

SOP Interlocking Plate System



 Standard Operating Procedure



SOP

Standard Operating Procedure

Introduction

This document provides guidelines for the use of the SOP Interlocking Plate System in veterinary surgery. SOP differs from other locking systems in two important ways: it can be contoured with 6 degrees of freedom without compromising the locking function and the system uses only conventional cortical bone screws.

Along with bench testing and mathematic modelling, the extensive experience and feedback from scores of boarded surgeons using the SOP in their clinics has informed the production of these guidelines. Locking plate systems are relatively new to orthopaedics and it is clear that some of their potential benefits are yet to be defined. However, what has become evident is that all locking systems differ and guidelines cannot be extrapolated to or from other systems. Surgeons considering an 'off label' use of SOP should do so with caution, and then only after detailed discussion with an experienced SOP user.

Background

The SOP was designed to serve as a locking plate system for the veterinary and human orthopaedic community. As with all locking plate systems, the SOP can be thought of mechanically as an internal/external fixator. The SOP consists of a series of cylindrical sections ('internodes') and spherical components ('pearls'). The larger system with a full compliment of instrumentation accommodates 3.5mm screws, the smaller system accommodates 2.7mm screws and the mini system accommodates 2.0mm screws. The cylindrical component, or internode, has an area moment of inertia (stiffness) that is greater than that of the corresponding standard DCP. Mechanical testing using ASTM methods has demonstrated that the 3.5mm SOP is approximately 50% stiffer, and has a bending strength (the load at which the plate plastically bends) of 16-30% greater than the 3.5mm LCP, DCP, or LC-DCP.

The SOP can be contoured in six degrees of freedom; medial to lateral bending, cranial to caudal bending, and torsion. Properly performed, contouring results in bending or torsion at the internode, preserving the locking function of the pearl. Mechanical testing has demonstrated that although bending a SOP will reduce its stiffness and strength by approximately one third, a SOP bent through 40 degrees remains almost (96%) as stiff as an untouched 3.5mm DCP. Similarly, a SOP twisted through 20 degrees remains significantly stiffer than the new and untouched 3.5mm DCP.

The spherical component of the SOP accepts a **standard cortical bone screw**. There is a section of standard threads within the spherical component, and a section into which the head of a standard screw recedes. As the screw head recedes into the spherical component, it comes into contact with a ridge causing the screw to press fit into the pearl. This press fitting prevents loosening of the screw during the cyclic loading of weight bearing, and results in a very rigid screw/plate construct. This concept removes critical limitations of current locking plate designs employing a hole with either single, double, or conical threads. The larger diameter part of the pearl receives a drill/tap guide and allows drilling, measuring with a depth gauge, and tapping of the screw hole, with standard instrumentation. The circular cross-section of the implant and the increased diameter of the pearls in comparison with the internodes give the implant a relatively consistent stiffness profile – the screw holes are not notable 'weak points'. The larger size of the pearl protects it against deformation during contouring or load bearing. The use of inserts ("bending tees") placed into the pearls protects the pearl absolutely and preserves locking function completely during contouring.

There is theoretical potential for the screw to cold weld over time, making it difficult to remove. However, this has not been seen in practice but should it happen, a section of the plate can be simply cut through an internode using a bolt cutter and the offending section removed. Not all screws are alike. The SOP is designed to be used with high-quality screws manufactured to standard tolerances for screw head and thread sizes. Self-tapping screws must have triple flutes so that consecutive screws will tap without lifting the plate away from the bone. Inferior screws with unsympathetic design and loose manufacturing tolerances are becoming more common in veterinary orthopaedic surgery as most orthopaedic companies outsource screw production. Such screws may not have sufficient quality control to work in the SOP system. Either use screws from Orthomed, or test several screws from a supplier.

Biomechanics

The biomechanics of interlocking plate systems differs fundamentally from conventional bone plates – extrapolation of experience gained using non-locking (loose screw), DCP systems, is not appropriate. Screws in conventional bone plates press the plate onto bone as the

screw is tightened. The threads of the screw pull and slightly deform the bone that the threads engage. Because bone is viscoelastic and remodels, the pull lessens over the first several minutes after plate application due to bone relaxation (material 'creep'). Further loss of tension occurs over days and weeks due to remodelling of the living, reacting bone. The oval holes that facilitate dynamic compression allow the screw to move slightly along the long axis of the plate as this bone relaxation and remodelling occurs.

In contrast, locking systems, including the SOP, will function invariably as 'buttress' systems – even when they are applied to an anatomically reconstructed fracture. The screws of interlocking plates act as transverse supporting members, subjected to cantilever bending. The primary loads on bone during weight-bearing are axial, along the long axis of the bone. Axial loads of a bone encounter a screw and the load is transferred at the bone/screw interface to the screw, then to the plate, then back to the screw on the other side of the fracture, then to bone. Here, there is no pulling of the plate down to the bone so the resistance to pullout of a screw is less relevant. Importantly, the screw is integrally and always part of the transmission of forces across areas of fracture.

Locking plate systems rarely utilize dynamic compression, and are invariably acting as buttress devices. The result of die back of bone, in the initial healing phase, and the reliance upon lag screws, wires or other mechanically inferior components within the reconstruction means that even where load sharing is achieved at surgery, locking systems invariably function in buttress mode.

With the difference in transmission of forces across the area of fracture, pullout strength of bone screws becomes far less important, making locking screw systems the preferred choice in cancellous or osteoporotic bone. Conversely, the fatigue life of the screw/plate interface increases in importance. Clinically, this manifests itself of relatively less importance in engaging two cortices with a bone screw, and of much greater importance in increasing the number of bone screws, unicortical or bicortical, to enhance fatigue life. While adding a unicortical screw may be of limited benefit with conventional plates, **unicortical screws, within a locking system, function effectively and are appropriate.** However mechanical testing of SOP constructs in a long bone fracture model has revealed that bicortical screws increase bending stiffness when compared to unicortical screws and unicortical screws are unlikely to effectively resist torsional forces

if used exclusively. Therefore in long bone fractures ideally at least one screw per fracture fragment should be bicortical and to increase the stiffness the number of bicortical screws per fragment can be increased.

This highlights an important mechanical feature of all interlocking plate systems including the SOP. Specifically, there is a distinct stress riser at the screw/plate interface where forces are transferred from a less stiff element (the screw) to a much stiffer element (the plate or SOP). If excessive force is cyclically applied across the fracture, the shaft of the screw will cold work and become brittle.

The yield point from elastic to plastic deformation will become less, and cracks will develop and propagate across the screw. This is fatigue failure and ultimately the screw will break. Theoretical considerations suggest that 4 screws in each major fragment is appropriate to protect the screws against fatigue failure.

The cross-sectional area of the 3.5mm SOP is πr^2 or 20mm². That of the shaft of a 3.5mm screw is about 5mm². Therefore, by installing four screws on either side of the fracture the shear area of the screws will approximately equal that of the SOP. Again, the screws may be unicortical although at least one screw should be bicortical in long bone fractures. Four screws per fracture fragment can be achieved by application of an additional SOP for example if the distal segment is short.

As the holes ('pearls') are no longer weak points empty screw holes are tolerated, even desirable, unlike with DCP plates where empty holes are contra-indicated.

A second SOP can be on the contralateral or orthogonal side of the bone, or two SOPs can be nested side by side. The use of an intramedullary pin (SOP-rod technique) enhances the stiffness of a construct to an extent which is not appreciated by many surgeons. The current clinical recommendation for DCP-rod constructs is to use an IM pin diameter of of 35-40% of the medullary cavity. Mechanical testing has shown a SOP-rod construct with an IM pin of 30% of the medullary cavity is as stiff as a DCP-rod construct with an IM pin of 40%. Therefore smaller diameter IM pins can be used with SOP plates allowing bicortical screws to be placed more often without a loss in stiffness of the construct. This increased stiffness substantially protects implants against fatigue failure and consequently, the use of

SOP

Standard Operating Procedure

SOP plates in pairs (for example, in the spine) or in conjunction with a rod (for example, in long bone fractures) should be considered the norm.

Bone slicing is a potential problem associated with the use of locking systems in poor quality bone. With conventional plating systems applied to weak cancellous or osteoporotic bone, screw pullout is the critical factor. However, with locking screw systems screws cannot pullout, especially if there is some divergence or convergence with screws. Instead, failure will occur through slow creep of the screw through the weak bone, known as 'bone slicing.' Therefore, as locking plate systems are preferred in weak or osteoporotic bone, they may still exhibit this mode of failure if the bone/implant system used is not sufficiently robust. Bone slicing has not been identified in SOP cases so the importance of this phenomenon in veterinary patients is not yet known.

Bending Techniques

Bending irons have been developed for the SOP plates to allow controlled bending and twisting of the plate. In bending the irons 4-point bending is achieved which when compared to traditional bending irons used on standard bone plates achieves a smooth uniform bend as opposed to a 'crease' in one point on a traditional plate. The SOP bending irons control where the bend will occur and at all times the functional integrity of the hole is preserved.



01 Prior to bending and twisting every hole in the SOP should be loaded with a SOP bending Tee.



02 The SOP plate should be loaded in the bending irons on adjacent pearls.

03 The bending irons work at their best if brought together rather than pulled apart.

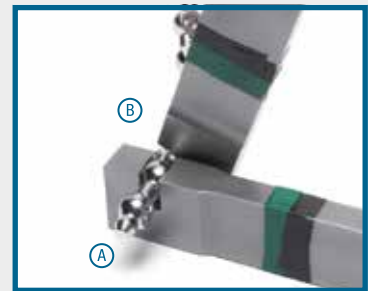
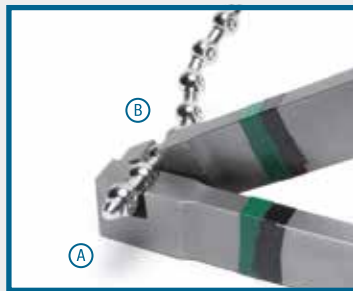
SOP

Standard Operating Procedure



- 04** The orientation of the SOP plate in the bending irons can be varied through 360° to determine the nature of the bend in the plate. The SOP can be bent up-down/down-up/side-to-side or indeed any angle in between.

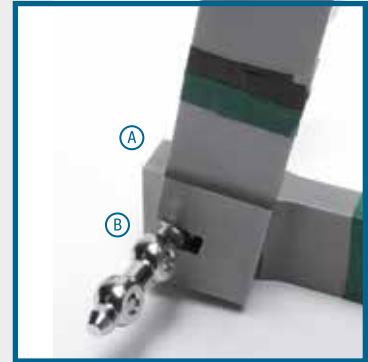
Twisting Techniques



- 01** The twisting end of the irons are placed onto adjacent pearls. Note the 'offset' due to differing angulation of the twisting slot within the irons. Drawing the irons apart (elevating iron B) will produce a clockwise twist in the internode between A and B. If it is necessary to twist and bend at the same internode it is essential to twist first.

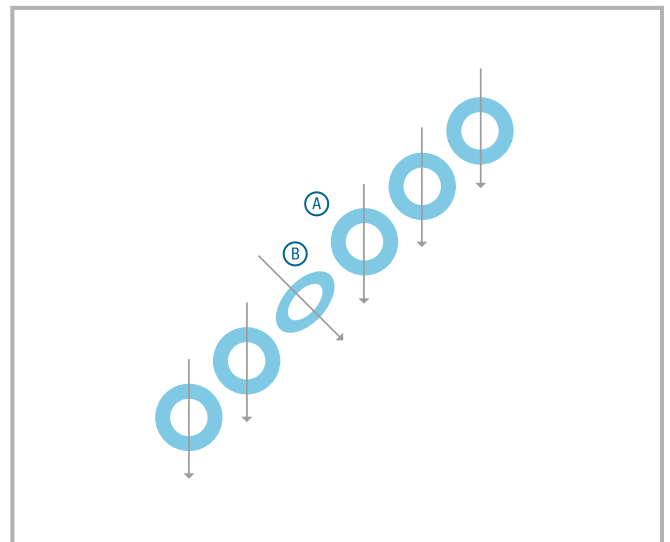
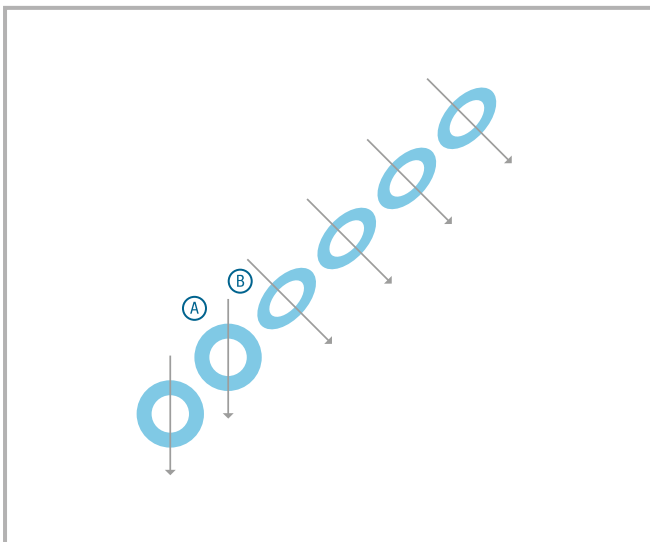


APPROX 20° TWIST



APPROX 70° TWIST

02 Twisting irons are placed onto another pair of adjacent pearls. Note that the twisting irons B and A have been switched and also that this has resulted in the 'offset' changing. Now when the twisting irons are drawn apart the result is a counter-clockwise twist in the SOP.



INDICATES SCREW ANGLE FOLLOWING TWISTING

SOP

Standard Operating Procedure

Drilling and Tapping



01 The dedicated SOP drill guide is used to drill (and tap, if using standard thread screws).



02 After the screw has been selected it is useful to know its position in the SOP as you progress through the plate. When you have placed the tip of the screw into the plate, reverse the thread as if taking the screw out. You will feel the start of the screw thread click into the threads within the pearl. If at this point you then advance the screw by 1 full revolution you will end up with the tip of the screw just protruding from the underside of the pearl as below. This results in the screw hole being tight up against the bone as below:



- 03** To stand the plate off the bone, the screw should be advanced through the plate before engaging bone. For each complete revolution the screw will advance 1.25mm.

Application Techniques: Appendicular Skeleton

The primary utility of the SOP in the femur, humerus, tibia, radius, and ulna is in comminuted fractures. Although the SOP can be used in conventional ‘open approach’ fracture surgery, it is especially valuable with so-called biologic fixation methods and minimally invasive techniques. For example, techniques involving SOP and screws installed with stab incisions or mini-approaches, or more open approaches where the area of comminution is preserved. This is known by some as the ‘open-but-do not-touch’ (OBDT) method.

The comminuted, diaphyseal femoral fracture is used as an example of standard SOP methods.

Comminuted diaphyseal femoral fractures are best repaired using the SOP in combination with an intramedullary pin; SOP- Rod fixation. A standard surgical approach appropriate to the specifics of the fracture is made. An intramedullary pin similar in diameter to the internode of the selected SOP is chosen and placed normograde from the intra-trochanteric fossa, threading the area of comminution, into the distal femoral segment. Retrograde pin placement can be used. The limb is aligned with reference to adjacent anatomical landmarks. In the femur,

the coxofemoral joint should be in slight anteversion while the stifle is flexed. An elevator is passed along the lateral aspect of the femur, under the biceps and vastus to create a tunnel into which the SOP plate will be placed. Inserts should be placed into all the SOP holes **before** contouring to prevent distortion of the holes. A SOP plate of appropriate length is contoured: it is helpful to have radiographic images of the opposite, un-fractured femur to guide the contour. The contour does not have to be perfect, as the SOP does not need to lie directly on bone. The distal aspect of the SOP can be contoured to follow the femoral condyles caudally and the proximal SOP can be twisted directing the screws antegrade into the femoral neck. The SOP is placed in the soft tissue tunnel, and contour is reviewed. Four screws should be engaged on each side of the fracture. Unicortical screws are appropriate and three or four “empty” screw holes – even over the fracture – are desirable. The IM pin will prevent bending of the SOP, so there may be a long area without screws in the centre of the femur.

The drill guide is placed into a screw hole on one end of the bone and the remaining screw holes observed to make sure the SOP is positioned properly. Remember that the screw will always be directed perpendicular

SOP

Standard Operating Procedure

to the spherical component of the SOP so it is essential to ensure that all planned screws will engage bone. Though you can twist the SOP to change screw direction, this is done prior to installation of screws.

The drill and tap guide will direct the drill and tap in the proper direction. The insert is removed from the SOP at the first screw location, either proximal or distal. The drill hole is made using the drill guide, and then the depth measured. A screw is placed. Self tapping or pre-tapped screws can be used according to surgeon preference. It is possible for the tap/self-tapping screw to not engage the bone hole immediately. This results in the SOP being pulled too far away from the bone. This can be prevented by applying gentle axial pressure during early placement of the tap/self-tapping screw. Note also that when using a bone tap, care must be taken subsequently when placing the screw to ensure that the screw threads engage in the bone as desired and not 360° later.

The screw should be tightened so that the screw head seats firmly into the spherical component of the SOP. If a unicortical screw is placed, the depth gauge measures the minimal length the screw needs to be by the standard method of hooking the near cortex. Then the depth gauge is advanced to the transcortex or, in some cases, the intramedullary pin. A screw 2-4mm longer than the measured minimum distance is chosen. Measuring the distance to the transcortex or intramedullary pin will assure that an oversized screw will not interfere with any structure. The same procedure is repeated for all screws.

Applying a SOP is similar to standard ORIF principles and procedures with these notable exceptions: the SOP does not need to lie directly on the outer cortical surface. It should be placed close to the bone to keep its profile as low as possible, but might contact the bone in a few locations or not at all. This preserves the periosteal blood supply of the bone and healing callus. The screw will tighten into the plate; this does not assure that the screw is in solid bone. However, locking screws are better for soft or osteoporotic bone as screw thread holding power is not the method of transmission of forces. Some divergence of screws is desirable. The SOP can be contoured in six degrees of freedom. It is possible, and sometimes desirable, to contour the SOP in non-standard shapes, to follow the fracture configuration or tension surface of a bone. The SOP can be contoured into a spiral for example.

Technical Guidelines

Note well that these are guidelines and not rules. They are provided to experienced, knowledgeable sensible surgeons with the assumption that such experience, knowledge and common sense will be brought to bear on each individual case.

Femur

SOP-Rod

IM pin 20%-40% diameter of medullary cavity (see page 3),

Normograde or retrograde.

Open or closed placement.

4 screws in distal and 4 screws in proximal fragments.

Single 2.0mm SOP (plus rod) in patients up to 5kg (lateral aspect)

Single 2.7mm SOP (plus rod) in patients up to 10 kg (lateral aspect).

Single 3.5mm SOP (plus rod) in patients up to 35 kg (lateral aspect).

Double 3.5mm SOP (plus rod) in patients over 35 kg (lateral aspect).

Humerus - Diaphysis

SOP-Rod

IM pin 20%-40% diameter of medullary cavity (see page 3),

Normograde or retrograde.

Open or closed placement.

Bed into medial epicondyle.

Consider reverse placement through medial epicondyle in very distal fractures, 4 screws in distal and 4 screws in proximal fragments.

Single 2.0mm SOP (plus rod) in patients up to 5kg (lateral aspect)

Single 2.7mm SOP (plus rod) in patients up to 10 kg (medial aspect, lateral aspect or "spiral").

Single 3.5mm SOP (plus rod) in patients up to 35 kg (medial aspect, lateral aspect or "spiral").

Double 3.5mm SOP (plus rod) in patients over 35 kg (medial aspect, lateral aspect or "spiral").

SOP

Standard Operating Procedure

Fractures Humerus - Elbow 'Y' or 'T'

Combined medial and lateral approaches.

Anatomic reconstruction with lag screws, K wires etc.

Two SOPs, one medial and one lateral.

Total of 4 SOP screws in reconstructed condylar fragment (not necessary to have all 4 screws in the same SOP).

Total of 4 screws in proximal major fragment (not necessary to have all 4 screws in the same SOP).

Two x 2.7mm SOPs in patients up to 20 kg.

One 3.5mm and one 2.7mm SOP in patients 20-35kg

Two x 3.5mm SOPs in patients over 35 kg.

Tibia - Diaphysis

IM pin 20%-40% diameter of medullary cavity (normograde) (see page 3).

4 screws in distal and 4 screws in proximal fragments.

Single 2.0mm SOP (plus rod) in patients up to 5kg (lateral aspect)

Single 2.7mm SOP (plus rod) in patients up to 10 kg (medial aspect).

Single 3.5mm SOP (plus rod) in patients up to 35 kg (medial aspect).

Double 3.5mm SOP (plus rod) in patients over 35 kg (medial aspect).

Ulna – Radius

Small IM pin in ulna (normograde or retrograde).

SOP on radius (4 screws in proximal and 4 screws in distal fragment).

SOP on medial or dorsal aspect distally.

SOP on cranial aspect proximally.

Avoid overlong screws transfixing radius and ulna.

2.7mm SOP in patients up to 10 kg.

3.5mm SOP in patients over 10 kg.

Spine - Fractures or Distraction-fusion

The SOP serves well as a locking spinal fixation system, much like a pedicle screw system or locking cervical fusion device. It does not lag onto bone which accommodates irregularities of the vertebral column. The SOP is applied to the dorsal lateral aspect of the spine, directing the screws at 30 to 40 degrees from the mid-sagittal plane into the vertebral bodies. Two SOP plates are applied to the left and right sides of the spine. With vertebral luxations, two three-hole SOPs with three screws in the vertebral bodies on either side of the luxation. With vertebral fractures or instabilities, longer plates are applied and may engage two vertebrae on either side of the instability. As the SOP is not lagged onto bone, the irregularities do not pose a problem as seen in applying standard orthopaedic plates. The cylindrical shape lies on the pedicle and avoids compression of nerve roots exiting the intervertebral foramen. As the angle of screw placement is greater in the thoracolumbar area compared to the lower lumbar area, the SOP can be twisted to vary the screw angles.

The SOP can be used for cervical fracture repair, or cervical fusion in cases of instability. Two SOPs are applied to 4 adjacent vertebrae. In this way a minimum of 4 screws are on either side of the fracture or instability. The screws are directed slightly laterally. The screws need not penetrate the vertebral canal. It is important to direct the screws without damaging the spinal cord, nerve roots, venous sinus, or vertebral artery.

SOPs should always be used in pairs.

Cervical – ventral aspect of vertebrae.

Thoracic, T-L, Lumbar - SOPs bilaterally on lateral aspects with screws directed ventro-medially.

Lumbo-sacral – bilateral SOPs with screws directed ventro-medially into lumbar vertebral bodies.

Caudally the SOP can be twisted and contoured to engage the iliac shaft.

Minimum of 3 screws in each vertebral body (not necessary to have all screws in the same SOP).

Use longest possible screws to engage maximum amount of vertebral bone.

Penetration of far cortex is not essential.

Stand SOP off spine to avoid damage to emerging nerve roots.

2.7mm SOP in patients up to 10 kg.

2.7mm and 3.5mm SOPs can be used in combination.

SOP

Standard Operating Procedure

Pelvis

SOP can be used successfully in most pelvic fractures. The reconstructed pelvis is inherently fairly stable by virtue of its shape and extensive musculature and potentially disruptive forces tend to be very much smaller than those encountered in long bone fractures. Consequently, pelvic implants can be relatively smaller than those needed for long bones and, similarly, pelvic fracture fragments can often be effectively stabilized with relatively few screws.

Ilium

Gluteal roll-up approach – can be extend-caudally by trochanteric osteotomy.

SOP applied to lateral aspect of pelvis.

Minimum 2 screws cranial and 2 screws caudal.

Twist SOP cranially to optimise stability in thin bone.

2.0mm SOP in patients up to 7.5kg

2.7mm SOP in patients up to 20 kg.

3.5mm SOP in patients over 15 kg.

Acetabulum

Open reduction and temporary fixation with K wires, bone forceps etc.

SOP applied to dorsal aspect of acetabulum.

Minimum 2 screws cranial to fracture and 2 screws caudal to fracture.

Single locked screw in stable butterfly fragment is acceptable.

2.0mm SOP in patients up to 7.5kg

2.7mm SOP in patients up to 35 kg.

3.5mm SOP in patients over 35 kg.

Miscellaneous Applications

SOP has been used successfully in a variety of other situations including shoulder arthrodesis, pan-tarsal arthrodesis, and augmentation of TPLO and TPO procedures and in the revision/salvage of failed fracture and arthrodesis surgeries. The information provided in these guidelines and the recommendations given for 'standard' cases will provide the surgeon with a starting-point for implant selection and surgical planning in non-routine applications.

Hints and Tips from the Sawbone Workshop

Femoral Fracture



01 An appropriate IM pin is selected along with a suitable length plate.



02 The plate is contoured after the addition of the SOP bending tees.

SOP

Standard Operating Procedure



03 The first screw is placed and the orientation of the remaining screws is checked.

Note: The use of unicortical screws is acceptable and makes the application of the plate easier where the IM pin is located. Striv to have at least one bicortical screw to maximise torsional stiffness.

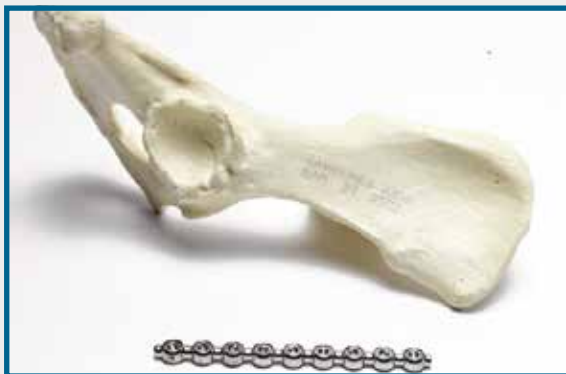


04 It is important to have several empty screw holes over the fracture site.



05 Perfect contouring is not necessary.

Acetabular Fracture



01 An appropriate plate is selected. In this case a 9 hole 2.7mm SOP. It is loaded with bending tees and contoured appropriately.

SOP

Standard Operating Procedure



02 Check orientation and alignment of screw holes.

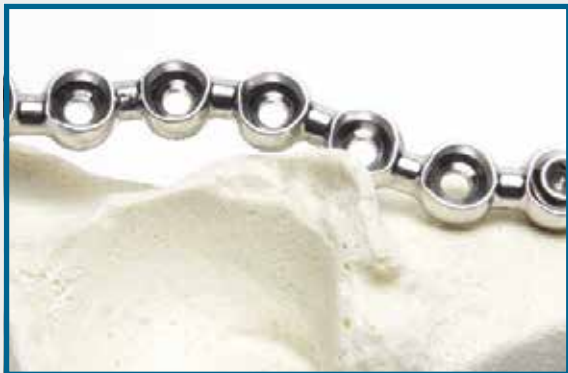


fig 3.1



fig 3.2

03 Correct alignment of the first screw is vital as all other screws will fit perpendicular in the remaining pearls. Fig 3.1 highlights the effect of an incorrectly placed 1st screw. Fig 3.2 shows correct orientation. Note: If after the insertion of the first screw alignment of the SOP is incorrect two options are open to the surgeon; 1. Remove SOP, re-attach with correct alignment using a different screw hole; or 2. Remove the SOP and re-contour around the original hole.



04 Note the effect of twisting the end screw holes, these divergent screws significantly enhance pull-out resistance.



05 The rest of the screws can be placed. Note the minimal bone contact.

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