Lo SCALPELLO Journal (2024) 38:61-69
doi number: 10.36149/0390-5276-315

InFix – a technique for anterior subcutaneous pelvic internal fixation in the management of pelvic ring injury

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Summary

The anterior subcutaneous pelvic internal fixation or ASIPF tecnique, more commonly known as INFIX, has been described and utilized since 2008 as an innovation in the traditional management of pelvic injuries [1]. The purpose of this article is to identify indications, describe the technique, equipment, review clinical and radiographic outcomes, complications and technical tips on the utilization of pelvic INFIX. The main indication is represented by anterior stabilization of unstable pelvic ring injuries, following the appropriate posterior fixation, particularly in large, obese patients. Pooled analysis showed overall good radiological (mean percentage of excellent to good reduction = 91.4%, 95% CI 0.860-0.969) and functional outcomes (mean Majeed score = 86.48, 95% CI 83.34-89.61) with InFix [2,3]. The INFIX and the appropriate posterior fixation results in healing of pelvic ring injuries in 99.5% of cases [4]. This technique can be considered as a viable alternative to anterior symphysis pubis plating or to applications of anterior pelvic external fixators. It has the advantage of less blood loss, better nursing for the patients, rapid recovery along with comparable functional outcomes, when compared to plating and an overall better tolerability by the patients when considering application of classic pelvic external fixators.The most common complications is lateral femoral cutaneous nerve (LFCN) injury (overall rate 28%, 95% CI 15.1-41% usually resolves at removal) and heterotopic ossification (HO) (overall rate 9.4%, 95% CI 5.5-13.3%), infection 1-3% [4,5].

Key words: pelvic ring injury, pelvic fracture, anterior pelvic ring injury, anterior fixation, anterior subcutaneous pelvic fixation, ASIPF, INFIX

Received: May 7, 2024
Accepted: June 7, 2024

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How to cite this article: Vaidya R, Court T, Morandi M "Max". InFix – a technique for anterior subcutaneous pelvic internal fixation in the management of pelvic ring injury. Lo Scalpello Journal 2024;38:61-69. https://doi.org/10.36149/0390-5276-315

Introduction

Unstable pelvic ring injuries are severely debilitating, lifethreatening injuries that require emergent or urgent intervention as part of trauma life support, damage control orthopedics [1]. External fixation (Ex Fix) of a pelvis has many shortcomings, remaining a cornerstone for its utilization as an anterior pelvis external fixator for emergent temporary stabilization of a pelvic ring injury. Drawbacks on the other hand include pin site infections that affect 25-50% of patients, osteomyelitis affecting 7% of patients, loosening of the pins, loss of reduction in up to one third of patients, challenges associated with obese patients, particularly nursing and pin site care, limitations with mobilization and sitting up [1,6-12]. Furthermore, any prone

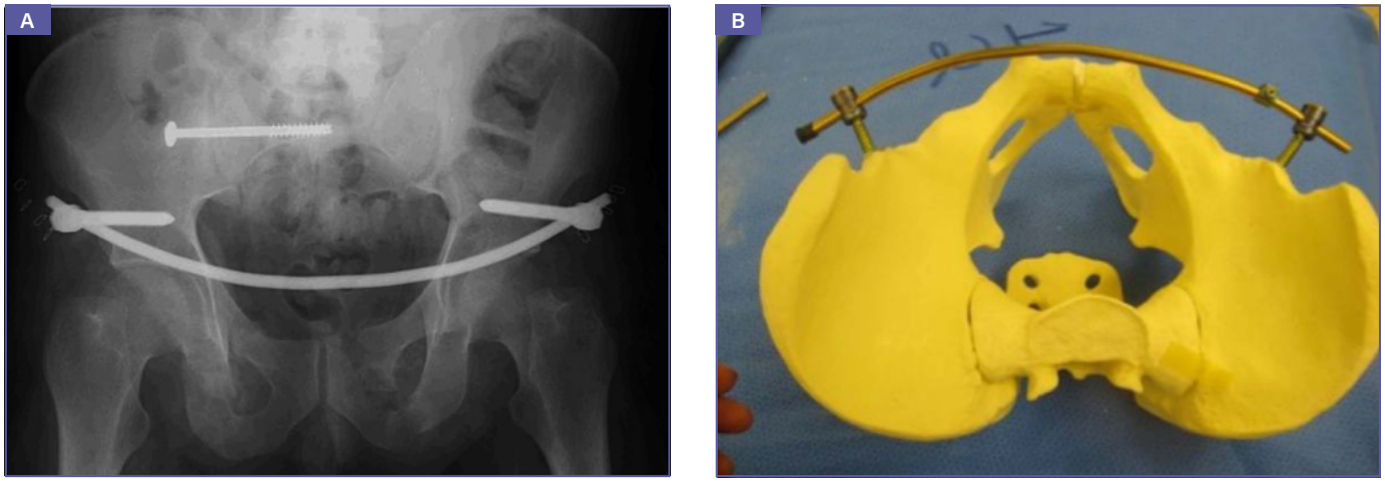


Figure 1A-B. Example of INFIX, with supra acetabular pedicle screws connected with a subcuta-neous titanium rod.

positioning for surgical approach to the spine is problematic. With the aim of improving patient comfort and minimizing the complications associated with an external fixator, the leading author Dr. R.Vaidya, popularized a technique using the established principles of anterior external fixation, but with internal implants [5]. The technique consists of single supra acetabular pedicle screws placed in each ilium, connected with a subcutaneous titanium rod, which is described as an anterior subcutaneous pelvic internal fixator (ASPIF); it is designed to be used in conjunction with posterior pelvic stabilization to effectively manage a pelvic ring injury, without the shortcoming associated with an external fixator (Fig. 1A-B).

Compared with external fixation, the INFIX is a biomechanically stronger construct due to its shorter working distance from the pelvis. The internal nature of the implant also allows it to be a definitive fixation construct, which improves patient comfort and mobility compared to the more cumbersome ex fix that may hinder ambulation [15,16].

Furthermore, INFIX has been used for definitive fixation in patients that are not ideal surgical candidates or do not wish to undergo multiple surgeries [16]. This paper is a technical guide for the effective implementation of an INFIX, providing an overview of tips that will help preventing known complications associated with its application. Minimally invasive techniques have become more popular recently in the management of pelvic injuries due to their lower incidence of surgical morbidity [10]. The application of a pelvic internal fixator (INFIX) has been presented as a comparable alternative to external fixation of anterior pelvic ring injuries. An INFIX involves the insertion of spinal pedicle screws in the anterior pelvis (supra-acetabular entry) and the placement of a connecting rod in the subcutaneous tissue of the patient [16]. The INFIX may be augmented with other pelvic fixation as dictated by the nature of the injury and it is generally removed at a minimum of 3 months after insertion, once fracture union has occurred.

Indications

The treatment of an unstable pelvic ring injury such an open book, has two stages. Stage one is a closed reduction of the pelvic volume via sheets, binder or external fixation, to provide a tamponade effect to any associated bleeding [11,12].

Stage two is definitive reduction and fixation.

Stage 1: temporary emergent stabilization

In patients presents with shock and severe, life threatening pelvic ring injury, emergent application of a pelvic sheet and initiation of transfusion protocols is paramount [13]. In the presence of an intra-abdominal or thoracic hemorrhage with an associated unstable pelvis, it is advice to accompany the general surgery trauma team to the operating room in order to apply an anterior external fixator before an exploratory laparotomy [13]. Insertion of an iliosacral resuscitation screw if warranted to provide further pelvic ring reduction [13]. These interventions are performed prior to preperitoneal pelvic packing (PPP) [14]. If the patient is still hemodynamically unstable with no other sources of hemorrhage identified, he is taken to the interventional radiology suite for selective arterial embolization. An INFIX is not used in emergent situations because the equipment is not always readily available and the EXFIX can be applied quicker.

Stage 2: definitive fixation

Definitive posterior fixation is performed once the patient is hemodynamic stable and adequately resuscitated. It starts with a closed reduction with the patient supine, traction applied to the unstable side with the hip in 30 degrees of flexion. Percutaneous techniques to reduce and stabilize the posterior ring with cannulated 6.5 mm up to 8 mm Sacro-Iliac screws under fluoro radiographic imaging are utilized. If closed techniques fail, the

first window of the ilioinguinal approach is used to access the sacroiliac joint or iliac wing fractures for a direct reduction. Other options include application of a Synthes C-Clamp on the greater trochanters to provide compression and stabilize the pelvis. For displaced sacral fractures, the patient is positioned prone followed by triangular lumbopelvic fixation. Regardless of approach or position, final pelvic ring stabilization is achieved with iliosacral or trans-sacral screws depending on the osseous morphology of the sacrum and ideal screw trajectory to reduce the pelvic ring.

Anterior fixation

The INFIX is a good option for anterior ring fixation, requiring:

- surgeon expertise: INFIX requires a mental attitude of a trauma ortopedic surgeon and a spinal surgeon combined. If surgeons are not comfortable with pedicle screw instrumentation or the INFIX surgical approach, they should use a traditional external fixator which has been the standard of care for several decades [13]. Femoral nerve or vascular compression are complications likely related to surgeon inexperience (placing the bar too deep, closed to the bone surface) [3]. Heterotopic ossification (usually asymptomatic) and lateral femoral cutaneous nerve irritation are common and unrelated to experience [15].
- equipment: INFIX requires a unique combination of implants that do not yet come in a standardized set or are sold by a specific company. Thus, time and planning are required prior to assemble the different components. Standard pedicle screw sets are outfitted with a maximum of 60 mm screws and these are typically too short for the INFIX design. Pedicle screws measuring at least 100 mm or Schanz pins 150 mm long need to be requested. In APC 3 injuries, it is suggested to use a monoaxial system with strong connectors, from Synthes-Johnson and Johnson or Medtronic [15].

Anatomy of the anterior injury

INFIX can be used for any rami fracture, saddle injuries or combined symphyseal and rami injuries, but there are injuries that are better served by open reduction and internal fixation (ORIF) with plates.

Symphyseal disruption: when the anterior pelvic injury is a symphyseal disruption, ORIF with a plate is a procedure orthopaedic trauma surgeons are familiar with and usually results in an anatomic reduction with good outcomes [1].

Acetabulum combined with a pelvic ring injury: the indirect reduction that one can achieve with an INFIX is adequate for most pelvic injuries (0.5-1 cm tolerance). But when the anterior ring injury also involves the weightbearing portion of the acetabulum, then a direct reduction is achieved by stabilization with plates and screws for the acetabulum and anterior ring.

Instruments/implants required for INFIX

The most frequently used implant for fixation into the anterior pelvis is a 7.0-8.5 mm polyaxial screw [15], ease to use when applying the titanium rod. Other implants that can be used based on the system or preference include screws varying from 6.5-9.0 mm or Schanz pins. Schanz pins are particularly helpful in morbidly obese individuals, as they can be up to the 150 mm long. For less obese individuals, ideal lengths of polyaxial screw fixation should vary from 80-120 mm. Caution should be taken when using screws shorter than 80mm as the minimum distance through bone to the sciatic notch is 60 mm and this does not account for measuring to just below the skin. A 5.5-6.5 mm titanium rod should be contoured and sized in accordance to the bikini line and the starting points [15-19]. Excess rod should be cut with a large rod cutter with 1cm remaining past the level of the two fixation points, which is typically performed after the rod is placed. The other equipment needed include a rod holder, a rod bender, a spinal distractor and compressor and c-rings (Fig. 2). The following instruments are required on a separate side table: a) A 4.8 mm K-wire, b) trocars and sleeves, c) wound retractor, d) tapping tool, e) screw driver, f) two screws 6.5 mm, g) flexible rod, h) titanium rod, i) instrument for insertion and manipulation of titanium rod, j) rod bending devices, k) covering caps on screw driver,l) counter holder (Fig. 2).

Anatomy

To start the case, the anterior inferior iliac spine (AIIS) should be identified by direct palpation. If palpation is limited based on obesity or alterations in the normal anatomy, an obturator outlet view should be obtained. In this view, the teardrop should be identified, and this can be used as the incision starting point. The focus of the approach for both the incision and placement of the INFIX is in regard to the "bikini line" [16]. This line is easi-

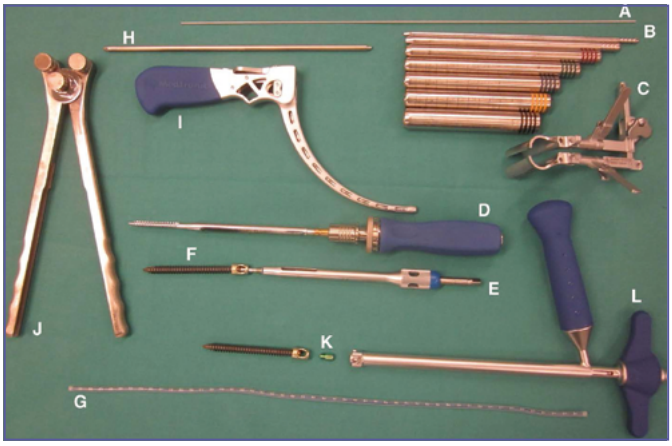


Figure 2. Equipment needed for application of INFIX.

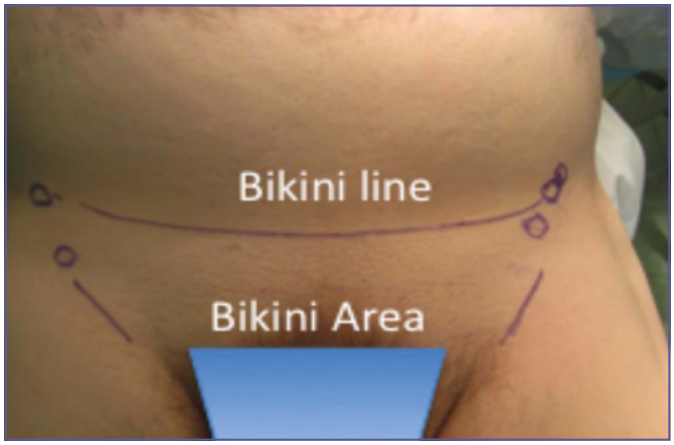


Figure 3. "Bikini line" where titanium rod is positioned subcutaneously.

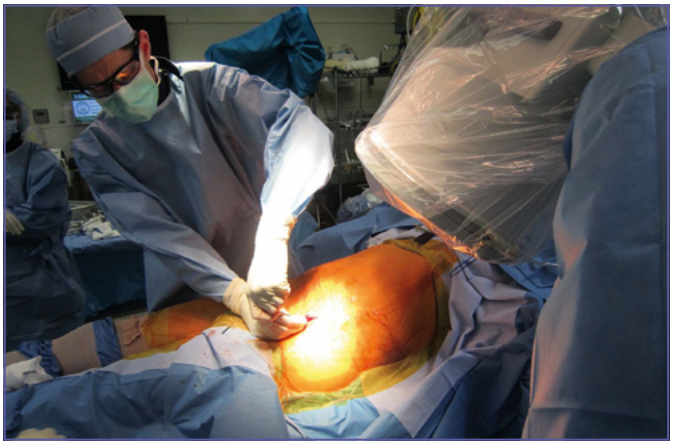


Figure 4. Iliac oblique projection to facilitate the screw insertion

ly identified on all individuals as the crease that forms between the abdominal skin and its associated fat and the suprapubic flat region it is easily identified as the constant region between when someone is sitting/flexed and when someone is standing/neutral [17] (Fig. 3).

When making an incision and placing the titanium rod, both should be in line with the bikini line as it does not move with flexion and extension and scarring is more cosmetic in the future and the rod placed below it.

Important anatomic landmarks and features to note in the placement of an INFIX include the lateral femoral cutaneous nerve (LFCN), the femoral nerve, and the femoral artery. The lateral femoral cutaneous nerve is just lateral to the incision and can be compressed with the INFIX construct, put on tension with retraction, and can be lacerated with the approach and care should be taken to avoid all of these. In the case of compression, elective implant removal after adequate bone healing commonly resolves the paresthesia anesthesia, but permanent impairment has been reported [18-20]. The femoral nerve and artery are found within the femoral triangle. Though the femoral triangle is not directly visualized in the approach, care should be taken to keep the INFIX construct superficial enough to not compress either structure [21].

Exposure

The incision is a 3-4 cm oblique incision centered over the tear drop and in line with the bikini line to increase cosmesis. If using the tear drop as your landmark for your starting point, the authors have routinely found this to be just lateral to the AIIS, correction should be made before screw insertion to account for this. As a reminder, just lateral to this incision will lie the lateral femoral cutaneous nerve. The first interval to cross through is between the tensor fascia lata and the sartorius muscles. Upon separating this interval as small protuberance can be palpated, this is the AIIS. Utilize two small Hohman retractors or a self-retaining retractor to easily visualize the starting point.

Screw insertion and trajectory

Imaging for proper screw insertion utilizes the iliac oblique view with the AIIS as your landmark. The screw should be angled at least 1 cm above the acetabulum and this location acts as your starting point (Fig. 4).

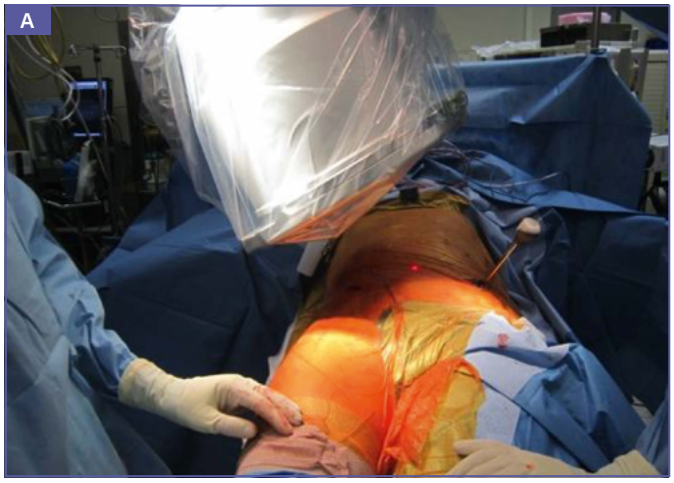
The iliac oblique view will also be used to ensure the drill or pedicle awl stays above the level of the sciatic notch (Fig. 5).

This view should be alternated with the obturator inlet view. This view will help to maintain the drill or pedicle awl between the two tables of the ilium (Fig. 6).

Measurement of the screw is from the sciatic notch to the skin. The goal should be to have the final construct superficial enough to prevent compression of the contents of the femoral triangle and deep enough to not overly tent the bikini line. The authors perform this by removing 5 mm from the measured length. This amount can vary in obese individuals increasing from amount of 10 mm up to almost 80 mm so the head of the screw is just below the level of the skin. When inserting the screws, they should not be sunk down to the level of bone to prevent compression of the aforementioned structures (femoral nerve) or depressing the bikini line.

Rod bending, insertion, and anterior reduction

The titanium rod should be contoured to follow the bikini line. Begin by over contouring the rod 1cm greater than its trajectory over the skin at the midpoint with a rod holder and bender. This is important as the application of fixation of the INFIX construct will flatten the titanium rod. The authors have noted that over contouring helps to keep the rod location superficial, preventing compressive complications.



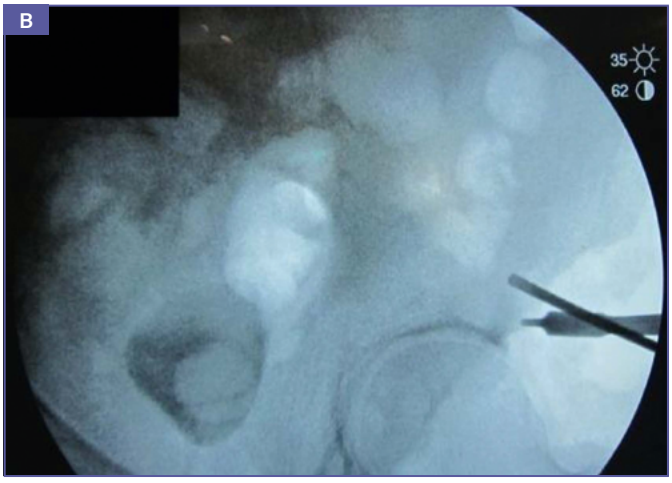


Figure 5A-B. Screw insertion with Iliac oblique.

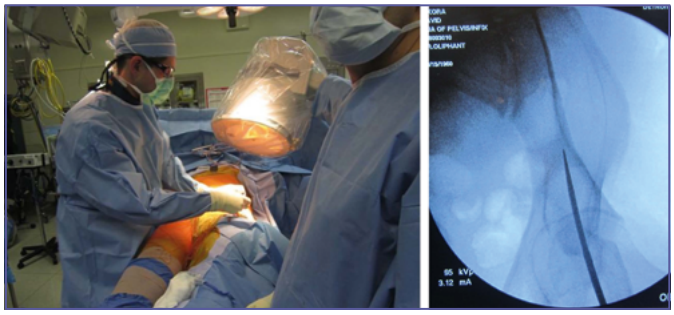


Figure 6. Obturator inlet view. Attention to maintain the drill between the two tables of the ilium.

Furthermore, the authors limit cutting the titanium rod before final tightening, as lateral compression injuries require distraction for reduction which requires compensation in the rod measurement. If the rod is cut before final tightening, retain 5-7 cm of rod for distraction associated with the reduction.

The titanium rod is inserted within the subcutaneous tissue via manual tunneling (Fig. 7A-C).

This is followed in line or just below the bikini line and through the fat layer found immediately below the skin. The trajectory of the rod is followed with palpation of the skin and adjustments can be made using the curve in the titanium rod. At the

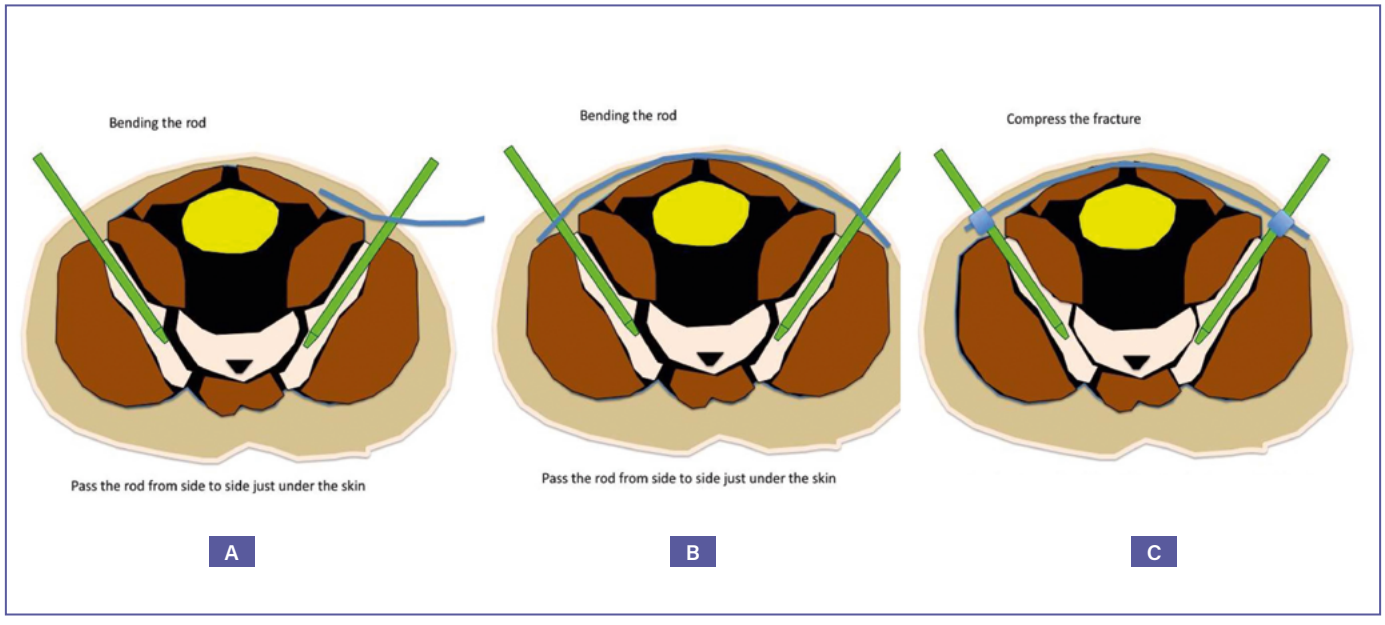


Figure 7A-C. The titanium rod (blue) is inserted within the subcutaneous tissue via manual tunneling.

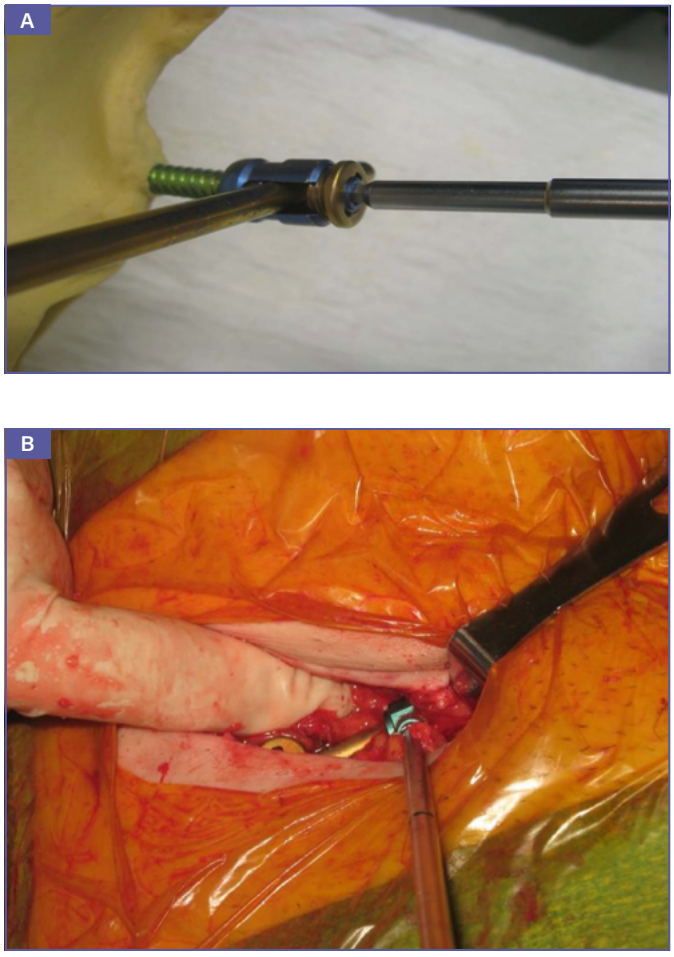


Figure 8A-B. Tightening the cap to secure the screws on the titanium rod.

level of the linea alba, additional force may be needed to penetrate the fascia and continue to the contralateral side. In obese individuals, this layer is more pronounced and should prompt the rod to be placed deeper.

Following tunneling, the rod is advanced so it is present lateral to both screws, superficial to the skin. Using a rod holder, the rod should be seated and caps are placed but not completely fixated. This allows for enough force to prevent the rod from moving during reduction, but not enough to lock the cap. Place a Vertebral Clamp 2 cm medial to the pedicle screw on the distracted injury side. The Vertebral Clamp acts as a temporizing force to prevent loss of reduction.

For compression, loosen the pedicle screw and utilize a compressor device against the Vertebral Clamp to complete your reduction and the tighten the caps (Fig. 8).

For distraction, loosen the pedicle screw and utilize a distraction device against the. Vertebral Clamp to complete your reduction. Excessive rod is cut with a large rod cutter with the excess piece being held to prevent harm to the patient or others.

The authors routinely leave 1cm lateral to the fixated screws when cutting the rods.

Tips and tricks in peculiar situations

Obesity

The anterior subcutaneous pelvic internal fixation was originally implemented for the obese population with pelvic injuries, where the application of conventional external fixator was creating problems with soft tissue and nursing. In large patients though, it can be difficult to directly visualize the starting point, so you need to relay on Xrays images to ensure you are centered at the appropriate position on your obturator oblique view. Obtain an iliac oblique view to verify you are directly on the AIIS prominence. Schanz pins 150 mm or 200 mm long readily available in any ortho trauma set are utilized. Long pedicle screws are necessary as often the skin can be 7 to 10 cm above the AIIS (Fig. 9A-B).

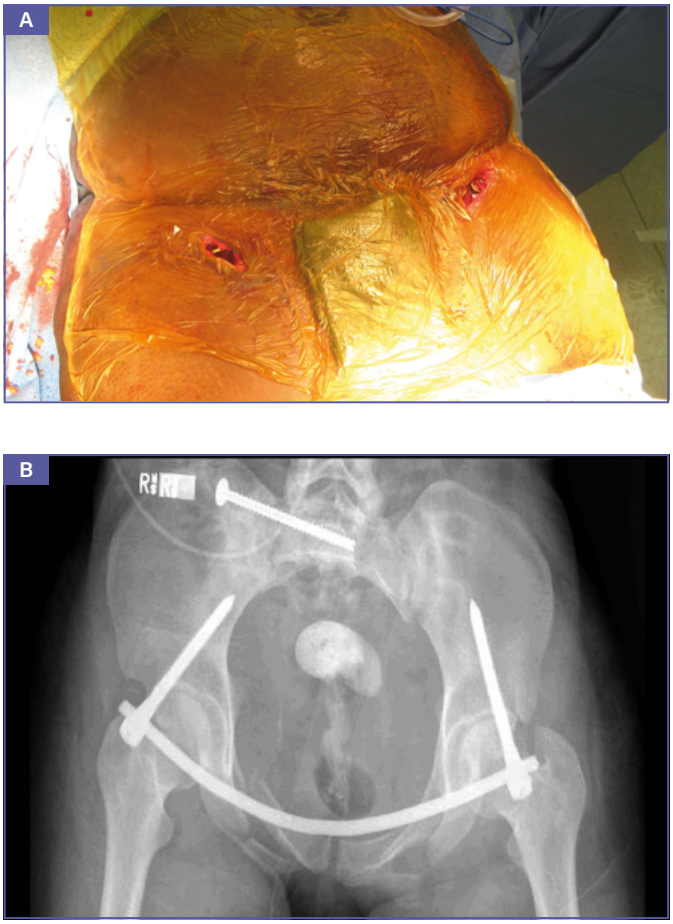


Figure 9A-B. Example of INFIX in obese patients. Note the long pedicles screws.

Open injuries
The INFIX can be used internally and externally, as a low profile external fixator as it is much easier to place a wound VAC over it.

Bladder rupture – urethral rupture
The INFIX can be routinely utilized for extraperitoneal bladder ruptures with anterior ring injuries as you never have to violate the area around the rupture; a simple foley without repair solves the issue. For intra peritoneal bladder ruptures the INFIX is ideal, paying attention that the suprapubic foley should be placed higher on the abdomen above the bikini line.

Pelvic and acetabular fractures
Although open reduction internal fixation is always preferred with combined injuries, often reducing the pelvic fracture, it reduces the acetabulum as well and an internal fixator can mix with acetabular implants unlike an external fixator [22].

Pathologic fractures
INFIX can bee used in a ring configuration for pathologic lesions with cement augmentation.

Osteoporotic fractures
In refractory osteoporotic pelvic injures, especially in lateral compression which occasionally need stabilization, screws may have sufficient purchase. The INFIX screws sit between the inner and outer pelvic tables and can hold and distract the pelvis easily.

Pediatric bladder extrophy
The INFIX has been used successfully to aid the pelvic osteotomy and closure during bladder extrophy [19].

Cannulated pedicle screws
One ad hoc option is the use of a cannulated pedicle screw system, with a cannula and trocar system as a method for screw insertion. Once the trochar and sleeve are in the appropriate position on the AIIS based on fluoroscopy or direct visualization, mallet this 1-2 cm into the bone while on your iliac oblique view followed by the obturator inlet view. Adjustments should only be made with the trocar in the bone, advancing this for several more centimeters. Once in the appropriate trajectory, the inner trocar is removed, and a guidewire for a cannulated pedicle screw system can be advanced. The protective cannula is then removed using gentle twisting motion and the guidewire is left in place. Cannulated drill is positioned over the wire and then a tap is used, prior to placement of the pedicle screw for the entire length of the screw [19].
In regards to rod contouring, the easiest way to do this is by keeping the rod holder and the rod bender in the same plane. Have an assistant hold the rod firmly at one end using a rod holder. This should be opposite the side you are going to bend. Keeping parallel to the ground, gently bend the rod at multiple points ensuring you stay parallel to the ground. Check the contour by laying the rod over the skin.

Postoperative

Patients are allowed to ambulate on uninjured hemi-pelvises with full weight and toe touch or foot flat on the injured side. Full weight-bearing started on the injured side for a type C injury between 6 and 12 weeks.

Removal
The device is removed 3-6 months postop and requires a separate procedure. The same incisions are made (Fig. 10A-B). Most patients are able to sit, stand, and roll over with the implants but most individuals can feel it under the skin and are happy to remove it. Elective implant removal was reported to take place between 10 weeks and 9 months, was reported to be safe, easy, and without complication, but required to be performed in an operative theater unlike an external fixator. Several authors have reported implants that were left in indefinitely in individuals who were asymptomatic and did not want another surgical intervention. The long-term effect of this is unknown [19].

Outcomes
Three recent systematic reviews have reported that INFIX and the appropriate posterior fixation resulted in healing of pelvic ring injuries in 99.5% of cases [23]. Pooled analysis showed overall good radiological (mean percentage of excellent to good reduction = 91.4%, 95% CI 0.860-0.969) and functional outcomes (mean Majeed score = 86.48, 95% CI 83.34-89.61) with INFIX [24,25]. The INFIX technique can be considered as a viable alternative to symphyseal plating for unstable pelvic ring injuries. It has the advantages of shorter operative times and less blood loss, along with comparable functional outcomes, when compared to plating [24].

Complications
The most common complications were lateral femoral cutaneous nerve (LFCN) injury (overall rate 28%, 95% CI 15.1-41%) and heterotopic ossification (HO) (overall rate 9.4%, 95% CI 5.5-13.3%) 25, infection 1-3% rates of other complications were low [18-21].

Conclusions

Physicians are always seeking better ways to provide treatment to their patients. It was this spirit that led to the development of the INFIX device as an alternative to the widely used external

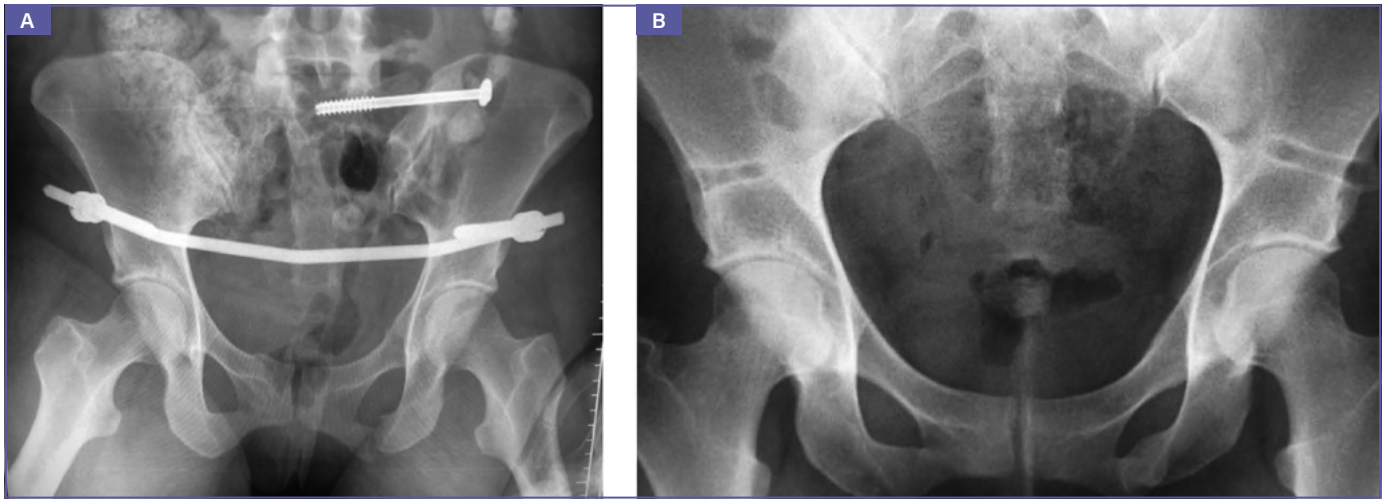


Figure 10A-B. INFIX on the right and after removal at three months on the right.

fixator for definitive fixation of anterior pelvic ring injuries. The use of INFIX has been reported in North America, Europe, Asia, and Australia. Most authors report it as a valuable tool for reduction and fixation in unstable pelvic ring injuries, which is biomechanically sound, well tolerated by patients, allowing good mobility, good outcomes with a low incidence of complications. There is a learning curve, where orthopaedic trauma surgeons need to think as vertebral spine surgeons and adapt to vertebral instrumentation. LFCN nerve irritation, HO, and the need for a secondary surgery are its negatives [25].

Acknowledgements
A special thanks to Gaia Morandi.

Conflict of interest statement
The Authors declare no conflict of interest.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions
RV: conceptualisation, supervision; TC: writing, conceptualisation, MMM: review, editing.

Ethical consideration
This study was approved by the Institutional Ethics Committee (Protocol number: 0000168940).
The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.
Written informed consent was obtained from each participant/patient for study participation and data publication.

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