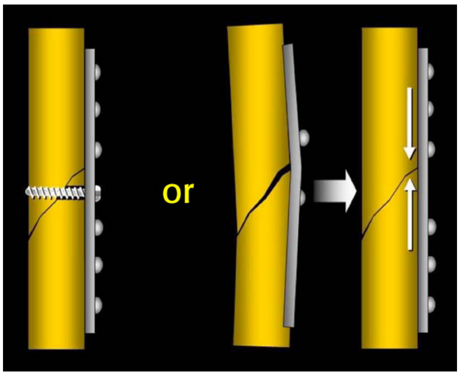
Where there is a single plane fracture, any interfragmentary movement, and similarly any strain on the healing tissues will be concentrated at that plane.



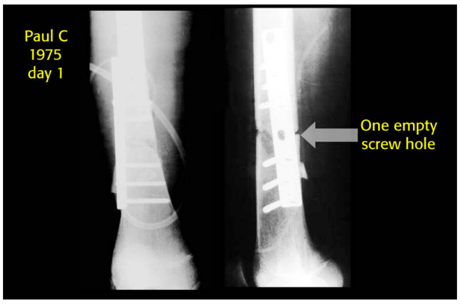
A fixation such as illustrated, with an empty screw hole directly level with a single fracture plane resulted in early fatigue failure of the implant, due to movement and stress concentration at that weak point in the plate.



If a single plane fracture is merely splinted with a plate, even with interfragmentary compression, the fracture gap will open up at the cortex opposite the plate, due to the elasticity of the plate, as illustrated.

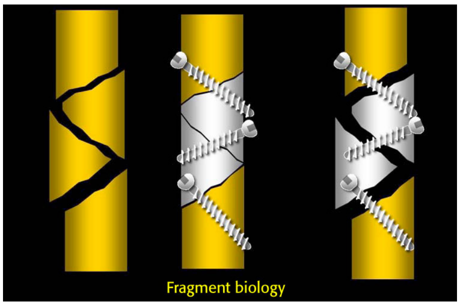


This instability can be avoided by inserting a lag screw through the plate and across the fracture plane; or the plate can be pre-stressed by over bending it slightly, so that when compression is applied, there is also good compression in the cortex opposite the plate: the tendency of the plate to try to return to its original slightly over bent shape will resist opening of the opposite cortex.

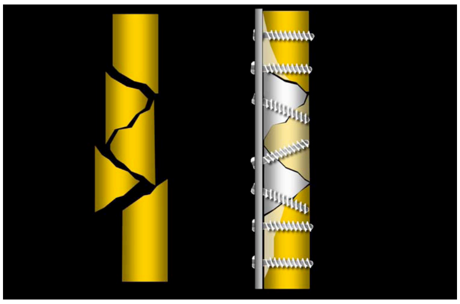


This is an old example of femoral plating, using a DCP. The surgeon could not insert a screw into the plate hole directly opposite the fracture plane. He recognised that this concentrated the forces at the plate hole and risked fatigue failure…

…he therefor inserted a bone graft medially with the intention that this would incorporate and "protect" the plate before it reached that stage in its fatigue life that threatened breakage.
This may not be the most elegant fixation in modern terms, but it illustrates an important principle that if a plating is known to be a compromise, then strategies need to be implemented to avoid complications.

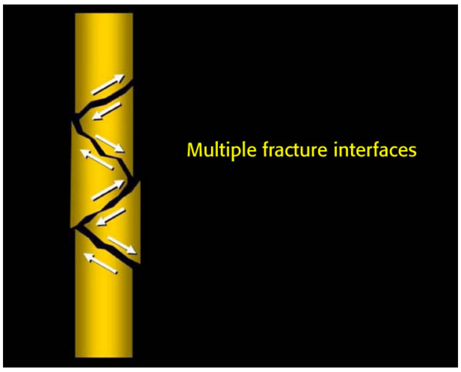


In a multiplanar fracture complex, the use of techniques to achieve absolute, rigid stability, can jeopardise the fragment biology and result in failure of healing and, therefore, of the fixation. The biology of the fracture site must never be sacrificed in order pusue a mechanical goal.

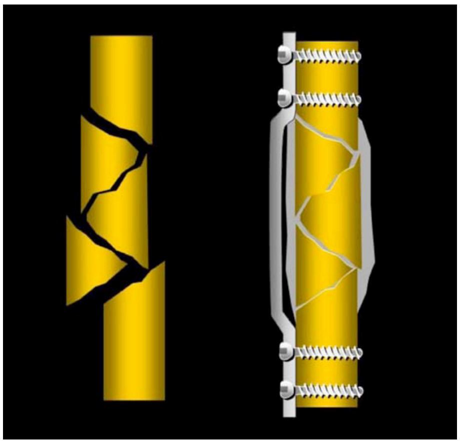


Similarly, the injudicious application of a plate over the top of wedge fragments may also damage their vascularity and similarly impair healing.

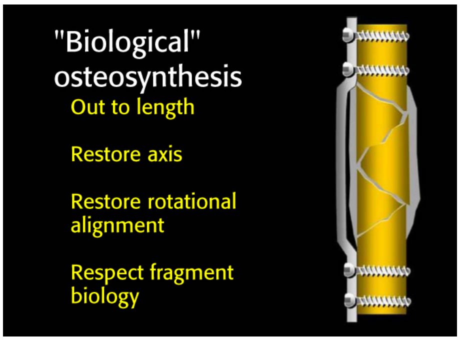
To avoid such complications of the quest for absolute stability, the concept of relative stability developed.



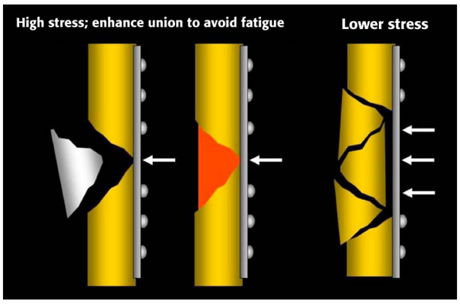
In a multifragmentary fracture complex, any minor residual instability will result in the motion being evenly distributed between the fracture planes, and at each one is likely to be of relatively low amplitude.



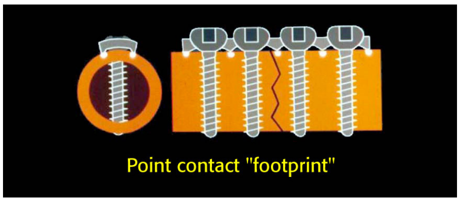
In such a multifragmentary fracture, if the comminuted zone is bridged by a plate in such a manner that the main diaphyseal fragments are aligned, correctly matched for rotation and out to length, the undisturbed intermediate fragments will heal rapidly by the formation of external callus in response to the small amplitudes of interfragmentary motion. If there is any concern about the biology, the addition of a bone graft will ensure rapid bony healing.



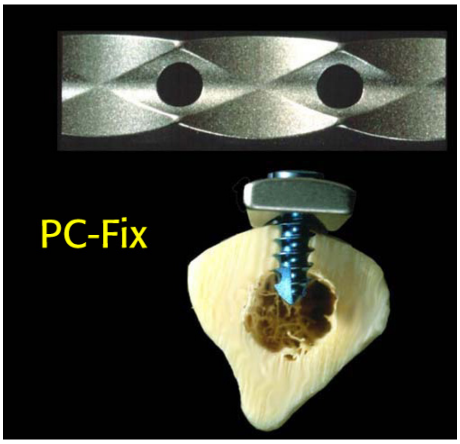
This has been given the nick-name "Bio-logical osteosynthesis.



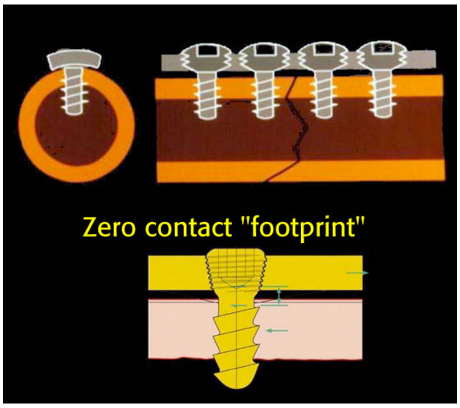
Some fractures have a missing bone wedge, either due to there being no soft tissue attachments, its being too small to incorporate, or even having been extruded in open injury.
Such a single plane fracture can result in a totally implant dependent fixation with a high risk of plate fatigue.
The solution is to insert a bone graft to enhance the rate of healing.
On the other hand, a plate bridging a multifragmentary zone, leaving several empty screw-holes, will be less likely to fatigue as the stresses are distributed evenly throughout all the holes, and therefore each hole is subjected to less stress.



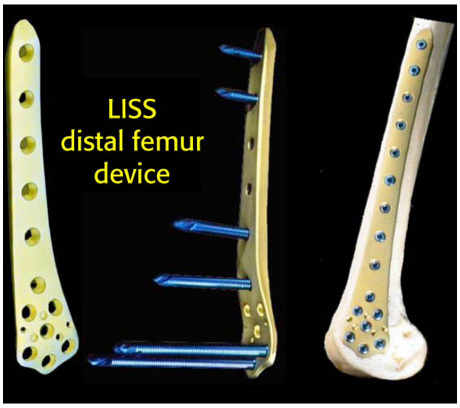
Considerations for the biology of the bone deep to the plate led to the concept of a point contact device…



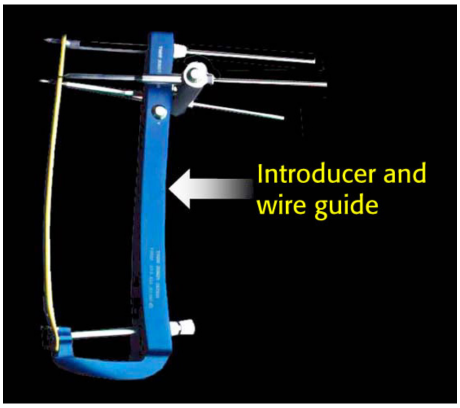
… and in the 1990s led to the development of the point contact fixator (PC-Fix), illustrated here. One of the features of this development was the locking of the screw head in the plate hole, by threading the screw head, and fixing only into one cortex. This revolutionary concept will be explored later as it has been refined with further evolution of plating (LISS, LCP).



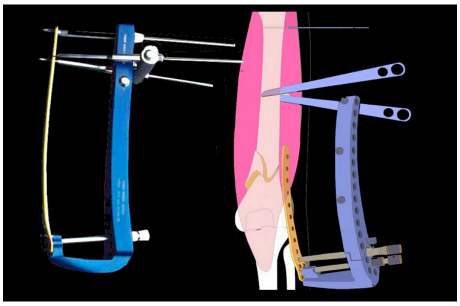
The next logical development was the use of plates which did not "sit" on the bone, but which had a zero contact footprint, i.e. no footprint.
A dedicated plate, suitably contoured for the anatomical site is held "hovering" over the cortical surface by screws which lock into the plate as well as engaging the underlying bone. This way the screw and the plate become a single, fixed angle, mechanical unit.



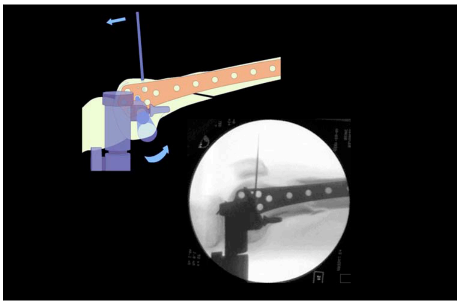
The LISS system comprises anatomically preshaped plates (they don't need exactly to conform to the bone as they hover over it), and a series of self-tapping (or self-drilling) screws with threaded heads.
The technique of insertion will be briefly considered.



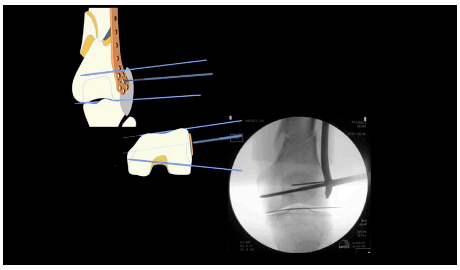
The plate is attached to a combined insertor/jig



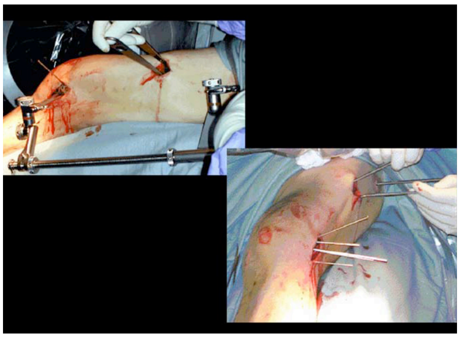
Through a small incision and using this jig, the plate is slid along the bone surface, after approximate fracture reduction, often using a distractor device. The diaphysis is minimally exposed above in order to guide the plate.



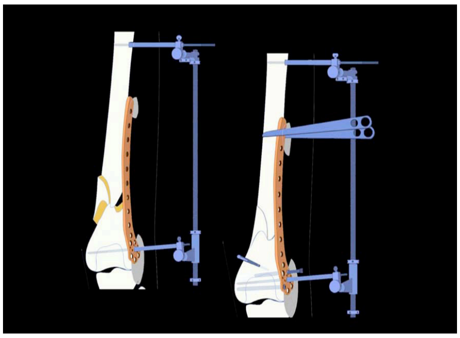
The position is checked radiographically.
In this example, a sagittal wire has been inserted as a "joystick" to tilt the distal femoral fragment into better alignment



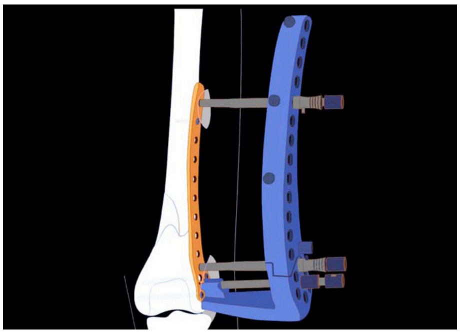
Wires are then inserted into the metaphyseal zone and checked radiologically before the insertion of any metaphyseal screws.



The minimal skin incisions are shown at this stage.

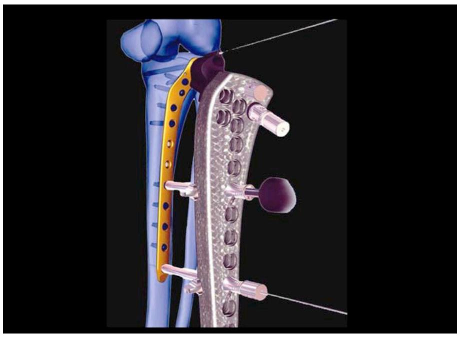


The reduction is then refined.

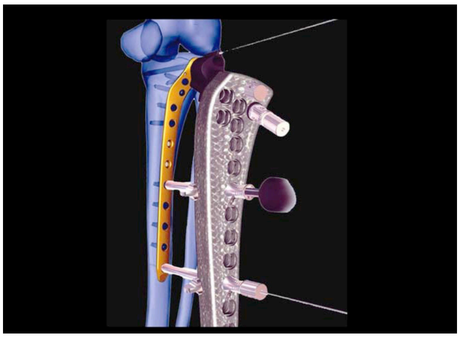


The drill guides are passed through the jig…and the screws inserted, locking them home into the plate holes.
The screws and the plate then provide good angular stability…..

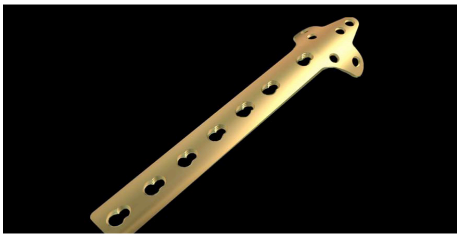
…with reduced surgical invasion.



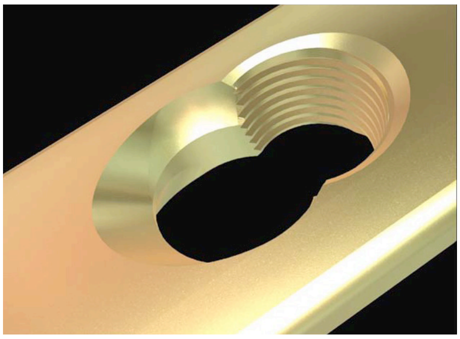
Similar systems have been designed for other anatomical sites, such as the proximal tibia.



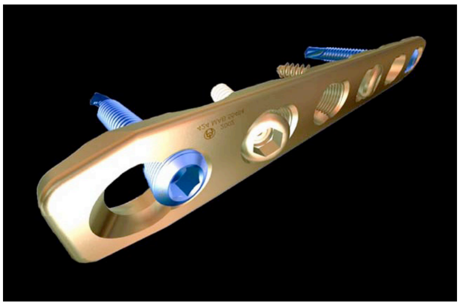
The Locking Compression Plate – LCP.



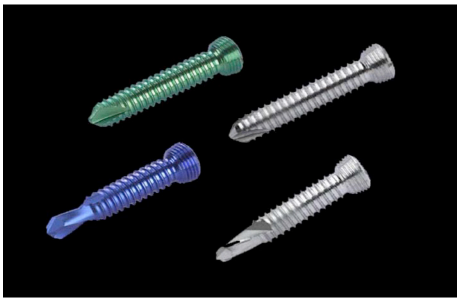
The LCP is now available and combines the advantages of the DCP principle with the locking screw head principle, giving the surgeon great flexibility of choice within a single implant.
The plates come in most of the standard formats, and some dedicated ones.
The screw holes in the plate have been specially designed…



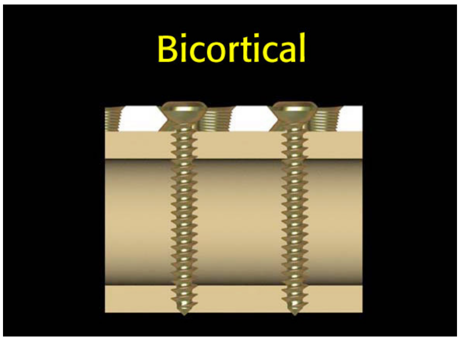
…to accept either a standard cortical screw with a hemispherical head, or a locking screw with a threaded head.
The locking compression plate (LCP) was approved as the new AO Plate standard by the AOTK in December 2000.



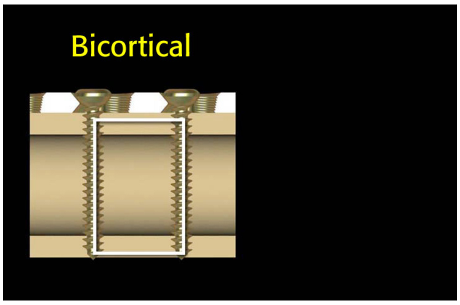
There are 3 screw categories that can be used in combination with the LCP. The standard fully threaded cortical and cancellous screws are used for fracture reduction and compression as in the DCP or LCDCP, and the standard partially threaded or shaft cortical screws are used as lag screws. Self tapping or self drilling, self tapping locking head screws are used as plate screws.



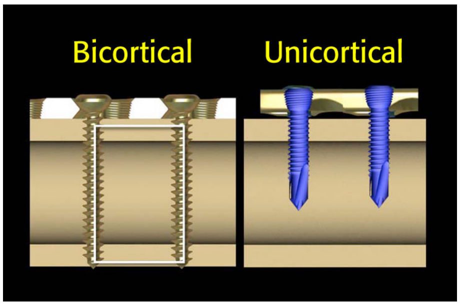
Two types of locking screws are available.
The self-tapping screws are used in metaphyseal areas and inserted after pre-drilling and length measurement. The self-drilling, self-tapping, locking screws are used mostly in the diaphysis and are placed unicortically.



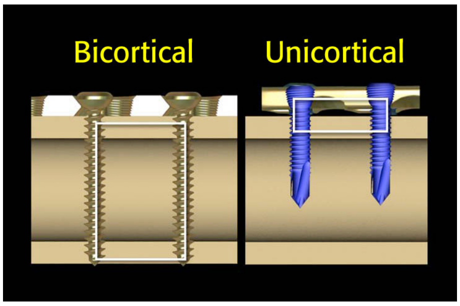
The traditional plating techniques produced stability by compressing the plate to the bone surface and engaging both cortices…



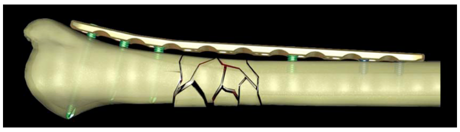
…thereby producing a rectangular hoop with 2 screws.



The locking screws, by achieving angular stability within the plate holes …

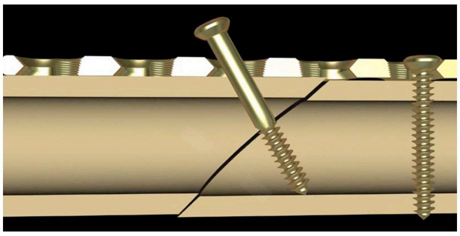


…are able to produce a similar hoop with just 2 unicortical screws.

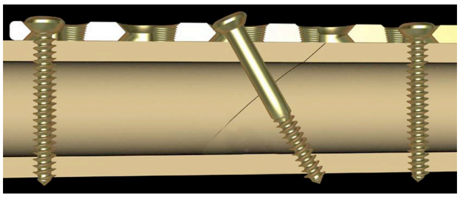


Here is an illustration of the LCP use as an “internal fixator” to bridge a multifragmentary diaphyseal fracture zone.

In this example an LCP is used with standard cortical and cancellous screws as a traditional plate.

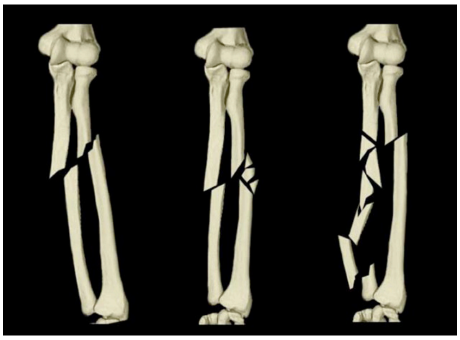


In single plane fractures, the insertion of a shaft cortical screw as a lag screw, through the plate, is possible with the LCP



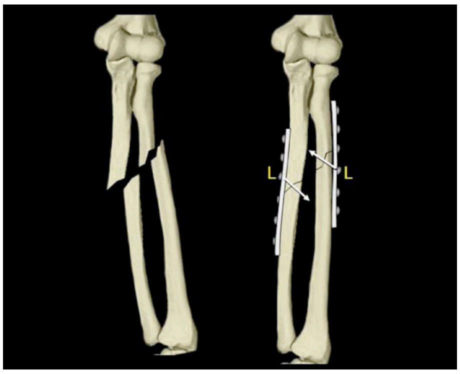
…followed by (slide 67) fixation of the other shaft fragment to the plate in the traditional DCP/LCDCP manner

Options

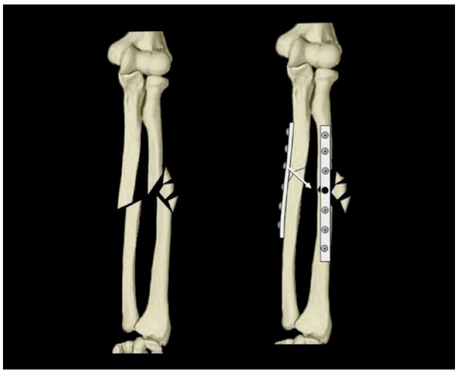


Let us now, as a conclusion, look at several fracture pattern combinations in the forearm, where the restoration of anatomical morphology is of paramount importance in preserving pronation and supination.

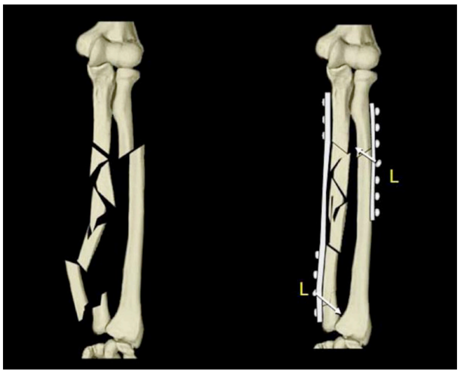
We should consider how each of these 3 theoretical combinations should be plated, using the principles outlined in this guide.



In this example, both the radius and the ulna have single plane fractures. These will require plating in an anatomical position, producing absolute stability, by using lag screws through the compression plates.



In this example, the ulna has a single-plane fracture, but the radial fracture has a multifragmentary wedge that cannot be incorporated into the bone-implant composite.
The ulna will be fixed using absolute stability produced by a lag screw through the compression plate. By contrast, the radial plating will need to be enhanced by bone grafting in order to avoid stress concentration at the empty screw hole.



In this third scenario, the radial fracture remains the same, but the ulnar fracture is multifragmentary and is largely bridged, producing relative stability. In order to gain a good hold distally, the lower fracture plane, just proximal to the inferior radio-ulnar joint, is treated as a single plane fracture and fixed with a lag screw through the plate.

Summary

We hope that this guide has:
served to give you a historical background to plating, helped to give you a flavour for the reasons behind the evolution of plate design and techniques, as well as giving you an understanding of the concepts of minimally invasive plating using the LISS and the LCP.

Enjoy your course.