

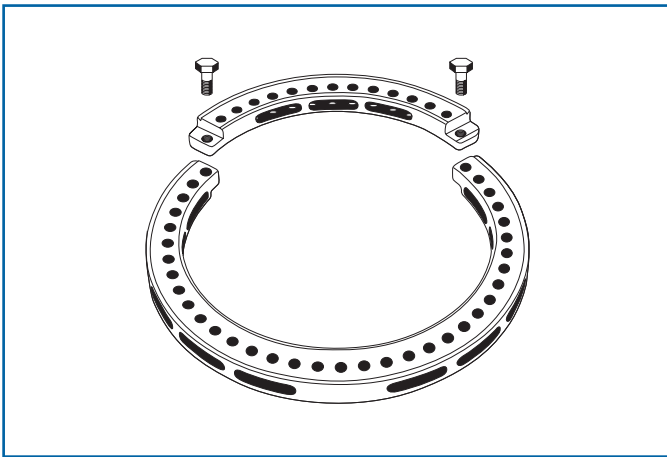


The Ring Fixation System

Part B: The Sheffield Ring Fixator - Standard Trauma Applications

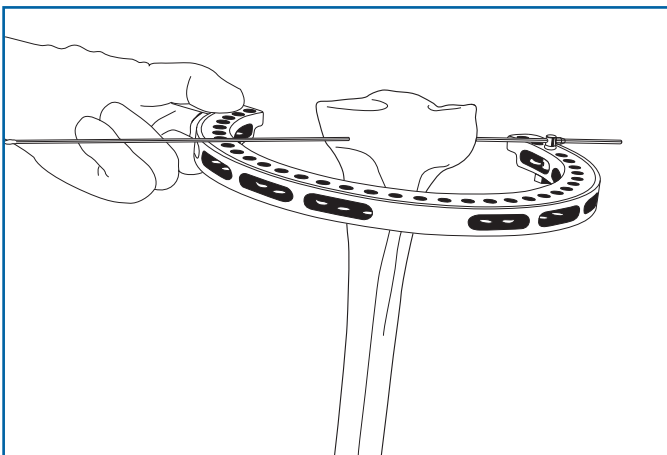
By Prof. M. Saleh

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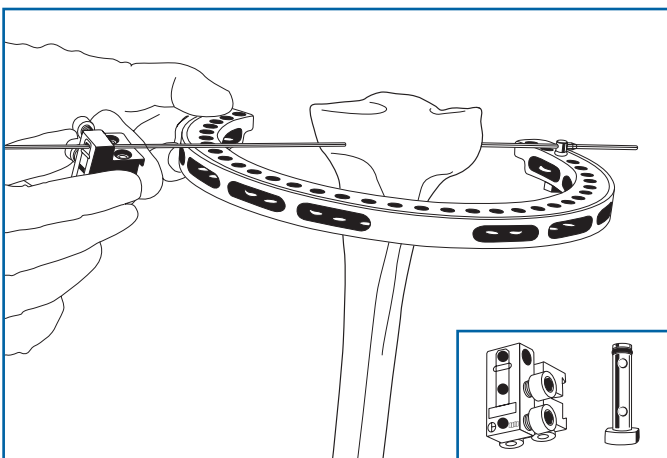
Kirschner wire insertion

Choose appropriate ring.
Full circumference rings may be made by joining 1/3 and 2/3 rings together with locking screws.



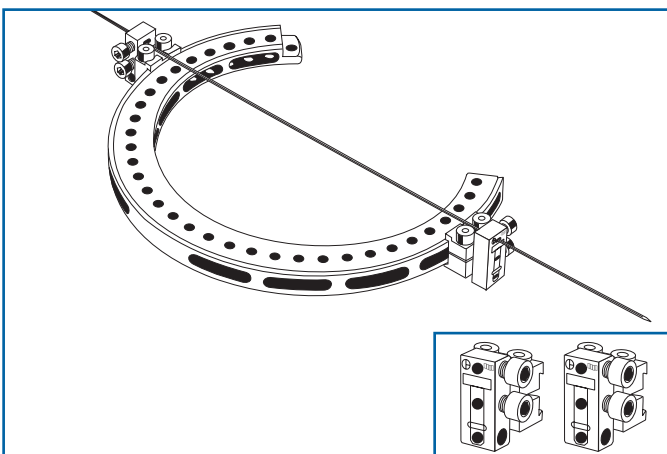
Reference anatomically safe corridors on cross-section of limb. Insert wire closest to the joint first. Insert a two-hole securing pin into appropriate hole in ring. Introduce tip of K-wire with lateral olive through the two-hole securing pin. Push wire through soft tissues and drill through bone, while assistant maintains ring at 90 degrees to bone axis with limb centered within it. Avoid joint capsule. When wire has exited far cortex, stop drilling and ensure wire is parallel to ring and joint line. Continue to advance wire by tapping it with mallet, until lateral olive is against securing pin.

NB: Wire may be drilled above, below or through the ring, for best position relative to fracture and joint capsule.

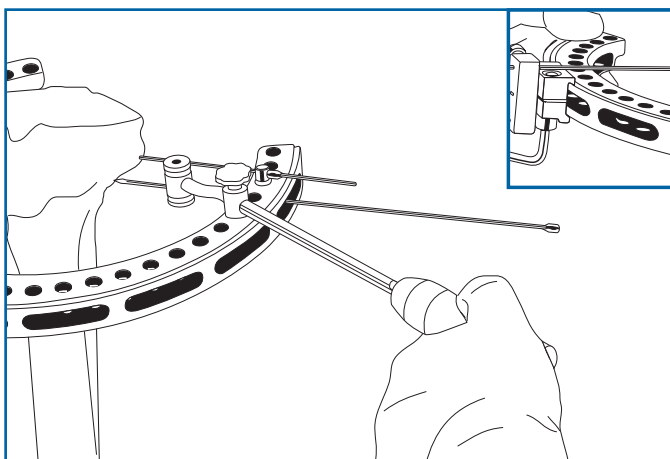


Loosen all screws of three-hole wire clamp slider unit. Orient clamp in same direction as securing pin. Introduce wire into appropriate hole in slider unit.

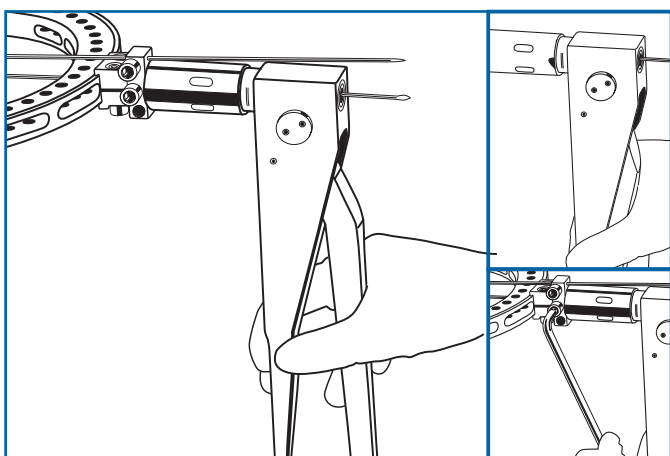
NB: First wire may be inserted free-hand. Use a K-wire without olive and attach it to ring using a three-hole wire clamp slider unit at each end.



Tighten both slider units to ring, then tighten wire clamp screw on one end of wire.

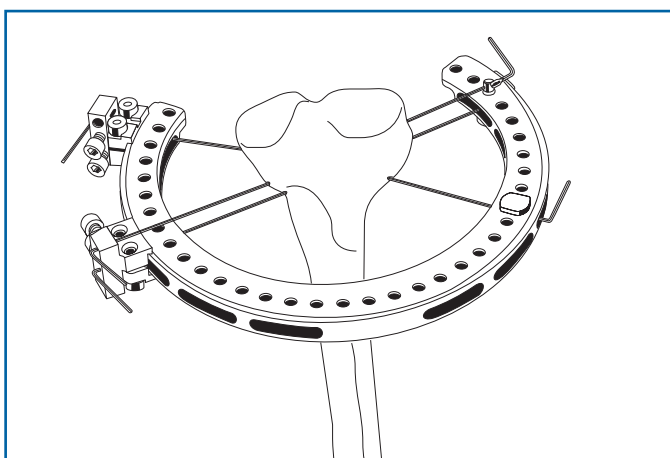


Insert parallel wire next through second hole in securing pin, using wire guide. Disconnect the slider unit temporarily from the ring and then insert it over both wires. Tighten slider unit on to ring fully, using 3 mm Allen wrench. Position limb in center of ring.

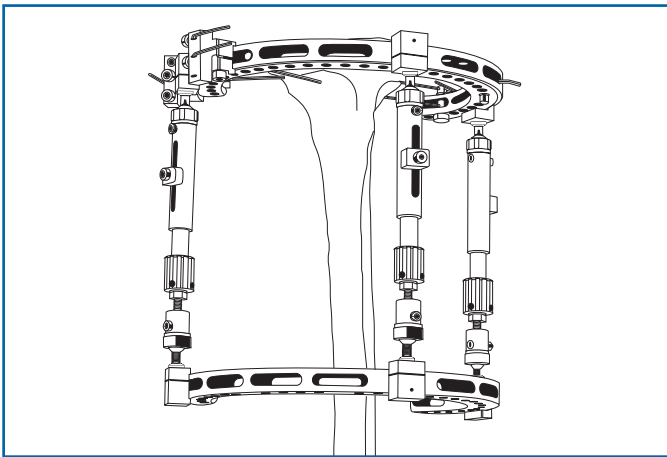


To tension wires, open handle of wire tensioning device to fullest extent. Fully insert wire through the device sliding it up against face of slider unit. Tension wire to minimum of 1200 N, in two stages if necessary. Tighten wire clamp screws with 5 mm Allen wrench. Cut and/or bend wire and apply wire cover.

NB: Where K-wires without olive have been used in conjunction with three-hole wire clamp slider units at each end, apply tensioning device to end of wire which has not yet been tightened in its slider unit and tension as above.

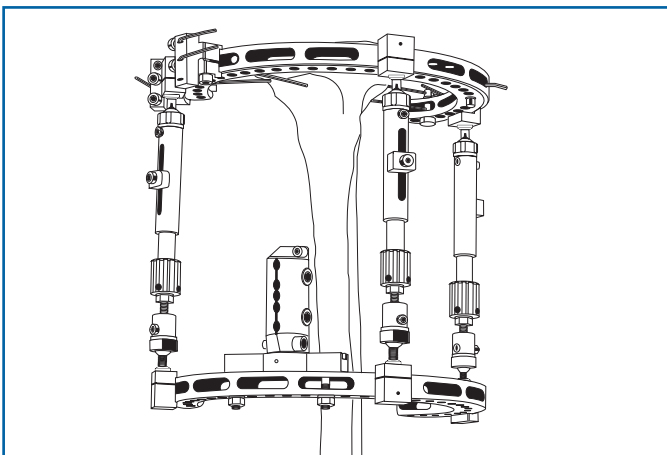


Insert crossing wires at widest angle neurovascular structures will permit (usually between 50°-70°). For optimal ring stability wires should cross in the center of the tibia. Insert the securing pin into the ring, upside-down relative to the first securing pin to prevent wires from intersecting in bone.

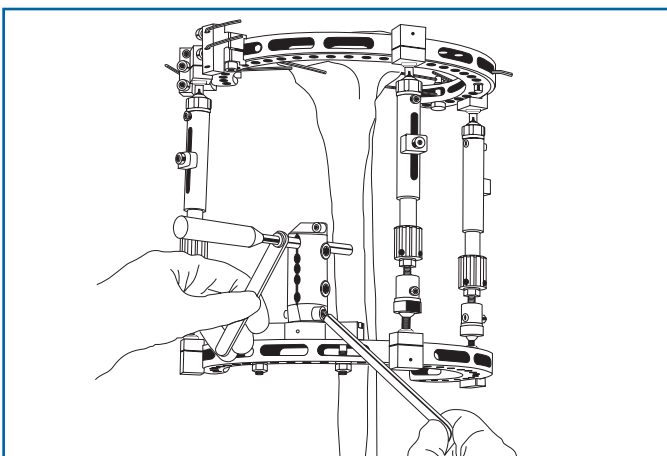


Diaphyseal screw insertion

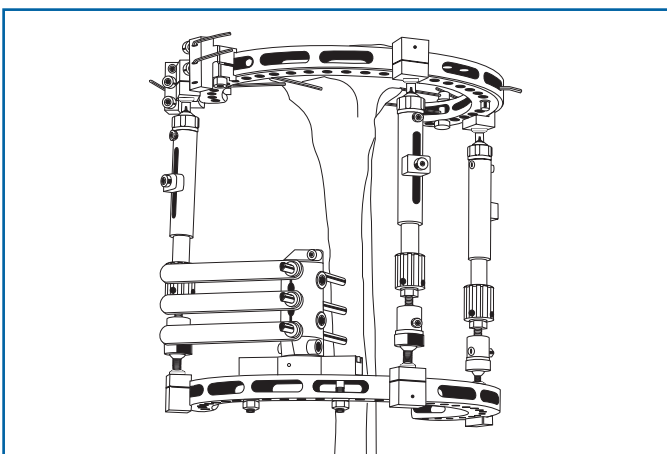
Attach diaphyseal ring using three reduction units (antero-laterally, postero-laterally and postero-medially). All rings in one frame should be the same size. The telescopic and micrometric mechanisms of the reduction units should be partially open, and spaced evenly around the circumference of the rings. Ensure that reduction units are perpendicular to the rings with the telescopic bodies oriented in the same way. Tighten all cams and locking screws.



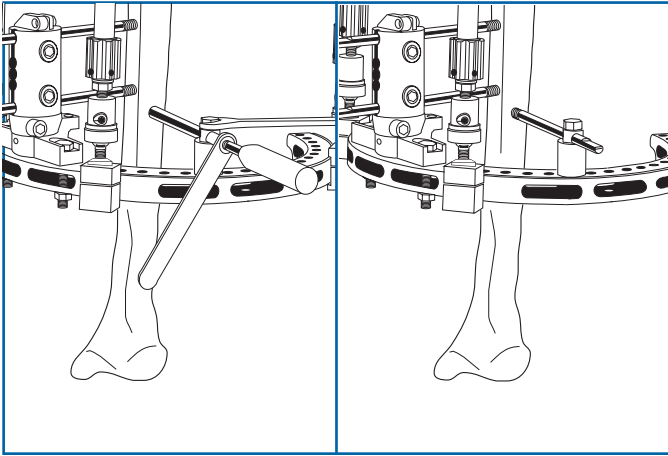
A Sheffield Clamp is attached to the diaphyseal ring antero-medially using 10 mm spanner. The rings should always be orientated so that the Sheffield Clamp is mounted on the 2/3 component, when a full ring is being used. Confirm fracture reduction.



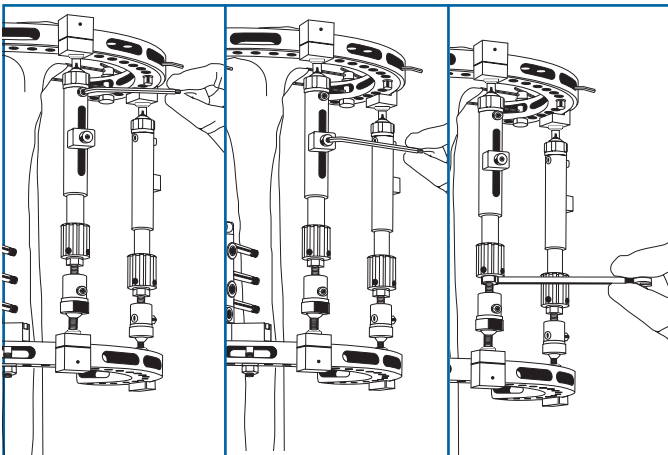
Clamp can be rotated to establish ideal position for diaphyseal screws. Clamp cover locking screws should face anteriorly. Clamp acts as its own template for screw insertion. Using a trocar, identify desired bone screw orientation and tighten rotational locking screw with 5 mm wrench.



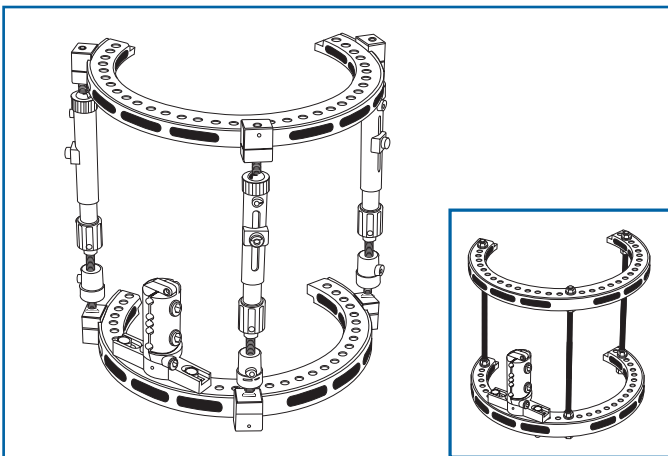
Screws are inserted in the standard manner. Where two screws are inserted, use clamp seats 1 and 5; where three are inserted, use seats 1, 3 and 5.



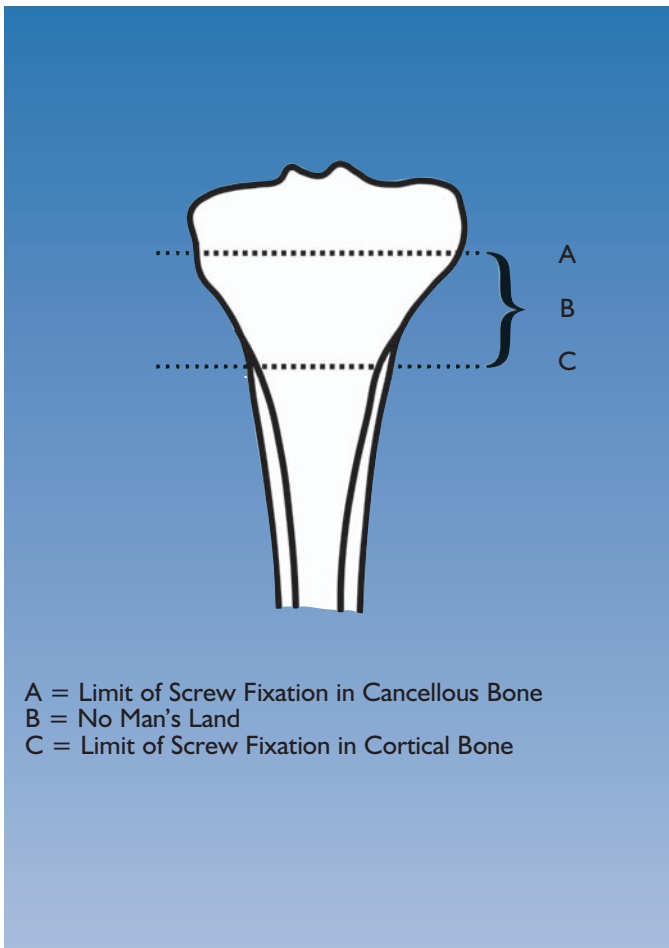
An additional screw may be inserted at 45°-90° to the first group using a single screw clamp attached to the diaphyseal ring. Where this screw is used, only two screws would normally be inserted through the Sheffield Clamp. This clamp can rotate for optimal screw placement.



Final fracture reduction can be made using the distraction and ball-joint facilities of the three reduction units, after loosening the cams and locking screws. After reduction, ensure that all cams and locking screws are fully tightened. The micrometric mechanism may be used for post-operative length correction of the fracture.



Standard frame may be preconstructed before inserting the Kirschner wires.



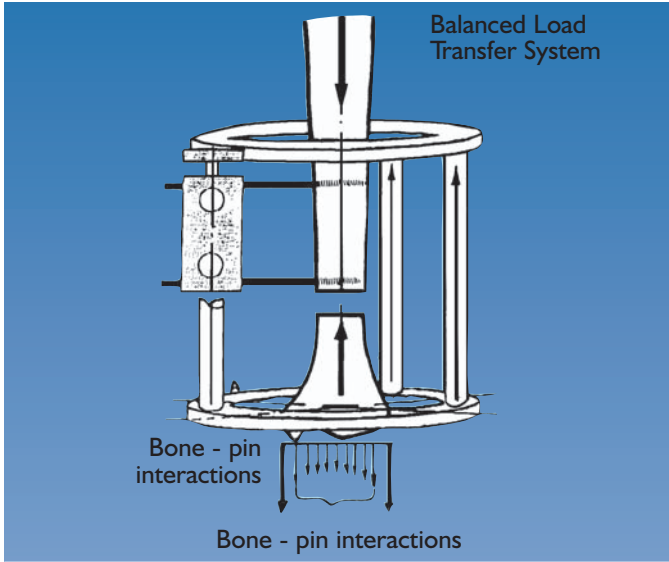
Fixation in metaphyseal bone

Secure, long term fixation in metaphyseal bone is often difficult to achieve with monolateral fixators because of the type of bone. Screws gain maximum purchase in the immediate subchondral area where the bone is both dense and wide. The rest of the metaphysis is known as “No Man’s Land”¹ since the cortex is thin and the width reduced, making fixation with screws less reliable^{2,3}.

Tensioned wires, on the other hand, are easy to apply in this region, with broad, safe corridors to maximize wire crossing angles, and provide good long term fixation in metaphyseal bone.

Fixation in diaphyseal bone

Where wires are used in diaphyseal bone, anatomical constraints limit available safe corridors, and this leads to reduced wire crossing angles and inferior stability. With circular frames, diaphyseal fixation is often achieved by mixing screws and wires on the same ring. Since screws are much stiffer than wires, mixing fixation devices of different modulus is inappropriate, and may lead to premature loosening. If screws are used uniquely on the diaphyseal side and wires on the metaphyseal side, fixation is improved and the elasticity and dynamization characteristics of tensioned wires are retained.



Rationale for Sheffield Ring Fixator

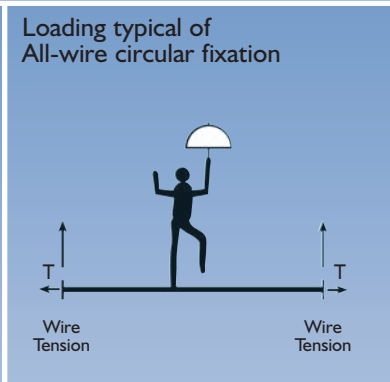
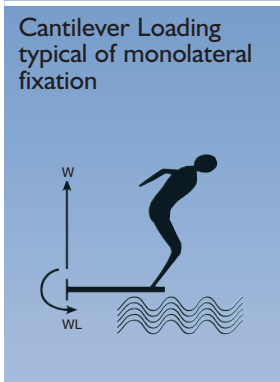
Hybrid External Fixation implies the combination of monolateral and circular fixation elements. It therefore combines the best features and properties of both monolateral and ring systems. These hybrid systems behave like an all-wire circular fixator in the metaphyseal region. When two pairs of fully tensioned wires are used on one ring, optimal stability is achieved in small metaphyseal segments.

The use of screws in the diaphysis via a specially designed clamp attachment to an additional ring (which carries no wires), provides for rapid stable application.

In extreme loading situations (e.g. obese patients or bone loss), further support may be achieved using an additional screw mounted directly on the diaphyseal ring.

The two rings are connected using three specially designed fracture reduction units, or alternatively threaded bars.

The efficient load transfer system of this construct provides the equivalent of beam loading support^{4,5}.



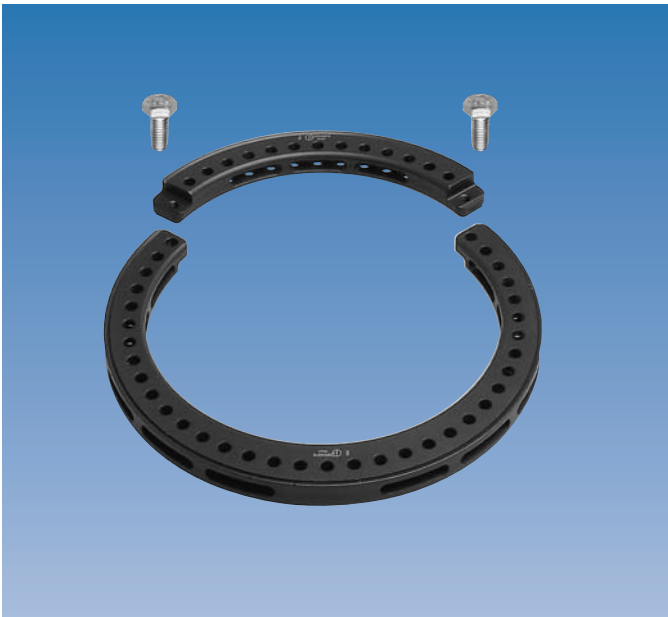
Acute trauma

- Tibial articular fractures: plateau and pilon
- Tibial articular fractures with diaphyseal extension
- High energy diaphyseal fractures of the tibia
- Femoral fractures, particularly distal
- Humeral fractures
- Fractures in osteoporotic bone
- Complex joint injuries where soft tissue or bony injury is such that fixation should be taken across the knee or ankle joint.

Limb reconstruction

- Correction of post-traumatic, acquired and congenital deformities: simple, juxta-articular, oblique plane, multi-planar. The Sheffield Ring Fixator is usually used in the lower limb for tibial and foot deformities, but is also useful for femoral and knee deformities. It may also be used in the upper limb, particularly the humerus.
- Arthrodesis: knee, ankle and subtalar joints
- Limb Lengthening: monofocal and bifocal
- Non-union and bone loss:
 - Monofocal - compression, neutralisation, distraction
 - Bifocal - bone transport, acute shortening, combined multifocal
- Joint contracture in adults and children: knee, ankle and foot
- Articulated distraction: ankle, foot and knee

NOTE: The present manual is primarily concerned with acute trauma situations, with or without articular involvement.



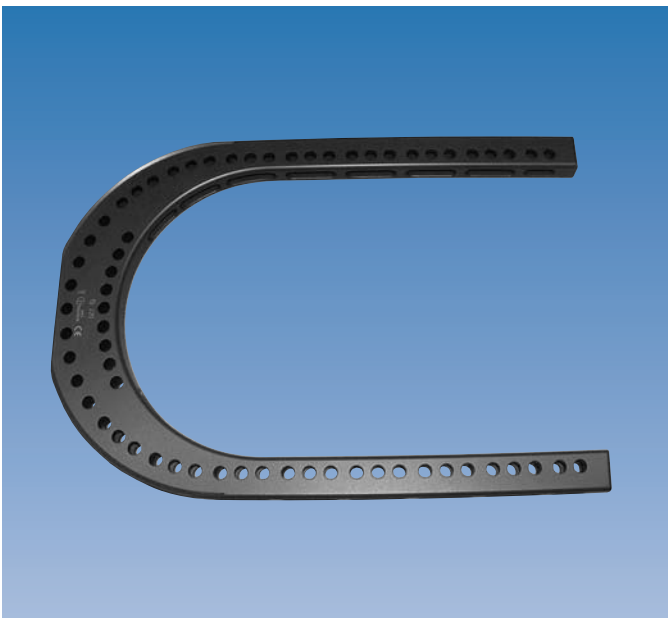
2/3 - 1/3 Rings

The rings are available in 2/3 and 1/3 configurations, and can be assembled together to create a full ring. 2/3 rings are commonly used near the joints to allow joint flexion through the opening in the ring. The rings are available in the following sizes:

Ring Size: Inner Diameter	2/3 Ring	2/3 Radio Lucent Ring	1/3 Ring	1/3 Radio Lucent Ring
125 mm	81050A	81125	81051	81125P
150 mm	81000A	81150	81001	81150P
175 mm	81002A	81175	81003	81175P
190 mm	81004A	81190	81005	81190P
220 mm	81006A	81220	81007	81220P

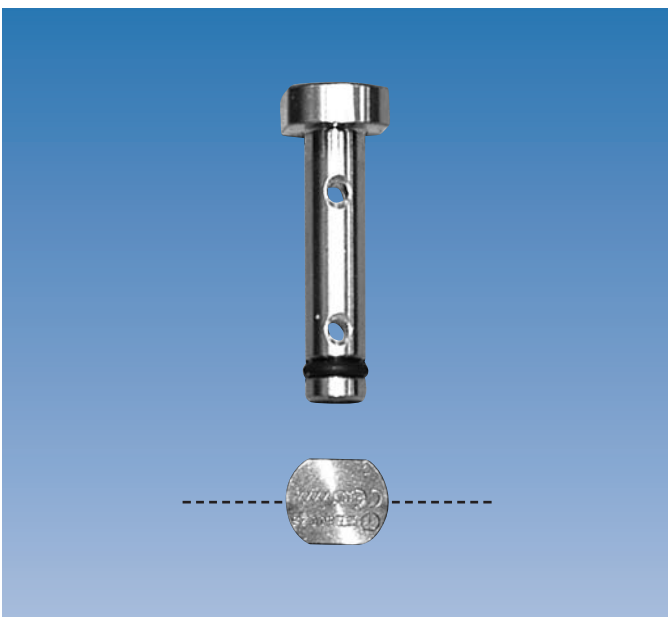
The rings are assembled with two:

81008 Ring Locking Screw (length 16 mm)



81500 Foot Ring - Inner Ø 150 mm

Foot fixation is indicated where ankle stabilisation is required during limb lengthening, and where a second level of fixation is required for a low tibial non-union. It is also indicated for severe pilon fractures and articulated distraction of the ankle. It can be applied to fuse the ankle and subtalar joints, for triple fusion and foot contracture. In most instances a foot ring is selected; however where correction of the midfoot is required with respect to the hindfoot, two 2/3 rings are used.

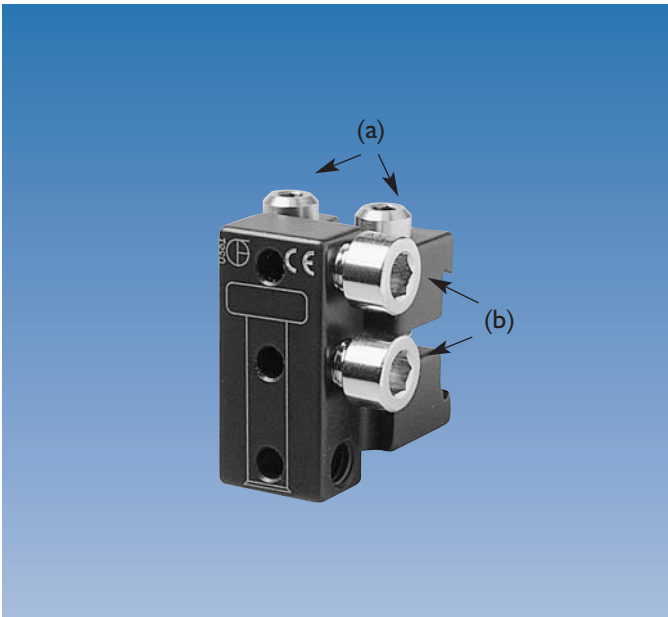


Wire-Ring Securing System

80025 Two-Hole Kirschner Wire Securing Pin

A 6 mm rod with two 2 mm diameter holes for the Kirschner wires. The hole in the securing pin closer to its head is offset from the center of the ring slot. This avoids contact between the crossing wires at the bone interface. It may only be used with Kirschner wires with lateral olives. Wires without olive may be used, but require a wire clamp slider unit at each end to secure the wire to the ring.

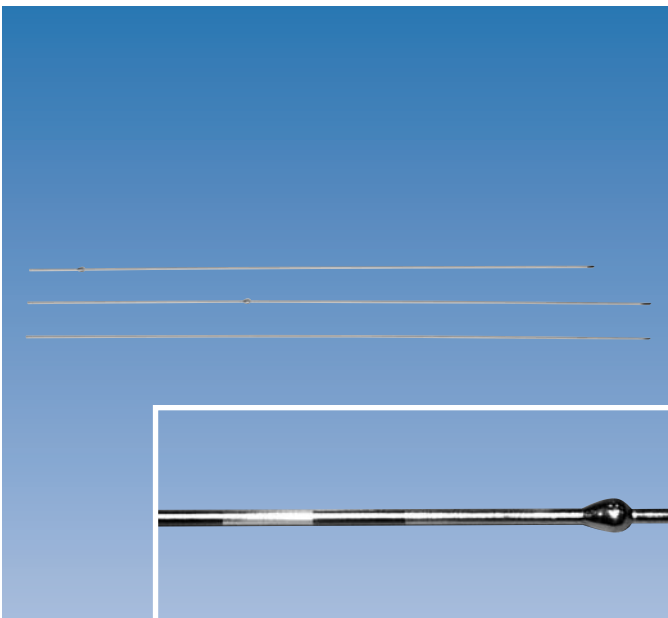
Note: the squared edges on the head of the pin line up with the holes for the wires, making it easier to insert the first wire.



80031 Three-Hole Wire Clamp Slider Unit

This component is used to secure wires to a ring. It has four screws: two (a) attach the slider unit to the ring, while the remaining two (b) grip the Kirschner wires in the slider unit, in any two of the three holes. The central wire hole is offset to avoid contact between the crossing wires in the bone. It may be used with all types of wire, allowing them to be placed above, below or through the ring.

Three-hole wire clamp slider units should be used with 1 or 2 wires only.



Kirschner Wires

Kirschner Wire (2 mm diameter) with Lateral Olive

- 80112 Length 400 mm
- 80111 Length 350 mm
- 80101 Length 310 mm

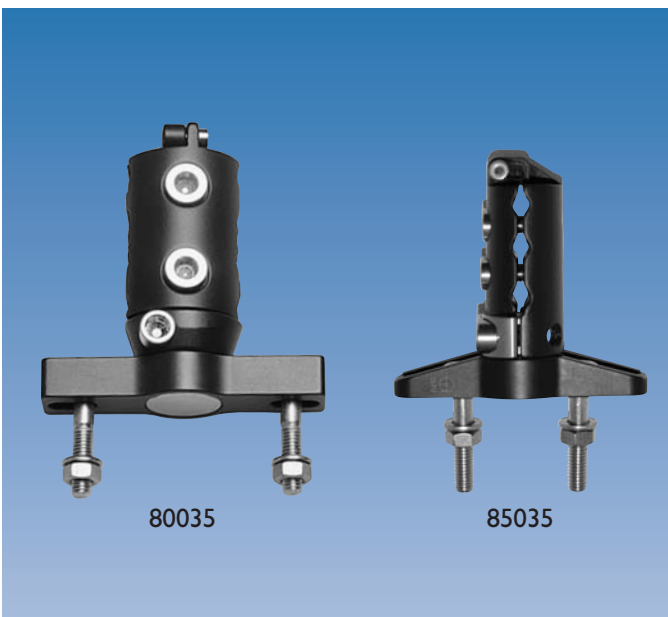
Kirschner Wire (2 mm diameter) with Central Olive

- 80123 Length 450 mm
- 80121 Length 400 mm

Kirschner Wire (2 mm diameter) without Olive

- 80124 Length 450 mm
- 80122 Length 400 mm

Note: all of the wires have markings at the end away from the tip. For the olive wires, this means that the markings are always on the same side of the bone as the olive. For removal, the central olive wires should always be pulled out by grasping the end with the markings.



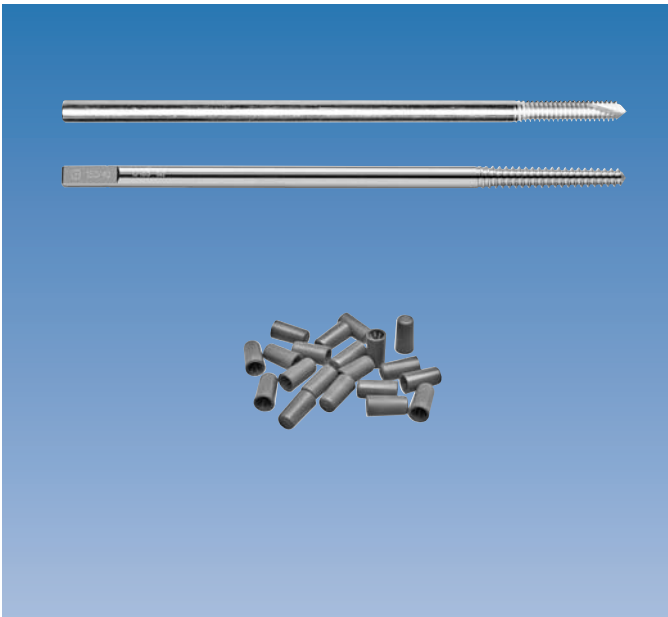
80035 Sheffield Clamp

This is similar to a ProCallus Straight Clamp but has a broad flange connecting it to the ring, and a rotational element to ensure optimal screw placement. It is used for diaphyseal fixation, and normally carries two or three 6 mm bone screws. It acts as its own template.

85035 Paediatric Clamp

Not to be used in adult patients, but in patients weighing less than 44 Kg (100 pounds). To be used with 125 or 150 mm rings, and 4.5-3.5 mm or 6.0-5.0 mm screws depending upon the bone diameter.

EQUIPMENT REQUIRED



Screws

Either standard tapered cortical screws or XCaliber screws are used, but they should not be mixed. Suggested sizes:

Tibia:

10110 Standard Cortical Screw 110/30 mm or

911530 XCaliber screw 150/30 mm

10114 Standard Cortical Screw 130/40 mm or

911540 XCaliber screw 150/40 mm

Femur:

10165 Standard Cortical Screw 150/40 mm or
911540 XCaliber screw 150/40 mm

10103 Standard Cortical Screw 180/50 mm or

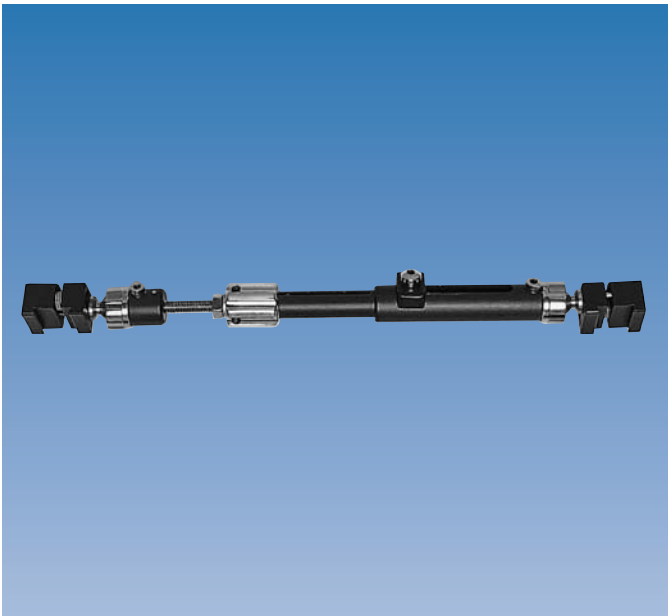
911550 XCaliber screw 150/50 mm

912640 XCaliber screw 260/40 mm

912650 XCaliber screw 260/50 mm

XCaliber screws are designed to be cut to length after insertion and fixator application.

10200 Sterilizable Screw Covers (set of 20)

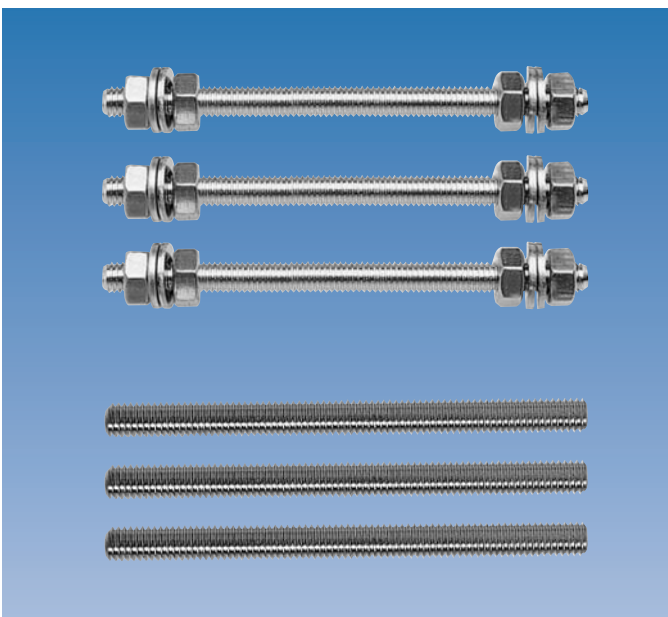


Ring Connecting Elements

80047 Reduction Unit

Telescopic, ball-jointed bars, connected to the rings via integral slider units.

Three are required for adequate stability.



Threaded Bars with Nuts and Washers (set of 3)

80036 Length 80 mm

80037 Length 120 mm

80038 Length 160 mm

80039 Length 200 mm

Threaded Bars without Nuts and Washers (set of 3)

81036 Length 80 mm

81037 Length 120 mm

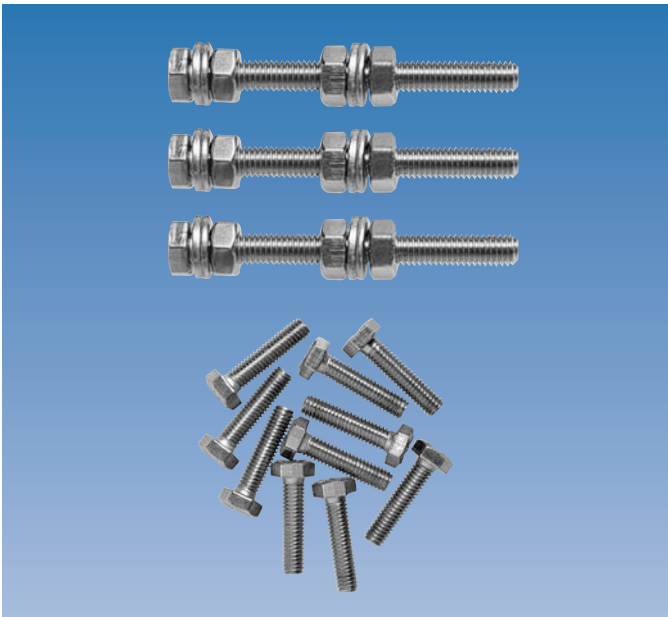
81038 Length 160 mm

81039 Length 200 mm

81048 Length 300 mm

81049 Length 400 mm

EQUIPMENT REQUIRED



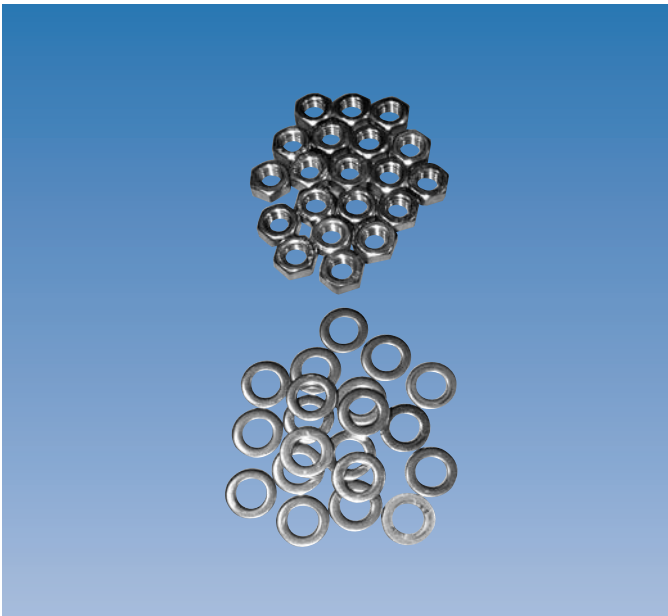
Bolts with Nuts and Washers (set of 3)

80034 Length 60 mm

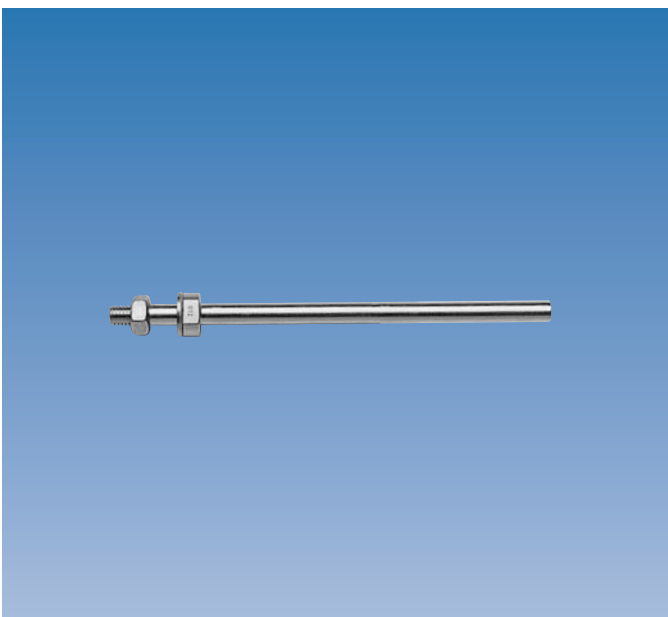
Bolts without Nuts and Washers (pack of 10)

81024 Length 25 mm

81021 Length 35 mm



81022 Nuts and Washers (pack of 20 of each)

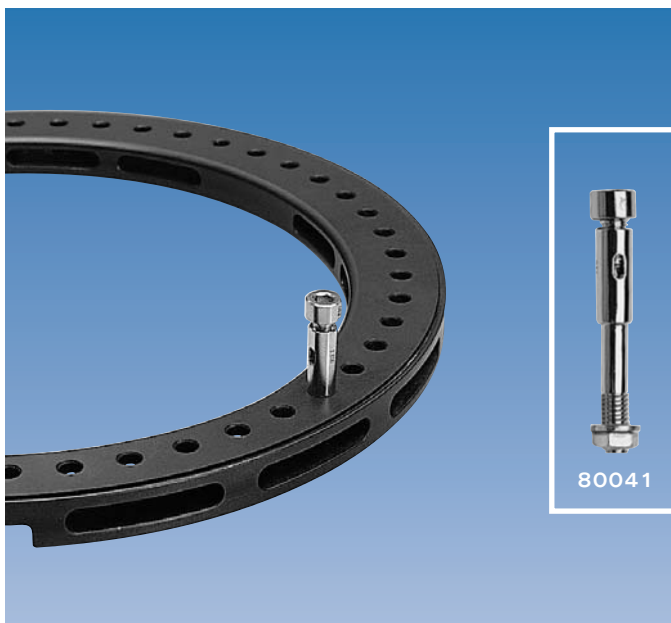


Post

80042 Length 50 mm

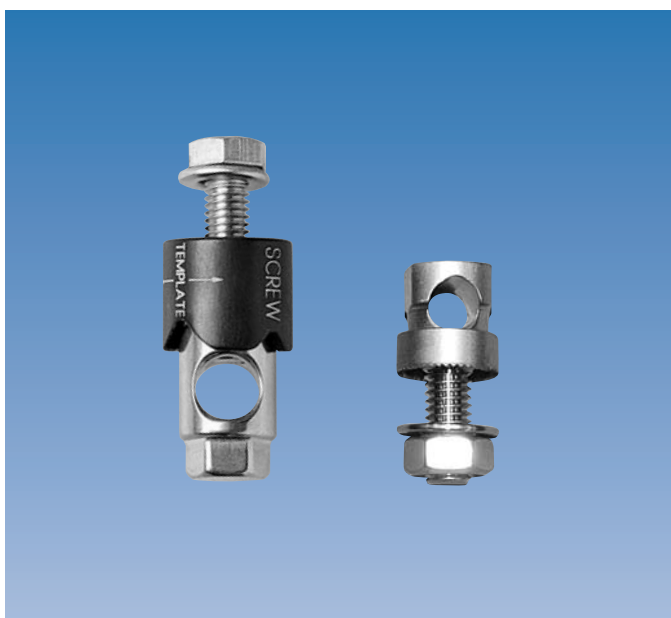
80044 Length 100 mm

Posts can provide support for supplementary fixation, and are useful for referencing.



80041 Independent Wire Clamp

Used with a 2 mm Kirschner wire with central olive, to secure an unstable fragment. A Washer (W2200, set of 4) may be used over the wire to reinforce cortical contact. The Independent Wire Clamp is applied directly to the ring.



80074 Single Screw Clamp

This is used to insert a single diaphyseal bone screw, usually at about 90 degrees to screws in the Sheffield clamp, for additional stability.

It may also be used to anchor Compression-Distraction Clicker Units for lengthening. In this case, six are required. (See Manual PM 12 "The Ring Fixation System - Part C: The Sheffield Ring Fixator: Limb Reconstruction and Complex Trauma").

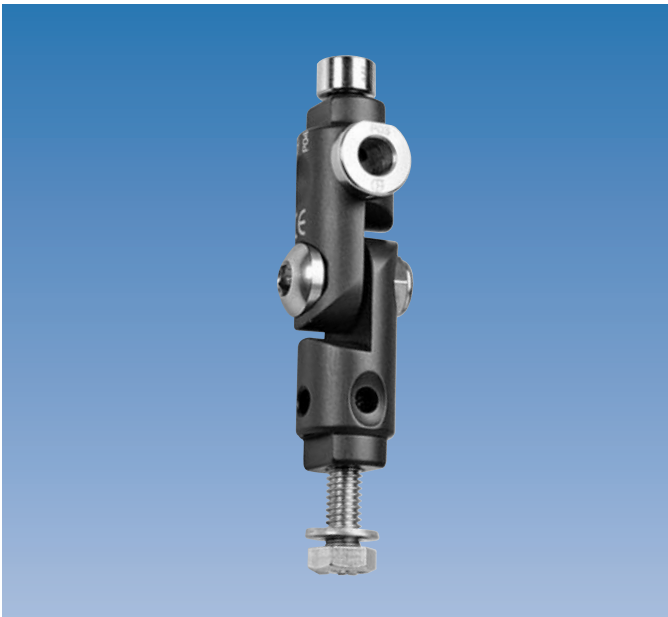
80076 Half Pin fixation bolt

This is used to attach a bone screw to a ring.



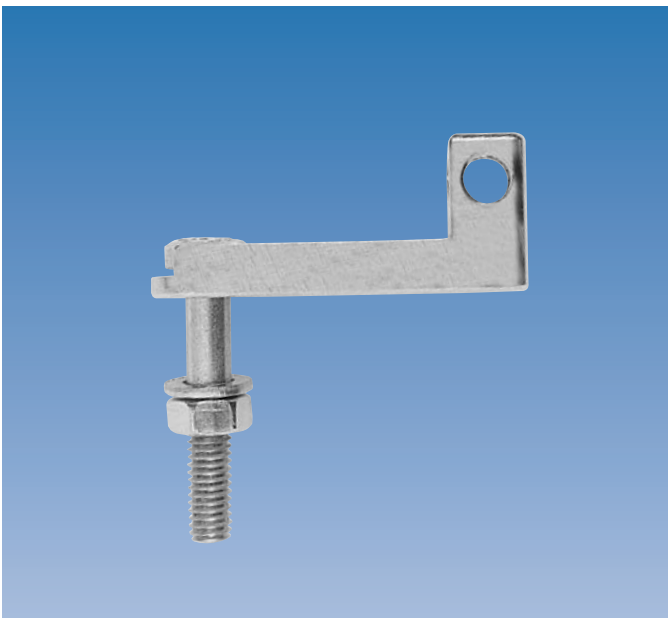
81018 Magic Cube

The Magic Cube provides a range of options for screw or wire fixation. It can be attached directly to a ring, mounted on an extension plate or post, or suspended between rings on a threaded bar.



81015 Hinge Clamp

The hinge clamp is multifunctional and can be used as a hinge or motor, or a clamp to secure a screw or wire. These techniques are described in Manual PM 12 “The Ring Fixation System - Part C: The Sheffield Ring Fixator: Limb Reconstruction and Complex Trauma”



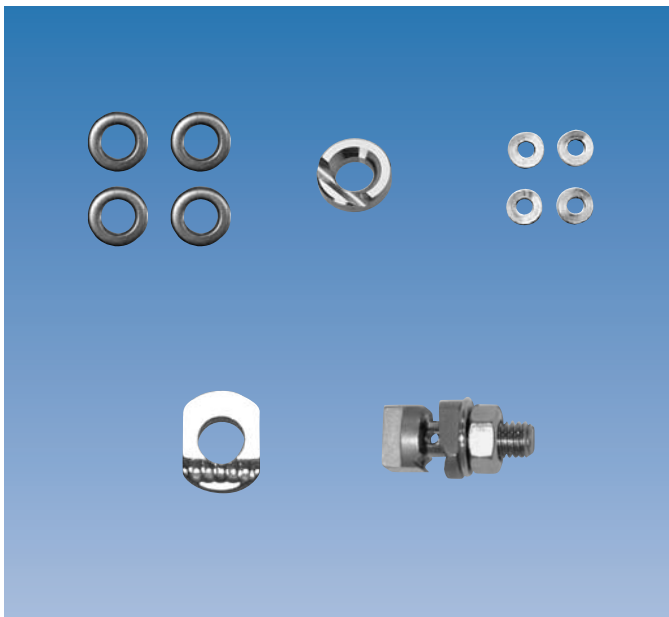
81020 Extension Plate

This is used for juxta-articular hinge placement, or with a slotted washer and bolt to angle wires off the ring. A Compression-Distraction Clicker Unit with extension plates attached to each ring may be used as a motor. It may also be used to connect rings of different sizes.



81010 Translation Rotation Hinge

These units may be used as simple hinges but are primarily indicated for correction of translation (see multiplanar deformity) and rotation. They may also be used to connect rings of differing diameters.



81023 Slotted Washers (pack of 10)

Slotted washers may be mounted on to the ring to provide a single level of wire fixation parallel to the ring. Where angled wires are required, a bolt and slotted washer combination may be used with a hinge clamp or extension plate. The most efficient configurations are in combination with the wire clamp component of the hinge clamp, using the hinge bolt to mount the washer, or attached to the side of an extension plate if it is fitted at 90 degrees to the ring. The wire is sandwiched between a slotted and plain washer.

80077 Wire fixation bolt

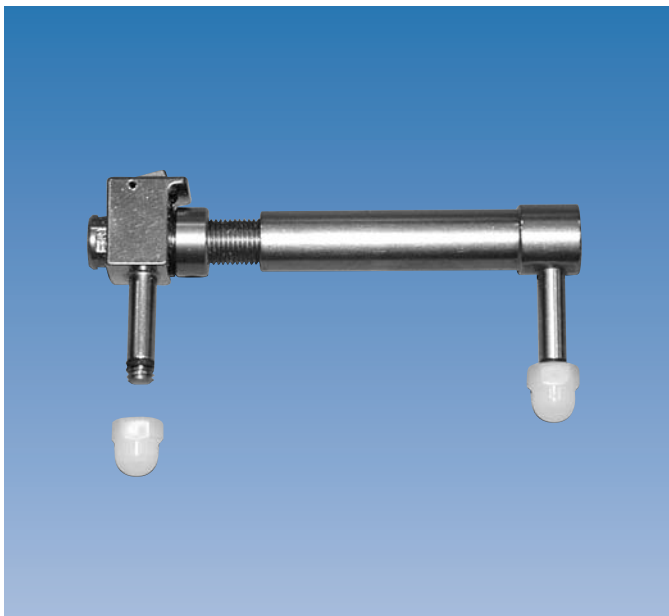
Used to fix a wire close to a ring or extension plate. The serrations in the washer help to grip the wire.

W2200 2 mm Washers (pack of 4)

For use to supplement cortical fixation of wires with a central olive.

74405 Revision Locking Screw Washers (pack of 4)

For use with the slotted washer.



Compression-Distraction Clicker Units

50008 Standard

50009 Long

With the blue button depressed and held they act as normal compression-distraction units. When the blue button is depressed transiently, they permit lengthening or shortening of one quarter turn (0.25 mm) only.

The white plastic nuts are used to retain the distractors in place.



81025 Counter Nut

They are used for more accurate lengthening or angular correction. The usual rate for lengthening is one millimetre per day (one full rotation of the nut), normally divided into 4 steps. Therefore, the patient usually begins each day with the same number of markers facing a particular direction. They may also be used as nuts where a fixing is required in a captive device such as the Sheffield clamp or an extension plate.

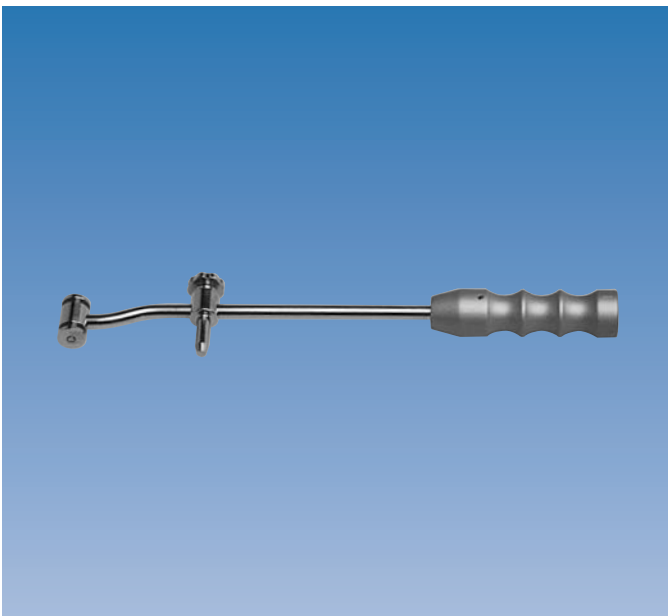
For more information on the use of products shown on pages 8 and 9, see Manual PM 12 "The Ring Fixation System - Part C: The Sheffield Ring Fixator: Limb Reconstruction and Complex Trauma"

EQUIPMENT REQUIRED



18001 Wire Tensioner

Calibrated from 600-1400N.



18002 Wire Guide

Used as an aid to accurate placement of a second wire when parallel wires are used.



81031 Open End Wrench

81030 Speed Wrench

10017 Allen Wrench 6 mm

EQUIPMENT REQUIRED



91017 Universal Allen Wrench 3 mm/ 5 mm, and Wire Bender

The hole in the polyhedral end of the wrench can be fitted over the end of the wire. The instrument can then be used as a Wire Bender.



W1003 Wire Cutter

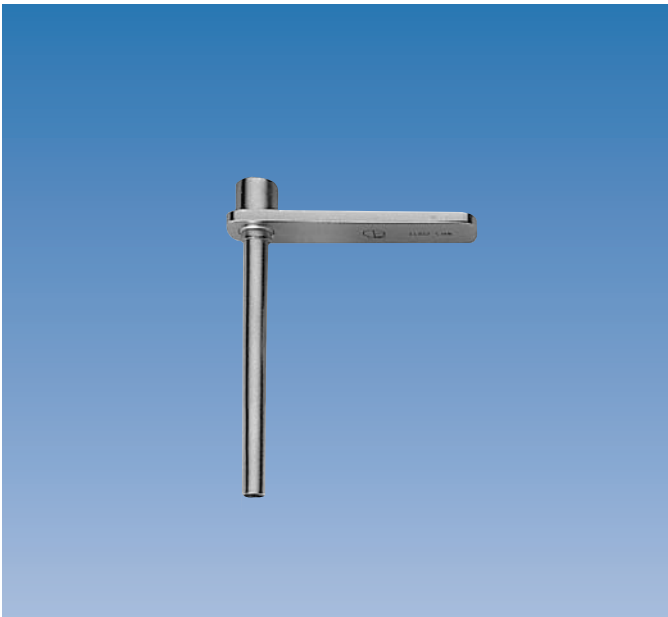
80200 Wire Covers (pack of 20)



Screw Guides

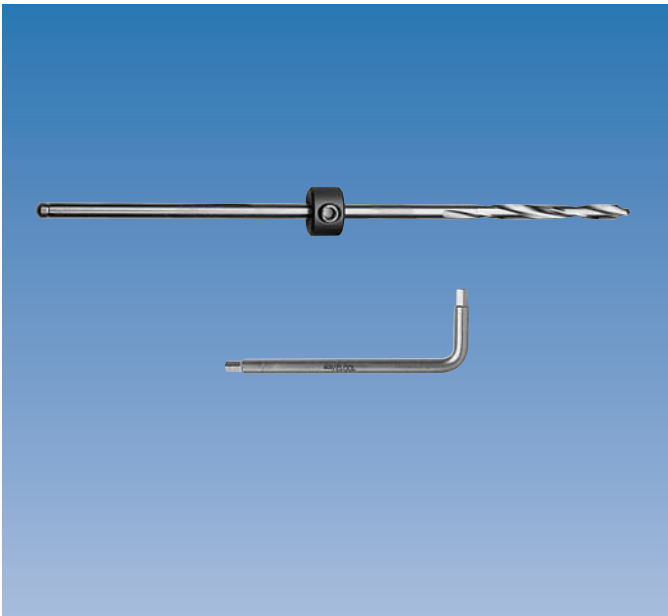
- 11102 Length 60 mm
- 11137 Length 80 mm
- 11103 Length 100 mm

EQUIPMENT REQUIRED



Drill Guides

- 11138 Length 60 mm
- 11105 Length 80 mm



Drill Bit Kits Ø 4.8 mm

- 11001 Length 180 mm
- 11002 Length 240 mm

ADDITIONAL INSTRUMENTATION

The additional instrumentation required comprises:

- Wire Driver Attachment
- Mallet
- Benders

Unless sterile, when products are used for the first time, they should be removed from their containers and properly cleaned using a medical grade solution of alcohol in distilled water, minimum strength 70%.

Detergents with free fluoride, chloride, bromide, iodide or hydroxyl ions must not be used, as they will damage the black anodised coating on any Orthofix products.

After cleaning, the devices should be rinsed with sterile distilled water and dried using clean non-woven fabric.

Prior to surgical use, the fixator, bone screws and instrumentation should be cleaned as described above and sterilized by steam autoclaving following a validated sterilization procedure, utilizing a prevacuum cycle [Orthofix recommends the following cycle: steam autoclave 132°-135°C (270°-275°F), minimum holding time 10 minutes].

Please refer to Manual 1, “Orthofix External Fixation: Basic Considerations” for more information on equipment maintenance.

Segment	Build of Patient	Probable Ring
Thigh	Slight	175 mm
Thigh	Large	190 mm
Thigh	Very large	220 mm
Knee	Slight	150 mm
Knee	Large	175 mm
Knee	Very large	190 mm - 220 mm
Calf	Slight	150 mm
Calf	Large	175 mm - 190 mm
Ankle	Slight	125 mm - 150 mm
Ankle	Large	175 mm
Foot	Slight	150 mm
Foot	Large	175 mm

The two rings used in a construct should be the same size. The size is determined by the larger of the two limb measurements.

SELECTION OF RING SIZE

Five ring sizes are available and may be used as full circumference rings or 2/3 circumference rings. Generally the 2/3 ring will be selected for the knee, since it facilitates knee bending and is more comfortable for the patient. With 2/3 rings, wire crossing angles are limited to about 70°. Full rings are indicated where protection of the soft tissues is required, if the distal tibial fixation will be taken across the ankle and for some Limb Reconstruction applications.

The appropriate size may be selected by placing the rings around the limb and ensuring clearance of at least 1.5-2 cm between the ring and the limb.

SELECTION OF RING/WIRE COMBINATION

Usually only one wire-bearing ring is used in the metaphysis. Crossed wires in the metaphyseal ring are preferred at two levels rather than at one level, provided that 20 mm of sound bone is available for their application. If less bone is available, single level wires may be used and if necessary, a further level of stability may then be achieved by extending the fixation across the adjacent joint. Occasionally, two wire-bearing rings may be used, if there is sufficient room in the bone, with two wires in each ring and connected by ring spacers.

SELECTION OF RING/SCREW COMBINATION

Diaphyseal fixation is normally achieved with 2 or 3 cortical screws in the Sheffield Clamp. If large forces in the plane of the screws are anticipated as, for example, in the correction of deformities, or if there is bone loss, additional stability may be achieved by inserting a single screw at 45°-90° to the initial group and attaching it directly to the ring with a Single Screw Clamp.

PRECONSTRUCTION

The main indications are in acute trauma. A standard frame may be preassembled using two 2/3 rings and three reduction units or threaded bars. The reduction units are attached to the rings and placed antero-laterally, postero-laterally and postero-medially, providing space for wires to be applied at maximum crossing angles. A Sheffield Clamp is connected to the diaphyseal ring inside the frame, facing the antero-medial aspect of the tibia. The clamp is attached with 2x35 mm bolts, nuts and washers. Nuts should not be tightened directly to the ring and spacing washers should be used to prevent damage to the surface of the ring. Washers should not be placed between the Sheffield Clamp and the ring.

BASIC PRINCIPLES OF SHEFFIELD RING FIXATOR

- 1) Ring connecting reduction units or bars should be spaced as evenly as possible around the rings. Normally 3 are sufficient. If 4 are used, care should be taken that excessive vertical loads are not transmitted to the ring by uneven alteration of the lengths of the connecting bars.
- 2) Rings should be assembled so that the 1/3 components, or the gaps where a 2/3 ring is used alone, are above each other.
- 3) The space in a 2/3 ring, or the 1/3 component of a complete ring, should always be positioned posteriorly.
- 4) A Sheffield Clamp should always be positioned on the 2/3 component of a ring.

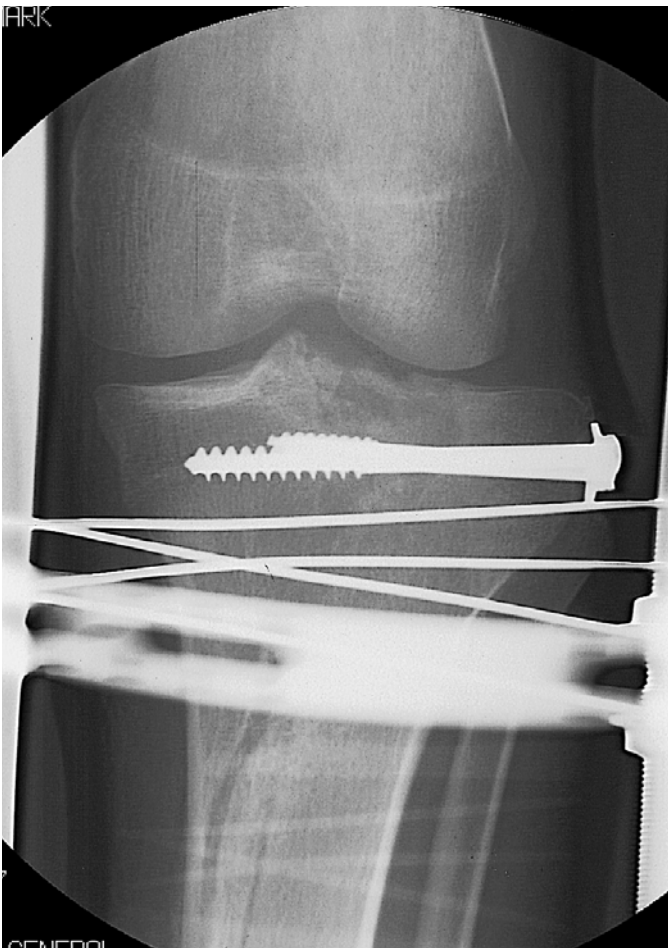




Metaphyseal Fractures without Articular Displacement

In the case of short spiral fractures involving the knee joint with little or no displacement, and short oblique fractures of the diaphyseo-metaphyseal junction, the frame should be applied with two to four wires proximally and two or three screws distally.

In longer spiral fractures, which often occur in the older age groups, improved fixation in the proximal fragment may be achieved using two rings connected by bolts. In this case, instead of a trans-fibular wire in the lower ring, a wire is placed more anteriorly in the coronal plane, to avoid the common peroneal nerve.



Displaced Articular Fractures

The fracture may be reduced by a standard arthrotomy⁶ or by limited percutaneous approaches^{7,8} using cannulated inter-fragmentary screws and/or the Orthofix Fragment Fixation System implants inserted under image intensification. CT scan assessment combined with percutaneous articular reduction and external fixation permits safe, early, accurate reconstruction even in cases where the soft tissues are compromised. Normally, three to four wires should be applied proximally. In Schatzker 6 fractures, a configuration with four wires has been shown to be biomechanically appropriate^{9,10}. In low energy spiral fractures, if reduction can be achieved by a closed procedure there may be no need for any additional internal fixation.



If the fracture is extensively comminuted, or where there is significant soft tissue injury, the frame may be taken across the knee joint with or without ligamentotaxis. Two screws are inserted antero-laterally in the distal femoral diaphysis.



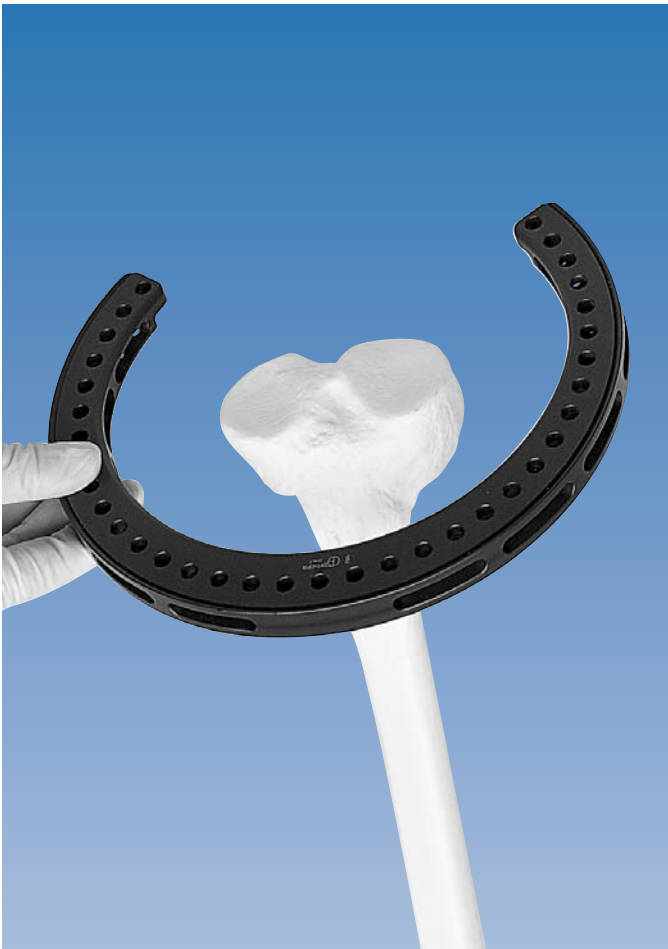
PRE-OPERATIVE PLANNING

The orientation of the fracture lines and extent of depression of the articular surface is determined. Important landmarks should be marked on the skin. CT scans are helpful.

Temporary fracture reduction is secured using tenaculum forceps and guide wires inserted through stab incisions in the skin. If the reduction proves more difficult, direct reduction techniques with bone levers and punches inserted through limited incisions may be required. Occasionally, mechanical distraction or formal open reduction is required. Cannulated screws are inserted in the subchondral bone to secure and compress the major fracture fragments. Smaller fragments may be secured using Orthofix Fragment Fixation System implants. Bone grafting of the subchondral area, if required, is performed at this stage and a percutaneous harvesting method is preferred^{11,12}.

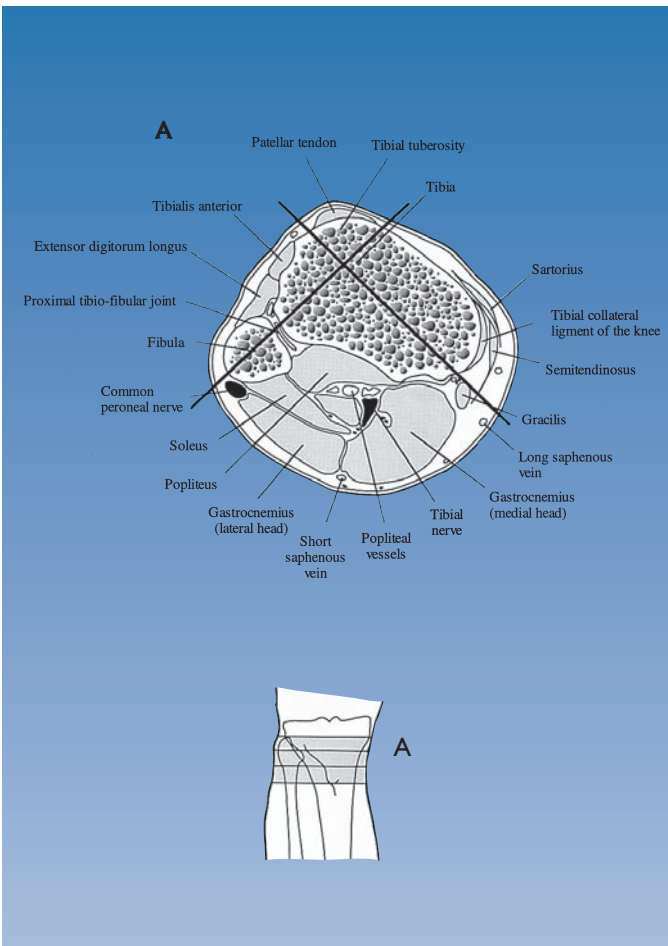
A preconstructed frame with two rings may be used for this application. It may be assembled in theater during the induction of anesthesia or by an assistant during initial fracture reduction.

Alternatively, the metaphyseal ring is applied first, and the remainder of the frame attached subsequently. This latter method is described below.



The metaphyseal ring is now placed around the upper tibia ensuring that it is at right angles to the axis of the leg in AP and lateral views (remember that the plateau slopes 10° caudally). The ring is oriented so that the broad flange is anterior or externally rotated 5°-10° from this position, and the open area posterior.

When using Kirschner wires, it is important to ensure that the path they will take will avoid tendons or neurovascular elements. In the region of important neurovascular structures, a 4cm incision should be made, dissecting the tissues down to the bone and inserting the wire under direct vision. No attempt should be made to insert a wire more than once, since the tip will have become blunt, and as this is the only cutting surface, undesirable heating of the bone may occur.



Safe corridors for Kirschner Wire insertion

When inserting wires in the proximal tibia, the head of the fibula is an important landmark, since the Common Peroneal Nerve passes posterior to it. Care should be taken to avoid transfixion of the Common Peroneal Nerve.

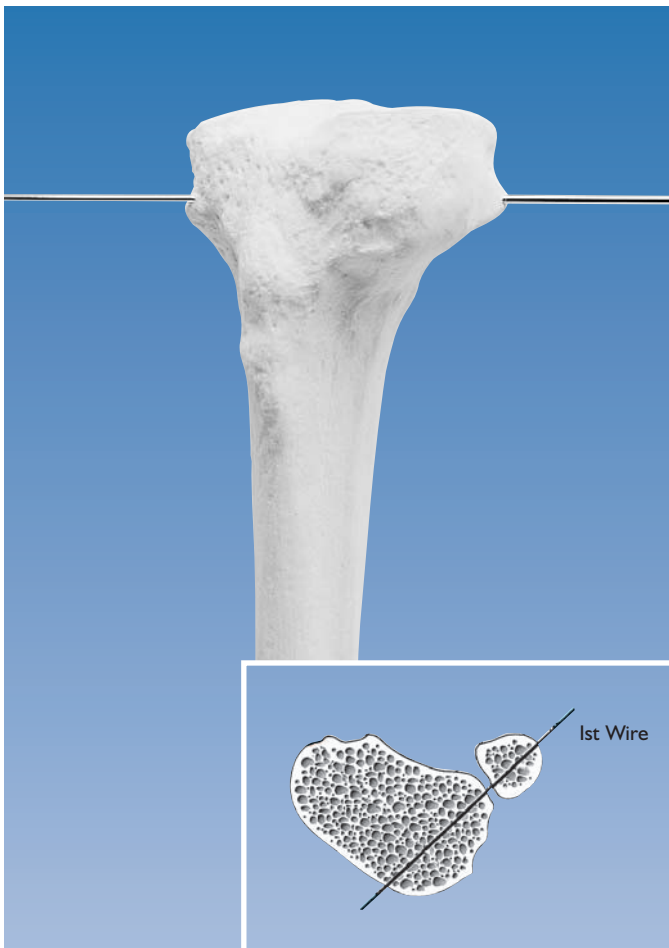
Where two levels of trans-fibular wires are used, both should pass through the head of the fibula, or one through it and one just above its tip. In either case the upper wire should be sited at least 14mm from the joint line to avoid capsular penetration, and the lower wire must be above the neck of the fibula, where the Common Peroneal Nerve is at risk. A securing pin should be positioned upside-down with one hole above the ring proximally. The wire closest to the joint is inserted through this hole.

The trans-fibular wire must avoid the Patellar Tendon, transfixion of which will cause pain and restricted motion. The crossing wire, called the medial face wire, is inserted just anterior to the antero-lateral compartment muscles, exiting at the postero-medial border of the tibia, anterior to the Gastrocnemius. It may cause some discomfort if it is too anterior, exiting through the Pes Anserinus (hamstring attachment), or too posterior, exiting through the medial head of Gastrocnemius. Transfixion of muscle leads to discomfort and restricted mobility. Should it be necessary to transfix a muscle, the appropriate joint should be moved to ensure that the muscle is stretched prior to insertion of the wire.

Kirschner Wire insertion

The first wire inserted (trans-fibular reference wire) is a postero-lateral to antero-medial one, through the head of the fibula, running parallel to the tibial plateau and exiting medial to the patellar tendon. It must be inserted below any internal fixation previously applied. It may be introduced either through a Kirschner wire securing pin, or alternatively, free-hand, using a wire without olive.

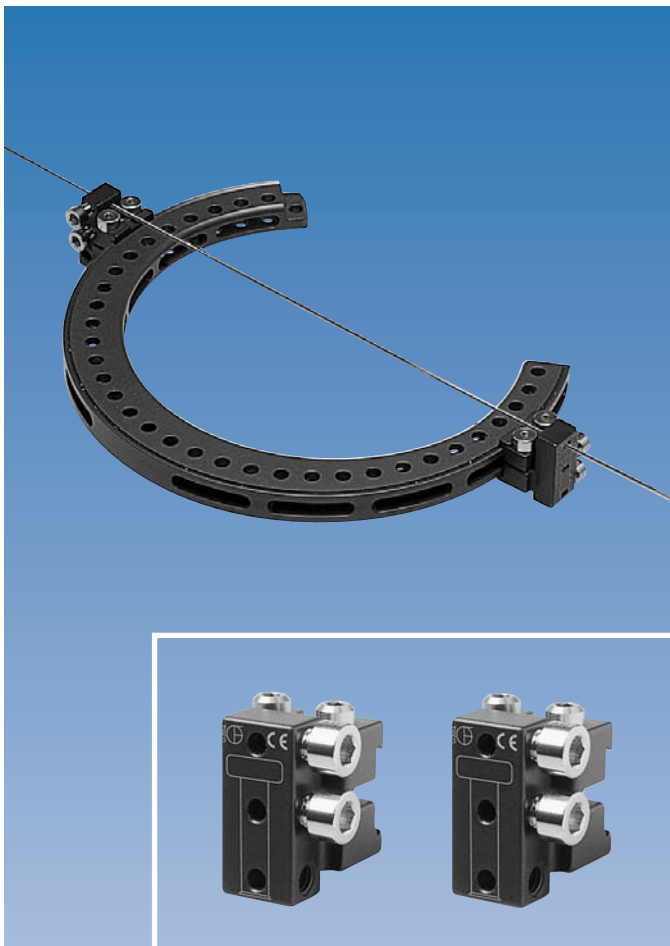
This wire often does not exit sufficiently anteriorly, resulting in a poor crossing angle. Be sure that it exits antero-medially (see inset).



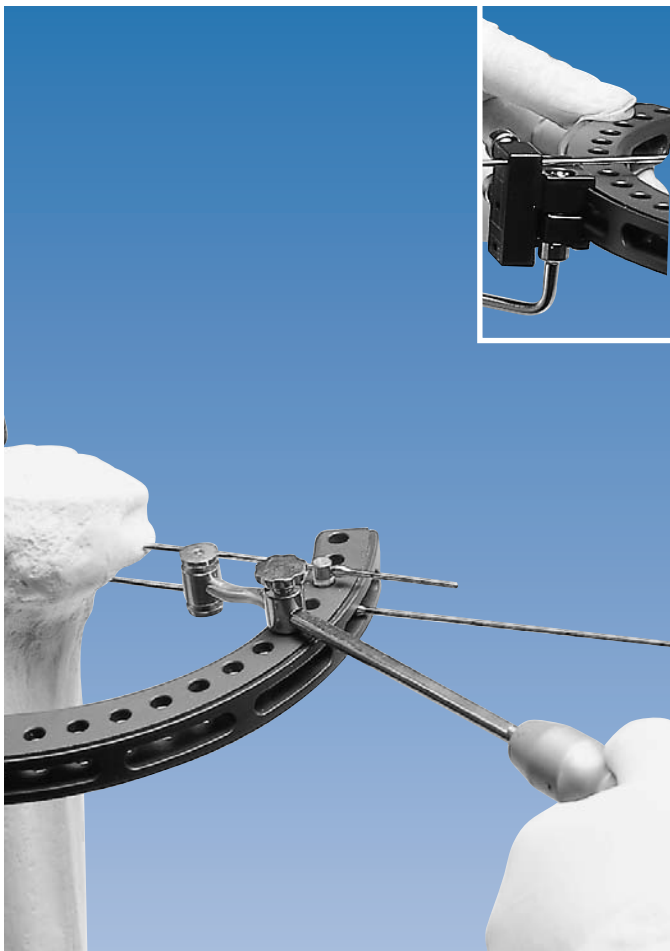
Where the wire is inserted through a securing pin, the ring is held in position by an assistant at 90 degrees to the tibial axis, with the limb centrally placed within the ring (it may be useful to position a trochar in the anterior hole in the ring and keep the trochar parallel to the tibial axis). In this case a wire with a lateral olive should be used. To insert the first wire, which is the one closest to the joint, the securing pin should be positioned upside-down with the hole above the ring. This allows better visualization of the wire during insertion. The wire is inserted percutaneously or through a small incision (3-4 mm) and pushed down to the bone before commencing drilling, which is carried out at slow speed and with gentle pressure. After it has penetrated the bone, it is tapped through the soft tissues on the far side, until the olive is against the securing pin.



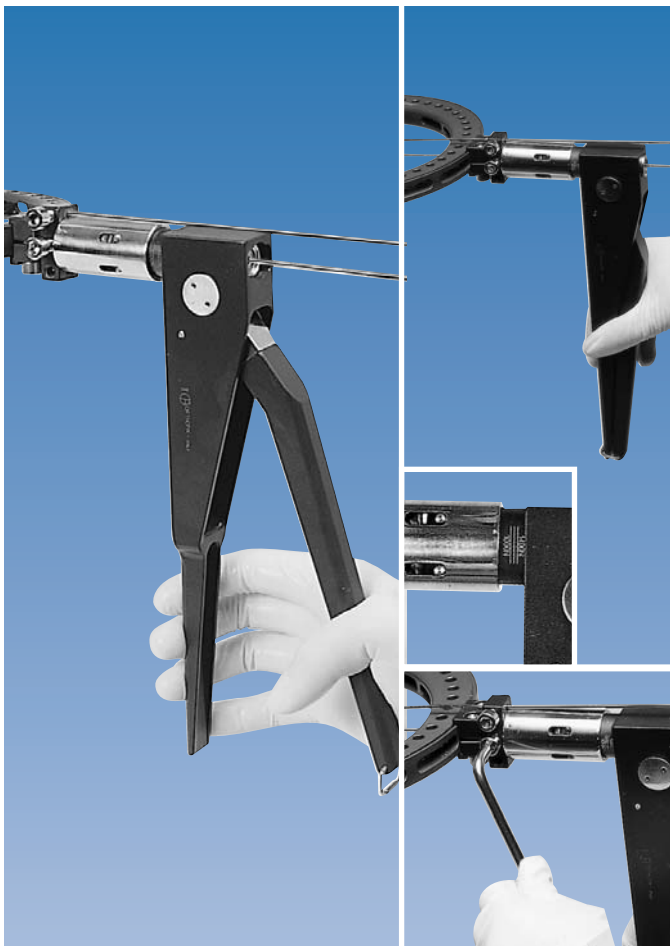
A three-hole wire clamp slider unit, with all screws loosened, is now oriented so that the etched outline of the securing pin on the clamp matches the position of the securing pin at the other end of the wire. The wire is inserted through the hole nearest to the joint, and the slider unit slid down to the ring.



If the first wire is inserted freehand, a three-hole wire clamp slider unit is mounted on each end of the wire through the hole which will be nearest to the joint. Both slider units should be oriented the same way when they are attached to the ring.



The parallel wire is inserted next. The wire guide (18002) may be used to assist in this procedure. With its knob loosened, the sliding support unit of the wire guide is inserted into one of the holes in the ring and its position on the bar adjusted so that one groove in the head of the wire guide is in contact with the wire already in place. The second wire is then kept in contact with the remaining groove in the head of the wire guide during its insertion. The slider unit may be temporarily disconnected from the ring, and then inserted over both wires using the appropriate two holes. The slider unit is then firmly secured to the ring by tightening the appropriate screws evenly with a 3mm Allen wrench.

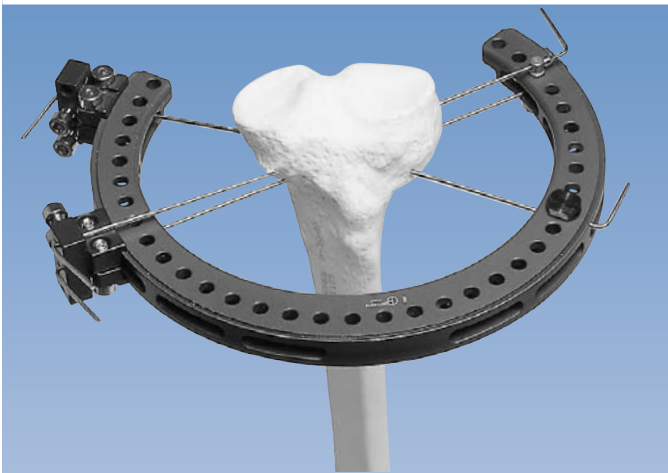


The ring must now be adjusted so that the limb lies at its center, since such adjustments cannot be made subsequently. Both wires are now tensioned, starting with the wire in the center hole. The wire tensioning device is opened fully and advanced over the wire until it touches the wire clamp slider unit. The handle is now closed and clipped, and the tension read off on the graduated scale. If it is less than 1200N, the wire clamp screw is temporarily tightened using the 5mm Allen wrench and the procedure repeated. Once the correct tension is achieved (i.e. 1200N), the wire clamp screw is fully tightened.

N.B. While tightening the wire clamp screw, it is important not to lever the wire tensioning device to avoid breakage of the Kirschner wire.



The Kirschner wires are now cut 4cm from the slider unit and bent at both ends. The cut end should be turned in towards the ring to avoid sharp edges being exposed, and a wire cover (**80200**) may be applied. Note that if the first wire of a pair is tensioned before the second is inserted, some difficulty may be experienced in guiding the second wire into the appropriate hole in the wire slider unit.



The position and direction of the crossing wires should allow a 50°-70° wire separation angle. Ring stability is optimal if the wire crossing angle is as large as possible and the wires cross in the center of the tibia. The crossing wires are now inserted, using the technique described above, taking care that the Kirschner wire securing pin is inserted from the OPPOSITE surface of the ring from that of the first pair of wires. This will ensure that the crossing wires are not in contact at the bone interface. These wires are now tensioned. Once tensioned, the ring may be considered to be securely attached to the metaphyseal segment. In order to avoid undue stress on a ring no more than two pairs of wires should be used on one ring.

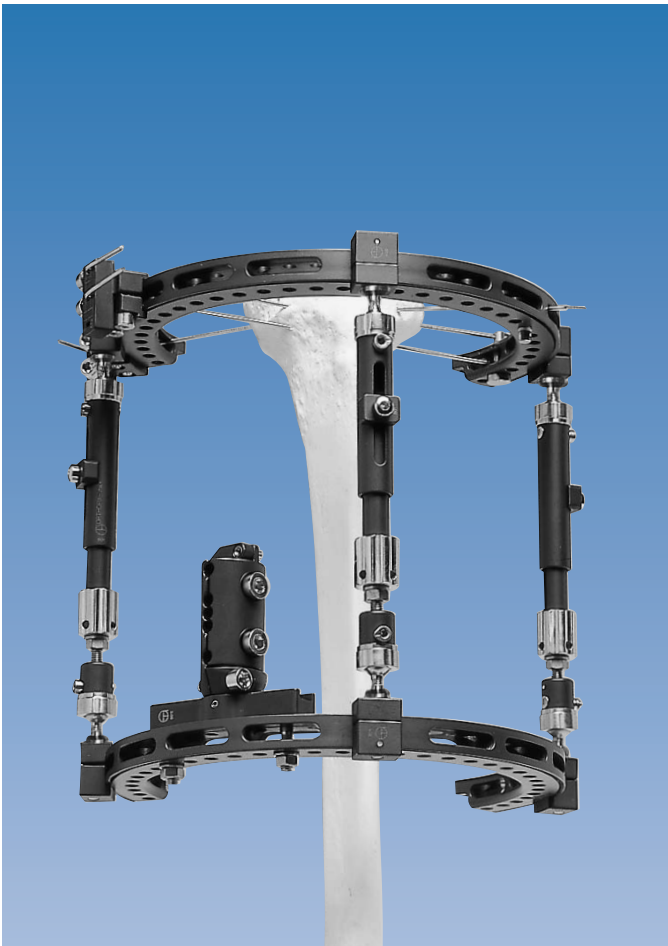


Wires with a central olive may be used in conjunction with a washer (**W2200**) where large translational forces are anticipated along the line of the wire, e.g. in any situation where narrow crossing angles may occur. The skin must be incised to permit passage of the olive through the soft tissue. As the olive cannot pass through a securing pin, the wire is inserted freehand, at approximately the height of the top hole of the wire clamp slider unit. Once the wire has been inserted, the slider units are attached and used to secure the wire to the ring. Wire tensioning is performed from the side distant to the olive, and tension should be reduced to between 800 and 1000N to avoid excessive pressure on the cortex of the bone.



Diaphyseal screw insertion

Three reduction units are now attached to the metaphyseal ring in the antero-lateral, postero-lateral and postero-medial positions, and the diaphyseal ring attached to these. A check should be made on each unit that the collars over the two ball-joints are fully tightened. The threaded screw for micrometric control should be slightly opened, and the telescopic locking mechanism in mid-position, to permit reduction. The frame should never be applied with the reduction units fully closed in a trauma case. The diaphyseal ring should be adjusted to be parallel to, and in line with, the metaphyseal ring. At this point, the reduction units should be perpendicular to the rings, with the telescopic bodies oriented in the same way. The cams and locking screws should be all tightened.



The Sheffield Clamp is now mounted on the antero-medial aspect of the diaphyseal ring, normally inside the frame. It must be sited distal to any fracture extension, and in comminuted or segmental fractures therefore, it may need to be mounted on the outer surface of the ring. The clamp cover locking screws should always face anteriorly. This clamp acts as its own template for screw insertion.

The diaphyseo-metaphyseal fracture is then reduced by manual longitudinal traction paying particular attention to rotation in unstable fractures.



Diaphyseal screw insertion is normally antero-medial in the tibia. Cortical screws (two or three) should be inserted at right angles to the diaphysis and sited in thick cortical bone near the isthmus. Screws should be in positions 1 and 5 (two screws) or 1, 3, and 5 (three screws).

In general, placement of three screws is advisable.

A screw guide and trocar are inserted through the Sheffield Clamp. Long screw guides are recommended: 80 mm screw guides should be used for the 150 mm and 175 mm rings and 100 mm screw guides for the 190 mm and 220 mm rings. The clamp cover locking screws of the Sheffield Clamp are gently tightened. The rotation locking screw is released. Once the desired screw orientation is identified, the rotation locking screw is locked.



The diaphyseal (cortical) screws are then inserted following the standard insertion technique (see Manual 1, "Orthofix External Fixation: Basic Considerations"). When the second and the third screws are being inserted, the clamp cover must be tightened on to the screw guides, to ensure that the screws will be parallel to one another.

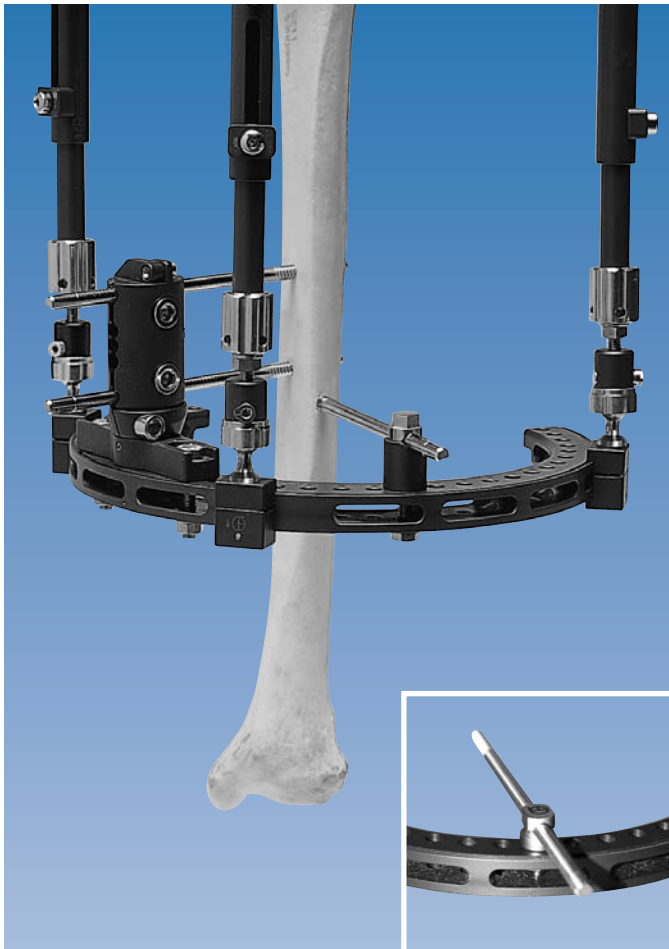
N.B. Purchase is maximal if the screws are inserted across the widest part of the medullary canal.



Once all the screws have been inserted, the screw guides are removed and the screw shafts washed free of blood before retightening the clamp cover. Tight skin around the screw sites should be released in the normal way.

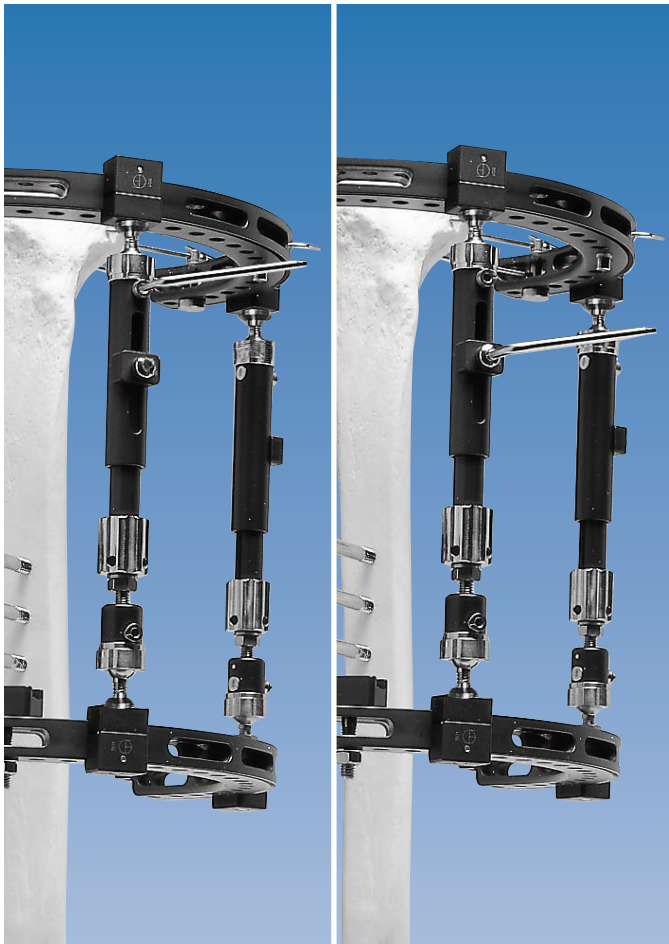


An additional screw may be inserted at 45°-90° to the first group to provide increased stability. If this screw is used, only two screws are required in the Sheffield Clamp, unless the bone is osteoporotic or the purchase of one of the screws is poor. A Single Screw Clamp may be attached on either side of the diaphyseal ring, usually at the front of the ring, to insert the screw through the antero-lateral aspect of the crest. The bolt and washer are removed from the single screw clamp and inserted through the ring. The screw clamp is then screwed loosely on to the ring by tightening the bolt on the opposite side. The screw clamp ensures that the screw is parallel to the plane of the ring but free to rotate about its axis for optimal screw placement. A screw guide and trocar are inserted in the single screw clamp hole of the cylinder making sure that the word "TEMPLATE" on the collar is in line with the hole. The screw clamp is then gently tightened using one Open End Wrench and one Speed Wrench.



The screw is inserted in the standard way. Once drilling is completed, the drill and drill guide are removed and the bolt gently unscrewed to remove the screw guide. The collar is rotated by 90° to line up the word “SCREW” with the hole. The Screw Clamp is then tightened using the single bolt attachment.

During screw insertion, when using a Half Pin Fixation Bolt (part number 80076) care should be taken to avoid the soft tissues becoming attached to the screw, because this component cannot be used with a screw guide.



Final reduction

Tibial alignment is checked radiographically. The Orthofix alignment grid is a valuable aid^{13,14,15}.

Further reduction may be achieved after the frame has been applied. To do this, the two cams and the telescopic locking screws on each reduction unit must be loosened.

Following satisfactory reduction under X-ray control, the cams and telescopic locking screws are fully tightened. Care should be taken to ensure that as far as possible the reduction units are parallel to the long axis of the bone.

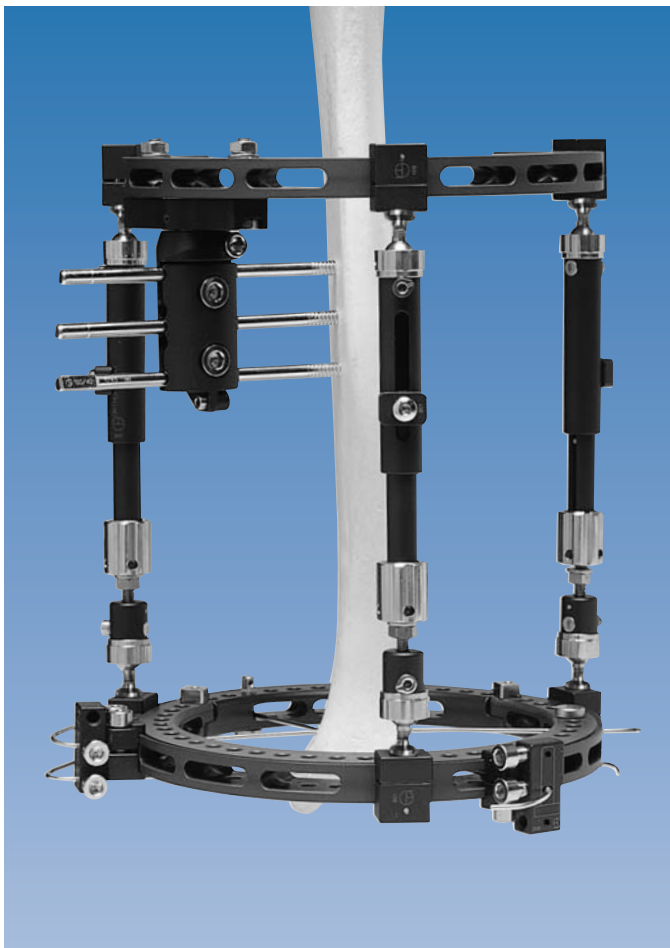


The micrometric mechanism in the reduction unit may be used post-operatively to adjust the length of the fracture.



Further stability may be required if the proximal tibia is comminuted or the soft tissues compromised. In this situation, the frame may be taken across the knee by the addition of a third ring and a second Sheffield Clamp attached to the distal femur. The Sheffield Clamp is connected to the proximal side of the femoral ring. It is then attached to the distal femoral diaphysis using two cortical screws (150/40 or 180/50mm) placed antero-laterally. The ring is then attached to the proximal tibial ring using three threaded bars and hinges.

If the articular fracture is difficult to reduce because of swelling or late presentation, reduction may be facilitated by initial mechanical distraction. A three ring construction is assembled similar to that required for bridging the knee joint (as described above) and applied to the leg. The proximal and distal rings are attached to the distal femur and mid tibial shaft respectively. The middle ring is slid 3-4cm distally to facilitate imaging of the plateau. Distraction is then applied between the two fixed rings.



Metaphyseal Fractures without Articular Displacement

Short oblique distal tibial fractures at the diaphyseo-metaphyseal junction and short spiral fractures involving the ankle joint may be fixed with a 2 ring system, 2 or 3 screws in the proximal segment and 3 or 4 wires in the distal segment.



Displaced Articular Fractures

Where there is articular involvement, the frame may be applied after limited percutaneous reduction of the major articular fragments using either interfragmentary screws¹⁶ or the Orthofix Fragment Fixation System implants. In this situation sufficient room (10-20 mm) should be left between the articular surface and the internal fixation to place the wires. More comminuted and unreconstructable fractures should be treated by trans-articular fixation and articulated distraction^{17,18,19,20,21} although in some cases a primary ankle arthrodesis²² using external fixation, should be considered.

OPERATIVE PROCEDURE

Preoperative assessment, planning and articular reduction are similar to those for the Proximal Tibial Metaphysis.

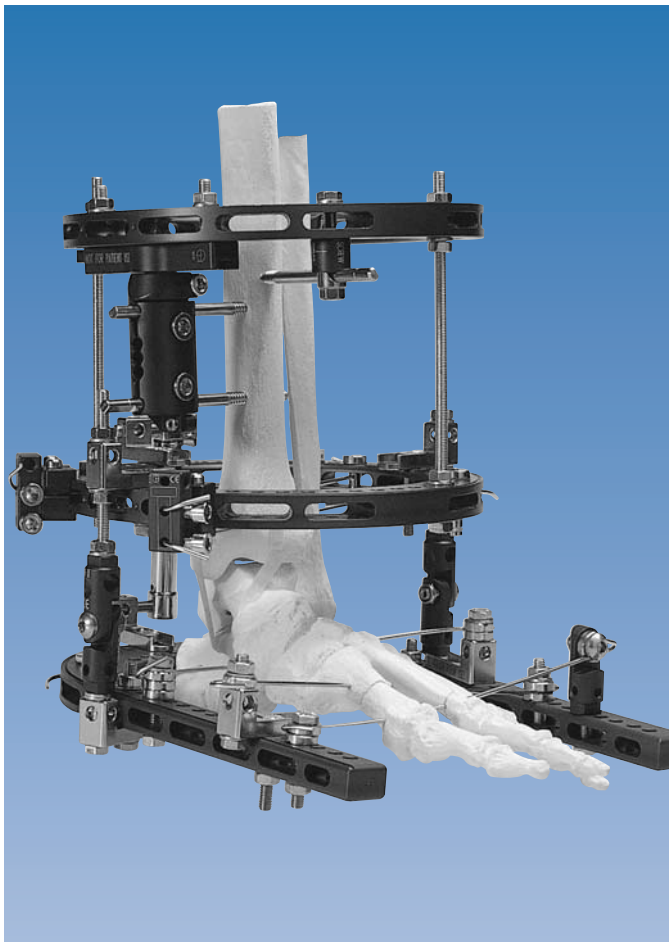
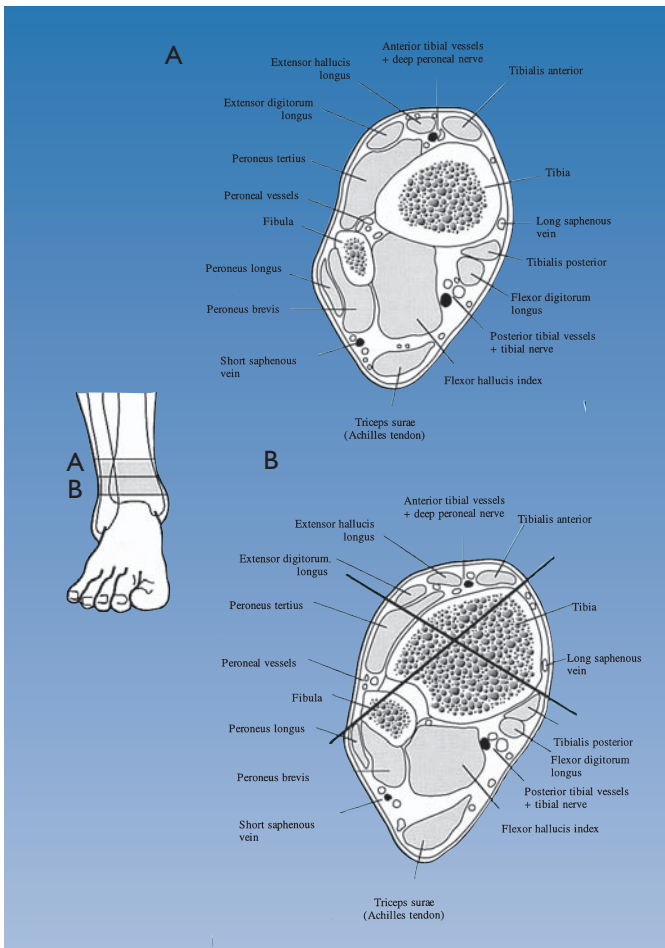
The metaphyseal ring is now placed around the ankle ensuring that it is parallel to the joint line in the AP view and at right angles to the axis of the leg in the lateral view. The ring is oriented so that the broad flange is anterior or externally rotated 5°-10° from this position, with the open area posterior.

Safe corridors for Kirschner Wire insertion

The first wire is trans-fibular from postero-lateral to antero-medial and is inserted between 5 mm and 10 mm from the distal articular surface of the tibia. It should pass medial to the Tibialis Anterior Muscle, thus avoiding the anterior tibial vessels. The crossing wire is from postero-medial to antero-lateral, and is inserted directly on to the subcutaneous edge of the tibia, thus avoiding the posterior tibial vessels and nerve. It exits lateral to the tendon of Extensor Digitorum.

If two levels of wires are used, the first trans-fibular wire should be inserted close to the articular surface of the tibia so that the more proximal wire remains close to, or immediately above the level of the inferior tibio-fibular joint, in order to avoid the peroneal vessels. All three neurovascular structures are potentially at risk. Transfixion of the Extensor Tendons must be avoided. Wires are generally well tolerated and crossing angles of between 60° and 70° may be achieved.

If the tibial plafond is too comminuted to insert two levels of wires, or where there is major soft tissue damage, the frame may be extended across the ankle. In order to achieve this, a foot ring is inserted around the os calcis and the forefoot.

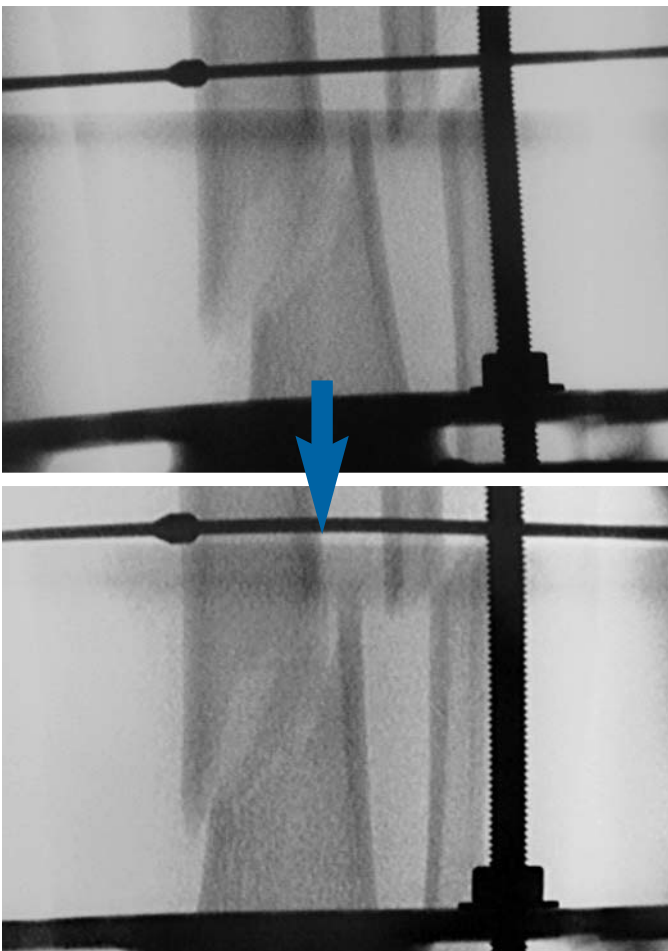


If the articular fracture is difficult to reduce because of swelling or late presentation, reduction may be facilitated by initial mechanical distraction. A three ring construction is assembled similar to that required for bridging the ankle joint (as described above) but without the forefoot fixation. The proximal and distal rings are attached to the mid tibial shaft and os calcis respectively. If the distal fixation is for distraction only, a single tensioned Kirschner wire inserted across the os calcis may be used. The middle ring is slid 3-4 cm proximally to facilitate imaging of the plafond. Distraction is then applied between the two fixed rings.

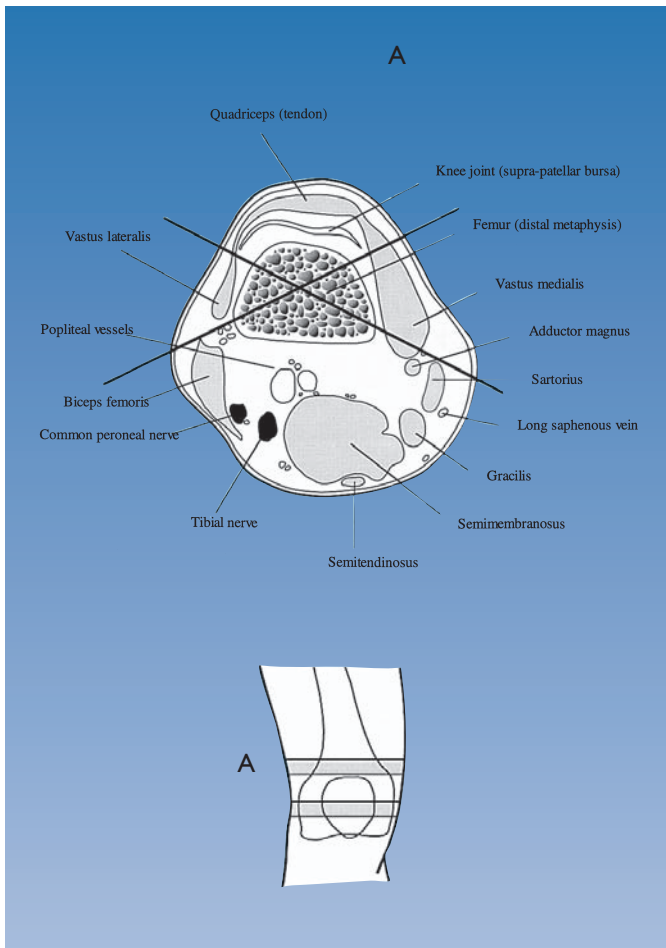
SEGMENTAL TIBIAL FRACTURES



Lengthy diaphyseal segmental fractures and fractures involving both metaphyses may require wire fixation of both metaphyses. Since one fracture often heals slowly, long term stable fixation is required, and the frame should be gradually reduced as the fractures heal. A three ring frame is constructed with either reduction units or threaded bars. Each fracture may be fixed and reduced separately around the middle ring which is attached to the diaphysis with a Sheffield Clamp and two cortical screws.



Unstable long oblique fractures may be stabilized and compressed using opposing central olive wires with washers. Each wire may be mounted away from the ring using either an independent wire clamp or a hinge clamp (page 7). The hinge clamp is applied directly to the ring or in conjunction with a threaded bar of appropriate length. The skin must be incised to permit passage of the olive through the soft tissues. Since the wires are suspended away from the ring, wire tension should be reduced to between 600 and 800N. Tensioning is performed on the side distant to the olive.

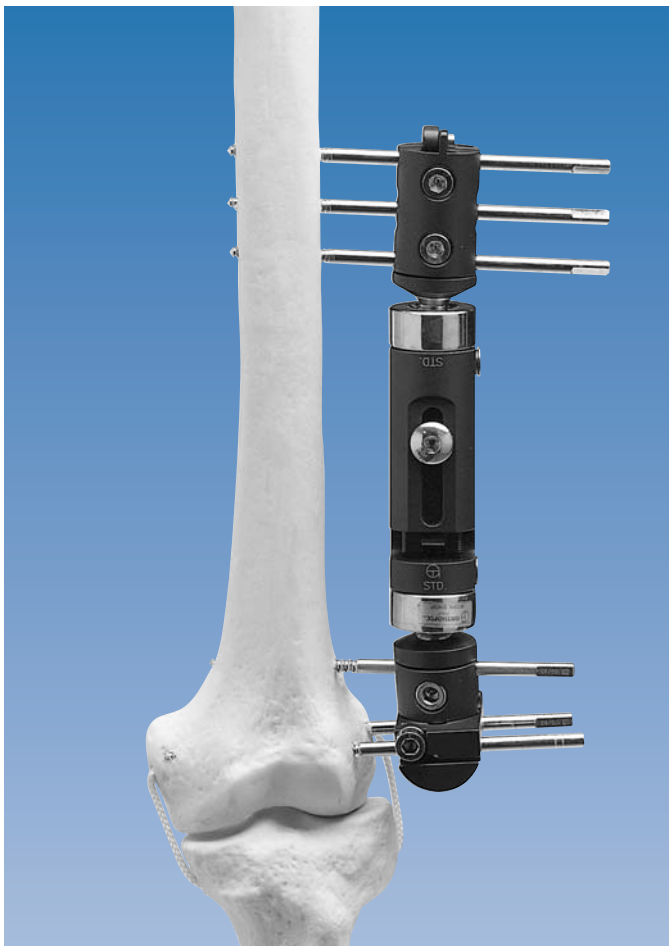


Wire fixation in the distal femur is problematic because narrow wire crossing angles produce instability in the sagittal plane and transfixion of the medial and lateral periarticular structures may lead to intractable knee stiffness. Early joint motion may be instituted, but soft tissue movement over the wires may result in discomfort and early loosening.

Safe corridors for Kirschner Wire insertion

The first wire should pass from postero-lateral to antero-medial, anterior to the Biceps Femoris Tendon, and the second from postero-medial to antero-lateral, anterior to the Sartorius. The wires should be inserted with the knee flexed and early joint movement encouraged.

It may be difficult to achieve crossing angles of more than 45°. In general, screw fixation is preferred to wire fixation, except in knee arthrodesis, where improved wire crossing angles may be achieved, as in this situation transfixion of the quadriceps and medial and lateral periarticular tissues is not a problem.

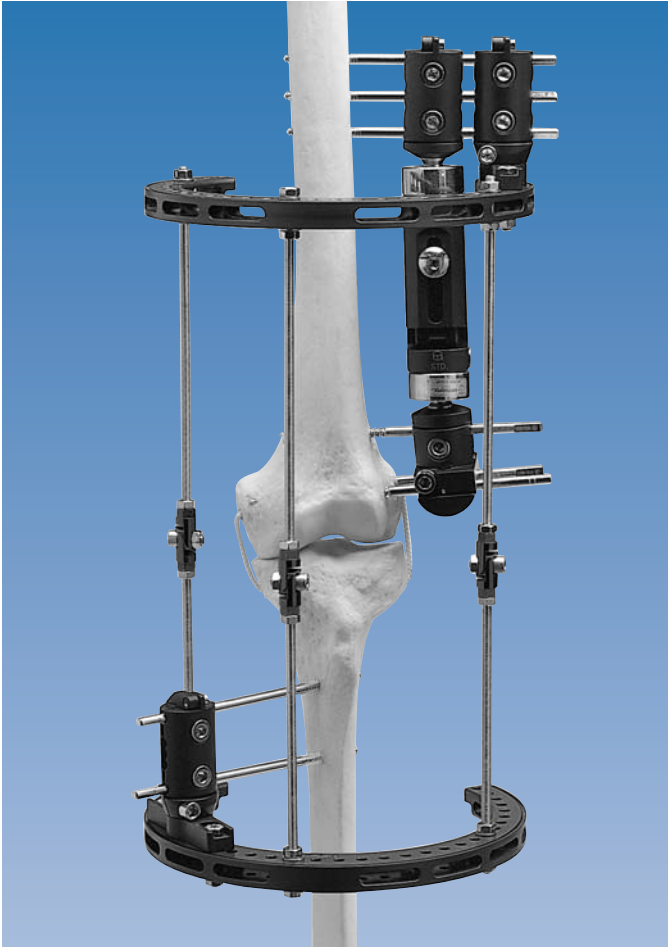


Monolateral fixation of the distal femoral metaphysis using either an Orthofix T-Clamp or preferably, a Metaphyseal Clamp, is recommended. A short or standard fixator body is selected depending upon the extent of the fracture. Stability will depend on the quality of distal screw fixation and the amount of fracture comminution.

OPERATIVE PROCEDURE

The intercondylar fracture is exposed and reduced using direct vision and imaging. Temporary fixation may be performed using K-wires. Careful planning is required since there is very little room to insert both cannulated screws and external fixation screws.

Bone screws are inserted just above the intercondylar notch using either a "T" or a Metaphyseal Clamp. There is some risk of fracture displacement during screw insertion. This may be avoided by drilling the external fixator screw tracks, leaving the drill bits in place, then inserting cannulated screws to compress the fracture. The skin is approximated and the drill bits are replaced with the external fixator screws. The metaphyseal fracture is then reduced, paying particular attention to the rotation of the limb. Two or three cortical screws with long screw shafts are inserted into the proximal femoral diaphysis and the fixator locked.



In more difficult situations, where there is a high degree of comminution or porosis, further stability is required. The system is used to extend fixation across the knee, providing three important benefits: a second level of fixation distally, neutralization of the lower leg lever arm and off-loading of the metaphyseal screws. The frame consists of two 2/3 rings connected by three appropriate length threaded bars and if necessary, hinges and two Sheffield Clamps. The proximal clamp is attached to the screw shanks of the proximal screw group (180-200 mm long screws should be used).

The knee is extended and two screws are inserted via a Sheffield Clamp attached to the distal ring into the proximal tibial diaphysis.

As healing progresses, the hybrid construct may be removed permitting knee exercises.

PIN SITE/WIRE SITE CARE

The visible parts of the screws and Kirschner wires, together with the surrounding skin should be cleaned on the day following surgery and at least once a day thereafter. Only sterile water should be used for this purpose. A dry absorbent dressing with additional gauze is used around the pin sites. After a few days, when they are dry, no dressing is needed.

Wires rarely require dressings unless skin releases are carried out. For the first 12 hours a padded dressing may be applied to the contralateral leg for protection.

There may be some loss of serous fluid from the pin sites, but this should not be mistaken for infection and is not a true complication. Normal pin site care is required.

Where inflammation is seen and the exudate is purulent, with the adjacent skin red and warm, a bacteriological swab should be taken and the appropriate antibiotic given for 7 to 10 days. Should local conditions not improve, more aggressive therapy may be needed, including possible removal of the screw(s) or Kirschner wire(s) involved.

If wire infection should occur, excess of soft tissue movement on the wires or loss of wire tension should be suspected.

Wire tension should be checked manually every two weeks. All securing elements, except for the wire locking screws, should be checked for tightness before discharge from hospital and every 4 weeks thereafter.

WEIGHTBEARING AND PHYSIOTHERAPY

Weightbearing and physiotherapy should be instituted in accordance with stability, and guidance derived from radiological assessment. Unless there is bone loss or instability associated with long spiral or segmental fractures, partial to full weightbearing is advised immediately post-operatively.

FRAME REMOVAL

This is a rapid procedure which can normally be performed in the outpatient clinic using an aseptic technique. The patient should be given an appropriate dose of paracetamol (acetaminophen) 30 minutes prior to frame removal. The skin is prepared and the screws controlling wire tension loosened. Each wire is then cut inside the ring at the end opposite the olive. The cut section of the wire protruding from the skin is then cleaned and the wire pulled out from the side of the olive. The ring must be held stable until all wires have been removed. Patients will generally tolerate the removal of up to four wires at any one time.

If wires with central olive have been used, the patient may experience increased discomfort and a small skin release under local anesthetic may be required.

These wires should **always** be removed by pulling on the end with the markings, which denote the position of the central olive.

Screws are easily removed by turning them counterclockwise, which will immediately loosen them since they are conical in design. If the patient is anxious, frame removal should be carried out under general anesthesia.

If the wires or screws are infected, the appropriate antibiotic should be administered orally, and frame removal delayed until the condition has improved.

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