

PERCUTANEOUS SCREW FIXATION OF THE PELVIC RING AND ACETABULUM: AN ANATOMICAL, TECHNICAL, AND FLUOROSCOPIC REVIEW

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AUTHORS

Guillaume David - Centre Hospitalier Universitaire d'Angers, Angers, France

Cyril Mauffrey - University of Colorado, Denver, United States of America

SUMMARY

Background: Traumatic injuries to the pelvic ring and acetabulum present significant management challenges due to their anatomical complexity. While historically treated with conservative measures or open reduction, the emergence of percutaneous techniques has provided a minimally invasive alternative for both high-energy trauma in younger patients and fragility fractures in the geriatric population.

Objective: This review aims to detail the anatomical, fluoroscopic, and technical requirements for percutaneous pelvic surgery, focusing on established osseous corridors and the prevention of iatrogenic complications.

Key Points: Successful percutaneous fixation relies on a precise understanding of sacro-acetabular and sacro-ischiatic trabecular systems. Key corridors include iliosacral, trans-sacral, anterior and posterior columns, and supra-acetabular pathways. Fluoroscopic guidance via Inlet, Outlet, and oblique views is mandatory to navigate these corridors while avoiding neurovascular structures, including the lumbosacral trunk, superior gluteal pedicle, and sciatic nerve. Technical refinements, such as the use of drill-tip guide wires for enhanced tactile feedback and specific reduction maneuvers like the "Metaizeau trick," facilitate accurate screw placement. Large-diameter cannulated screws (6.5 mm to 8.0 mm) are utilized to achieve stable internal fixation. Preoperative planning with three-dimensional imaging is essential to identify anatomical variations, such as sacral dysmorphism, which significantly alter safe screw trajectories.

Conclusion: Percutaneous techniques offer stable fixation with reduced soft tissue disruption and shorter hospital stays. Mastery of pelvic anatomy and radiographic landmarks is essential for surgeons to ensure safety and efficacy in treating these complex injuries.

KEYWORDS

Fracture Fixation, Internal; Pelvis; Acetabulum; Minimally Invasive Surgical Procedures; Bone Screws

INTRODUCTION

The complexity and diversity of traumatic injuries to the pelvic ring and acetabulum present a genuine challenge for the orthopedic surgeon. The management of these injuries has evolved over several decades. Historically, these patients were treated conservatively, often with prolonged bed rest, or with open surgery. Recent epidemiological studies have shown a distribution of these injuries into two groups. The first primarily involves young patients who suffer high-energy trauma, while the second concerns geriatric osteoporotic patients who experience ground-level falls, for whom these injuries represent a public health concern (increasing prevalence, potential complications related to prolonged recumbency, and increased length of hospital stay).

Enabled by concurrent improvements in techniques and intraoperative imaging, percutaneous pelvic surgery techniques emerged in the early 1990s. Initially limited to the sacroiliac joint, authors have described new techniques allowing posterior and anterior stabilization of the pelvic ring [1],[2], crescent-type fractures [3], and certain acetabular fractures [4],[5] with encouraging clinical results [6]. These techniques have also been described in elderly patients with osteoporosis [7],[8],[9], for whom non-surgical treatment often yields disappointing results. The advantages of minimally invasive procedures include limiting soft tissue dissection, minimizing intraoperative blood loss, reducing procedure duration, and allowing earlier patient mobilization [8],[10].

While these techniques are appealing, they require perfect knowledge of bone anatomy, radiographic views, and osseous corridors that allow for the placement of fixation screws [5],[11], often in proximity to at-risk structures, thus necessitating thorough knowledge of the surrounding anatomy. By definition, the life-threatening neurovascular structures are not visible during the procedure, and iatrogenic complications have been reported in the literature.

The objective of this review article is to provide a unique overview of the anatomical, fluoroscopic, and technical specifics for each previously described fixation corridor, as well as the basic equipment requirements and setup for percutaneous pelvic surgery. This will enable surgeons who wish to practice this surgery to better master its fundamentals while minimizing iatrogenic risks.

This review is structured to answer the following questions:

1. What are the anatomical osseous corridors?
2. What are the surrounding anatomical structures?
3. What are the useful radiographic views for each corridor?
4. What are the tips and tricks to facilitate the procedure?

ANATOMICAL CONSIDERATIONS

The coxal bone is structured as a flat bone, composed of trabecular tissue enclosed between two layers of cortical tissue. Its role in standing and sitting positions requires an architecture adapted to these two functions, as found in all other skeletal structures, with a specific arrangement of bone trabeculae in response to the pressures experienced and transmitted by the bone. According to the work of anatomists Latarjet and Gallois, the architecture of the pelvis is organized into two distinct systems. The first extends from the auricular facet to the

acetabular cavity and is adapted to standing or walking: it consists of sacro-acetabular trabeculae. The second, starting from the same surface and ending at the ischium, is adapted to the sitting position: it is formed by sacro-ischiatic trabeculae. These bone trabeculae are the basis for Letournel's theory of acetabular columns and the corridors described for percutaneous surgery (Figure 1).

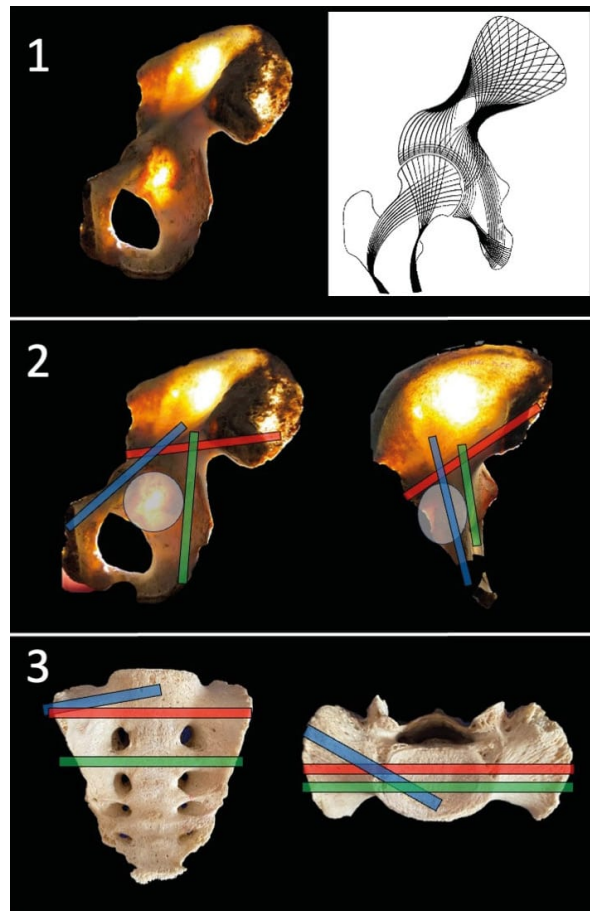


Figure 1 : Representation and visualization of screw corridors on dry bone through transillumination. Trabecular pattern of the coxal bone and schematic representation (1); Anterior Column corridor (Blue), Posterior Column corridor (Green), Supra-acetabular corridor (Red), Hip joint (white circle) (2); Iliosacral S1 screw corridor (Blue), Trans-iliosacral S1 corridor (Red), Trans-iliosacral S2 corridor (Green) (3).

The sacrum is a bone with a notable peculiarity. Located at the lower part of the axial skeleton, its inferior portion is not subject to the influence of pressures transmitted by the spine. It shows the most evident signs of highly specialized adaptation. As the junction between the spine and pelvis, only its superior portion, which transmits pressures, exhibits characteristics of robustness. Four transverse canals extend from each side of the sacral canal. Initially simple, they almost immediately bifurcate to end at the anterior and posterior sacral foramina. Within the canal itself, each of these conduits, a true intervertebral foramen, is separated from the neighboring conduit by an anteroposteriorly oriented bone column, reminiscent of true vertebral pedicles. These columns are particularly useful for iliosacral and trans-iliosacral screw fixation.

Beyond the hip joint violation for column and periacetabular screw fixation, the surrounding anatomical structures at risk during percutaneous surgery are primarily neurovascular. The iliac vascular network is rich and often close to the corridors. We will notably mention the superior gluteal pedicle and common iliac vein, particularly exposed during iliosacral or trans-sacral screw fixation [1],[12], as well as the femoral artery located near the anterior column corridor and the entry point of the LC2 corridor [5]. Regarding neural structures, we will discuss the lumbosacral trunk, formed by the 5th and 4th lumbar roots, which descends while molding itself to

the anterior surface of the sacral wing, to which it adheres through fibrous connective tissue. Along with the first sacral roots S1 and S2, these nerves are vulnerable during iliosacral or trans-sacral screw fixation. The sciatic nerve, as it wraps around the posterior column through the greater sciatic notch, is exposed during retrograde posterior column screw fixation, as is the posterior femoral cutaneous nerve. Finally, it is worth mentioning the lateral femoral cutaneous nerve, which can be injured by LC2 screw fixation after passing under the inguinal ligament (Figure 2). The genital structures at risk in women are the glans and body of the clitoris as well as surrounding sensory nerve branches, and in men, the cavernous bodies and spermatic cords [11]. These structures are at risk of injury during retrograde anterior column screw fixation.

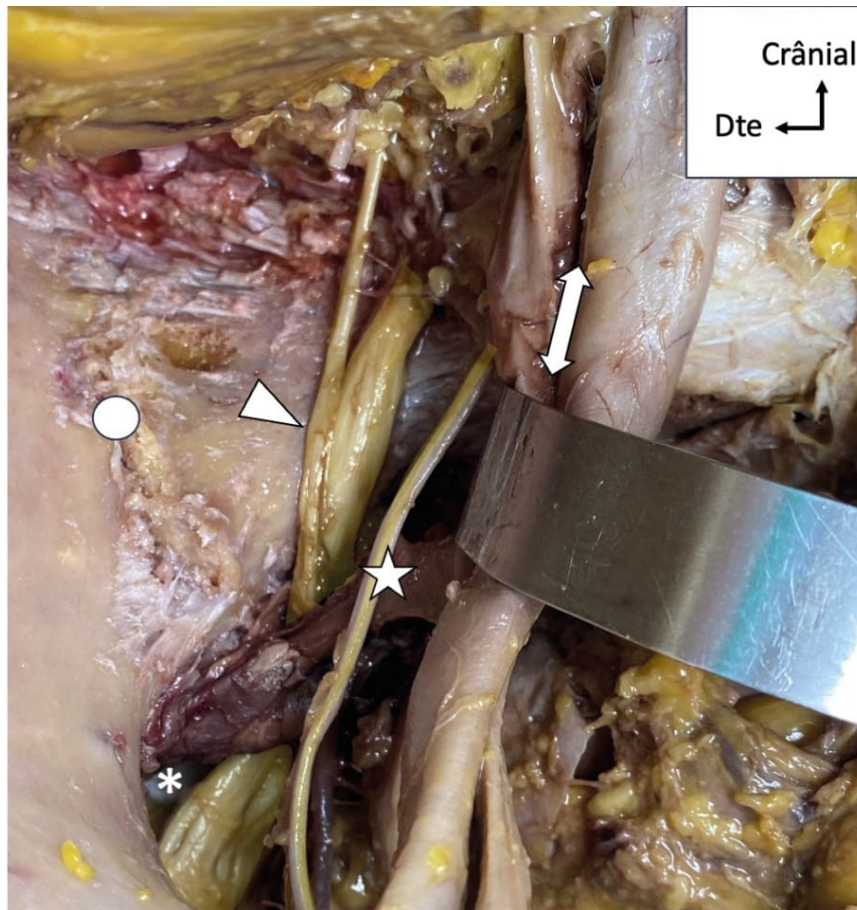


Figure 2 : Anatomical dissection of the posterior region showing: the right sacroiliac joint (White Circle); the right lumbosacral trunk (White Arrow); the Obturator Nerve (Star); the Greater Sciatic Notch (Asterisk); the Common Iliac Artery and Vein (Double Arrow).

PREREQUISITES

The architectural and anatomical complexity of the pelvis can be challenging for clinicians to comprehend. A thorough evaluation of injuries and their preoperative classification is essential. This sometimes difficult task is facilitated by modern diagnostic tools aided by three-dimensional reconstruction, now available in most centers. We will review the most important radiographic views.

An anteroposterior view quickly reveals any craniocaudal displacement of the pelvic ring or femoral head protrusion into the acetabulum. The acetabulum is evaluated using obturator and iliac oblique views, obtained by 45-degree axial rotation around the patient, allowing analysis of the landmarks described by Letournel. Inlet and

Outlet views, described by Pennal et al. [13], enable analysis of the pelvic ring. The Inlet view is a superimposition of the anterior landmarks of the S1 and S2 vertebral bodies. Visibility of the sacral canal and S1 vertebral body serves as a good quality criterion. It allows identification of anteroposterior hemipelvic translation.

The Outlet view, defined as the superimposition of the pubic symphysis apex with the S2 vertebral body, allows identification of vertical translation of a hemipelvis. This view is crucial for identifying signs of lumbosacral junction dysplasia. The numerical value of these inclinations may vary depending on pelvic version, and radiographic criteria should be used as quality indicators rather than specific values.

Finally, the true lateral view, as described by Routt, where perfect superimposition of both greater sciatic notches constitutes the quality criterion. It enables identification of S1 and S2 vertebral bodies, as well as the two iliac cortical density lines, located at the anterior portion of the sacroiliac joint and extending forward through the pelvic brim. These landmarks prove useful during guide wire advancement. (Figure 3)

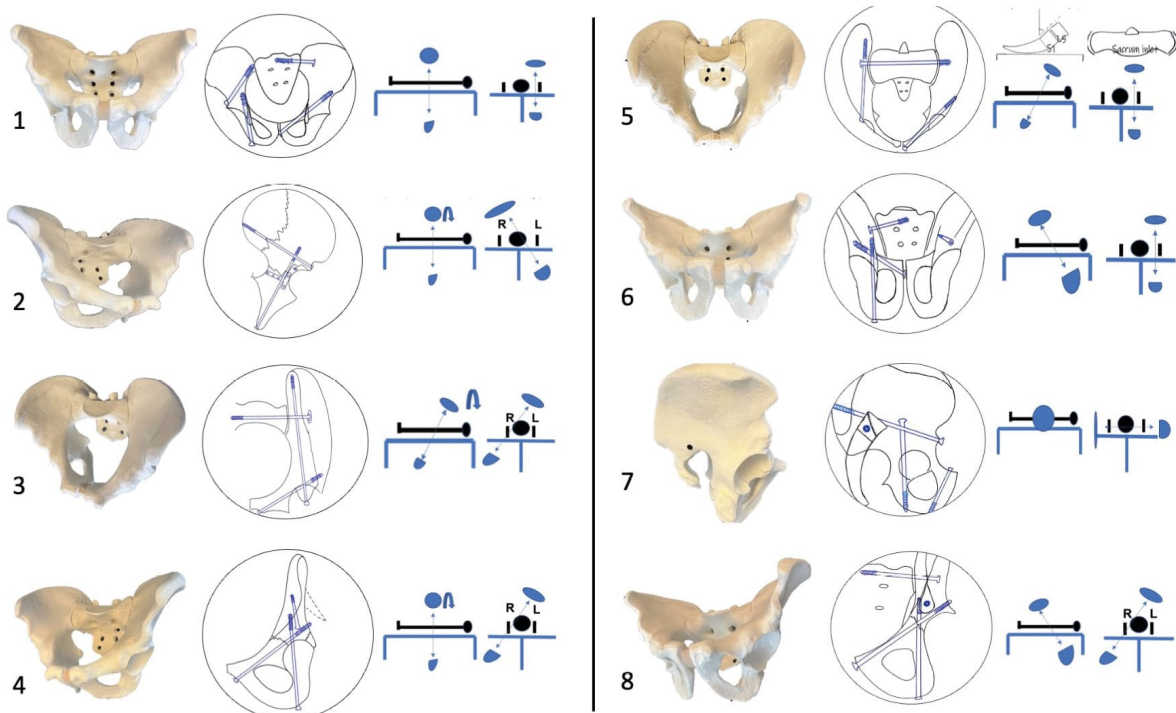


Figure 3 : Figure showing the main radiological views, with model representation, appearance of corridors and methods to obtain them. Anteroposterior view (1); Left alar oblique view (2); Inlet + Left obturator view (3); Left obturator oblique view (4); Inlet view (5); Outlet view (6); Lateral view (7); Outlet + Left obturator view (8).

The lumbosacral junction is one of the most variable regions of the spine. Although the total number of vertebrae in the thoracolumbosacral region remains constant, sacral fusion levels differ. It is important to look for radiographic characteristics of dysmorphism, as this variation significantly alters the upper sacrum and therefore the screw corridors (Figure 4). As comprehensively described by Tonetti et al. [1], the following characteristics should be sought:

1. On anteroposterior and outlet views: the most caudal mobile disc is close to the bi-iliac line; the sacral mammillary processes are hypertrophied; the first anterior sacral foramina are abnormally large, non-circular, and irregular;
2. On sagittal CT reconstruction: between the first and second sacral vertebrae, a disc remnant is visible and lordosis is very pronounced;
3. Transverse reconstructions show more complex and congruent interlocking of the sacroiliac joints;

4. Finally, on the lateral radiograph with superimposition of the greater sciatic notches, the iliac cortical densities are vertical.

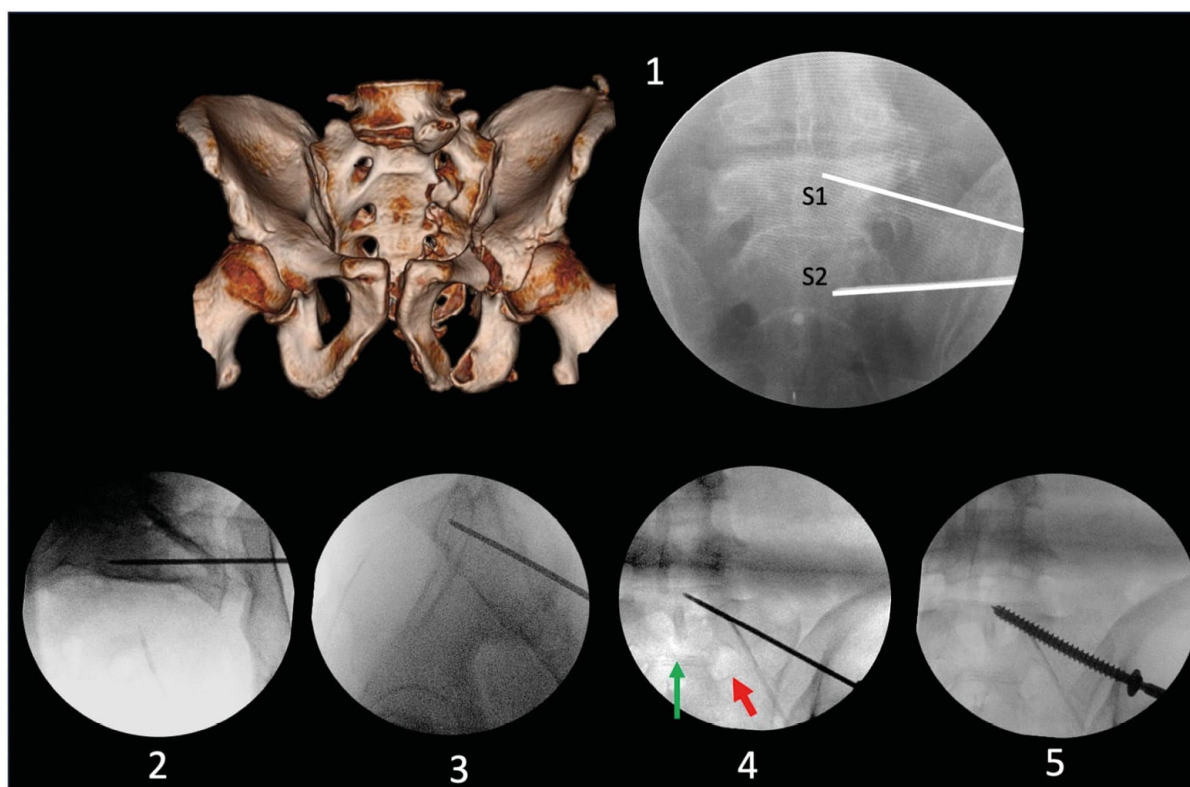


Figure 4 : Figure illustrating sacral dysmorphism. Note the particular direction of S1 and S2 corridors (1); Intraoperative images of left sacroiliac joint disruption fixation in sacral dysmorphism (2); Characteristic profile of dysmorphism (3); Characteristic outlet view showing visible S1-S2 disc (Green Arrow), as well as particularly visible foramina (Red Arrow), Compression using a fully threaded screw according to the lag screw technique (5).

MATERIALS AND INSTALLATION

Percutaneous pelvic surgery is a complex and demanding practice. In case of complications, the presence of a visceral and vascular surgeon, as well as an intensive care unit and radio-embolization service, is essential. Moreover, these interventions should exclusively be performed in facilities with such support.

After a basic preoperative assessment, the patient is positioned in the supine position under general anesthesia on a radiolucent table of sufficient size. This allows for the widest possible range of views without conflict with the operating table support. A cushion can be placed under the sacrum to elevate the pelvis and facilitate access to the posterior corridors and the anterior column. Muscle relaxation is necessary and mandatory in case of reduction maneuvers. Particular attention should be paid when percutaneous surgery is performed within the first hours of the management of a trauma patient, due to the stagnation of the contrast agent in the bladder, which can make the interpretation of radiographic views difficult.

A C-arm image intensifier is generally used with the sensor as close as possible to the patient to limit image magnification.

Before placing the surgical drapes, all views are repeated and adjusted as needed according to the anatomy or residual deformity to assess feasibility (presence of intra-pelvic feces or intestinal gas that may interfere with the visualization of bony landmarks). Reduction maneuvers are sometimes necessary; closed or open focus techniques have been described in the literature and will not be discussed in this presentation. For percutaneous pelvic surgery, large-diameter cannulated screws are generally used. For the posterior arch, 7.3 or 8 mm screws and for the anterior arch, 6.5 to 7.3 mm screws are used. They can be made of stainless steel or titanium, with full or partial threading, with the possibility of using washers. Regarding sizes, lengths from 60 to 165 mm in 5 mm increments are generally necessary. The dedicated guide wire should ideally have a maximum length (> 400 mm, especially for the trans-iliac procedure, or the use of a dedicated trocar).

Tips / Tricks

We prefer the use of guide wires with a "drill" tip rather than a "threaded" tip. Indeed, the "drill" wire offers the advantage of being fully dependent on the surgeon's hand (it does not progress with rotation), thus allowing a better feel of the bone densities while allowing a change of trajectory even during progression (Figure 5).

Its less aggressive tip (compared to the threaded wire) reduces the risk of false passage. Thus, a corridor can be found by using an American handle and making oscillating movements, allowing the wire to deform slightly (buckling) to follow a passage that is sometimes difficult to identify. This approach offers optimal tactile feedback, a technique that we employ very regularly (Figure 5).

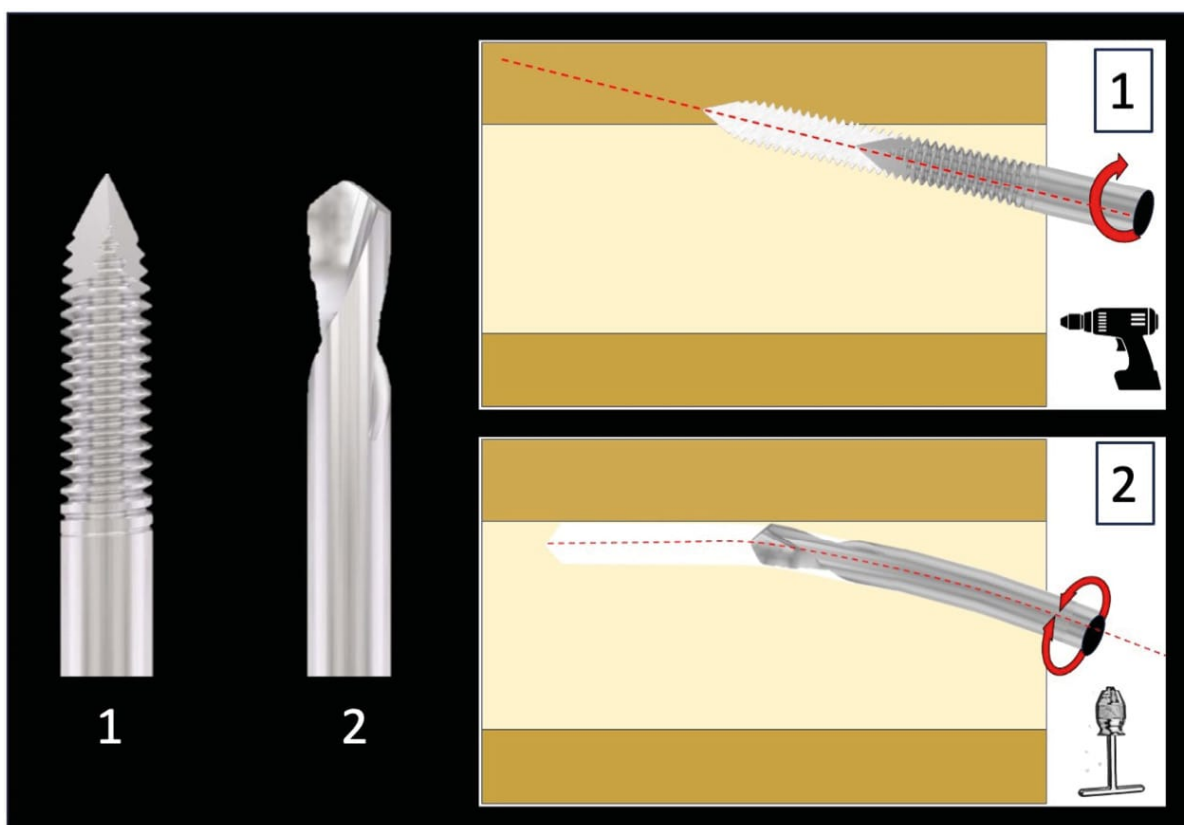


Figure 5 : Figure illustrating the advantage of the "drill" wire (2) advanced by hand using alternating movements, compared to the "threaded" wire (1) advanced by motor.

The Different Fixation Corridors of the Pelvic Ring and Acetabulum

The various fixation corridors, their indications, the required radiographic views, as well as the anatomical structures presenting a risk of adjacent complications, along with techniques and potential aids to facilitate their implementation, are described for each of them in the following paragraph and summarized in Table 1.

Screw Corridors	Indications	Radiographic Views	At-Risk Anatomical Structures	Tips / Tricks
Ilio-Sacral Trans-Sacral (S1 and S2)	Sacroiliac disjunction Sacral fracture	Inlet / Outlet / Lateral view Inlet + ¾	Superior gluteal pedicle Common iliac vein Lumbosacral trunk S1 and S2 nerve roots	<ul style="list-style-type: none"> CT reconstruction Identify dysmorphism Anticipate conflicts with the table (if dysmorphism is present)
Anterior Column ¹	Obturator ring fracture Low anterior column fracture	Outlet + ¾ obturator Inlet Face	<ul style="list-style-type: none"> Hip joint, gluteus medius External iliac vessels Glans and body of the clitoris Corpora cavernosa and spermatic cords 	<ul style="list-style-type: none"> Kirschner wire to mark the incision Metaizeau nail Bend the wire Drill bit / Wire
Posterior Column ¹	Posterior column fracture	Outlet, ¾ alar, ¾ obturator	Sciatic nerve Posterior femoral cutaneous nerve	<ul style="list-style-type: none"> Elevate the pelvis in the supine position or prefer the prone position (retrograde) Lateral view for length assessment Antegrade screw placement: Trocar is essential, 2 cm incision at 4 fingerbreadths from ASIS
LC2 ¹	Alar fracture Crescent fracture Anterior column fracture	("Water drop" view) ¾ alar Inlet + ¾ obturator	External iliac artery Lateral femoral cutaneous nerve	<ul style="list-style-type: none"> Avoid working with the "water drop" view Entry point: 2 fingerbreadths medial + 1 fingerbreadth distal to ASIS Strict lateral view is the only view that allows validation of length
Magic	Quadrilateral plate fracture Certain transverse fractures	Face ¾ Alar Inlet + ¾ obturator Outlet + ¾ obturator	Digestive perforation Obturator pedicle Superior gluteal pedicle	Use the drill in counterclockwise direction (palpate the inner table)
Transverse	Quadrilateral plate fracture Roof fracture and impaction			

¹: Antegrade and Retrograde

Table 1 : Summary table.

ILIO-SACRAL (IS) AND TRANS-SACRAL (TS) SCREW FIXATION

Fixation methods for posterior pelvic ring injuries, long described by numerous authors, are well-established and robust. These commonly used methods allow for the fixation of unstable sacral fractures, sacroiliac joint disruptions, and certain crescent-type iliac wing fractures.

Depending on the injury being treated, fixation can be either ilio-sacral or trans-sacral, highlighting the crucial importance of careful injury analysis and rigorous procedure planning. In cases of sacroiliac joint disruption with significant diastasis, ilio-sacral screw fixation is preferred, as it provides a reduction vector perpendicular to the displacement. IS screw fixation can be performed at either the S1 or S2 level. However, for sacral fractures, trans-sacral screw fixation may represent an interesting option due to the perpendicular orientation of the corridor relative to the fracture site. This type of fixation can also be used in the treatment of bilateral or highly unstable injuries, such as vertical shear injuries.

The osseous corridors have been extensively described in the literature, including IS-S1 or S2, TS-S1 or S2, and even S3 in cases of dysmorphism. In non-dysmorphic sacra, only S1 and S2 corridors are accessible, as the

inferior portion of the iliac tuberosity ends at the superior aspect of S3. In the presence of dysmorphism, the cranial rearrangement of sacral elements allows access to the S2 and S3 vertebrae.

Numerous studies have demonstrated the feasibility and safety of trans-sacral screw fixation at the S2 level. Although S1 is the vertebral body offering the highest bone density, it has been shown that the bone density of the posterior pelvic ring is higher in the iliac tuberosities and sacroiliac joints, providing trans-sacral fixation with better anchoring for the most unstable injuries.

These techniques can be performed in either supine or prone position; however, to minimize anesthetic complications in trauma patients, the supine position is preferred. The starting point for screw placement can be determined using a lateral view. The main fluoroscopic views used are the Inlet and Outlet views. The Inlet view shows the anteroposterior boundaries, while the Outlet view guides the caudocranial trajectory. A lateral view can be used for the entry point, but primarily to secure the trajectory in relation to the lumbosacral trunk. Finally, an Inlet + Obturator view will allow monitoring of the external table of the tuberosity and thus the length and application of the screws. (Figure 3)

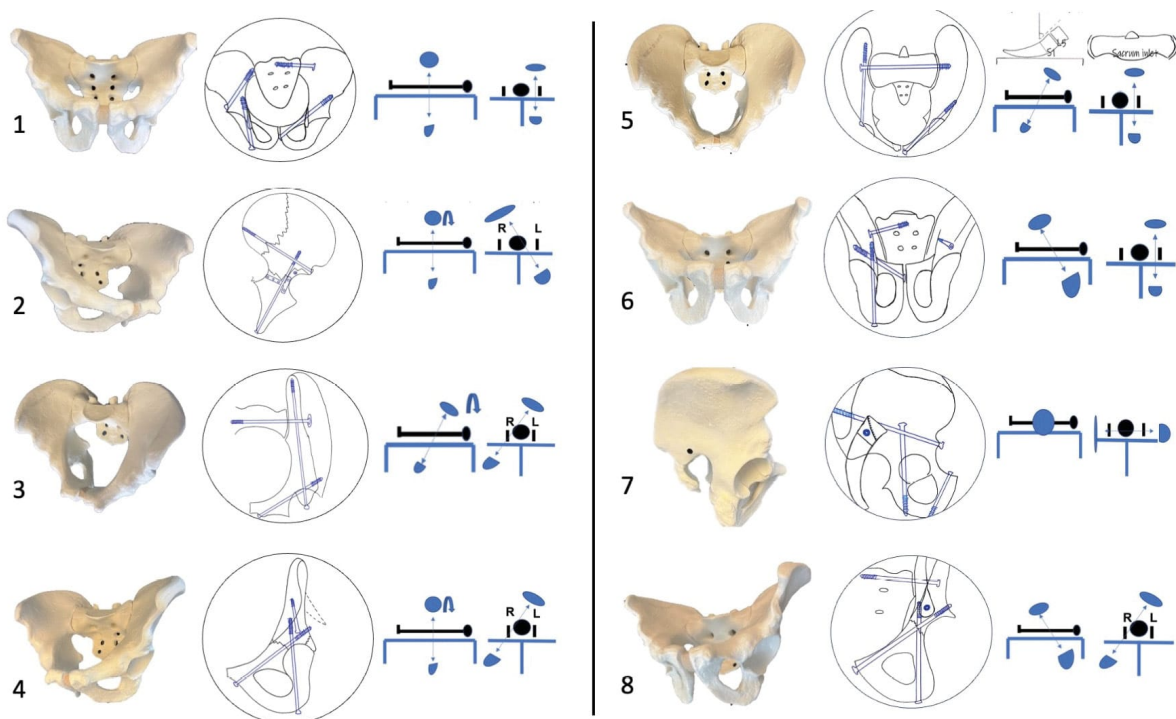


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For a unilateral IS screw, the starting point is slightly more posterior, with a trajectory directed upward and forward into the sacral promontory (Figure 6). A TS screw will have a more anterior entry point and a horizontal trajectory, thus allowing passage under the sacral wings and above the first foramen for a TS-S1 screw, and between the S1 and S2 foramina for a TS-S2 screw (Figure 7).

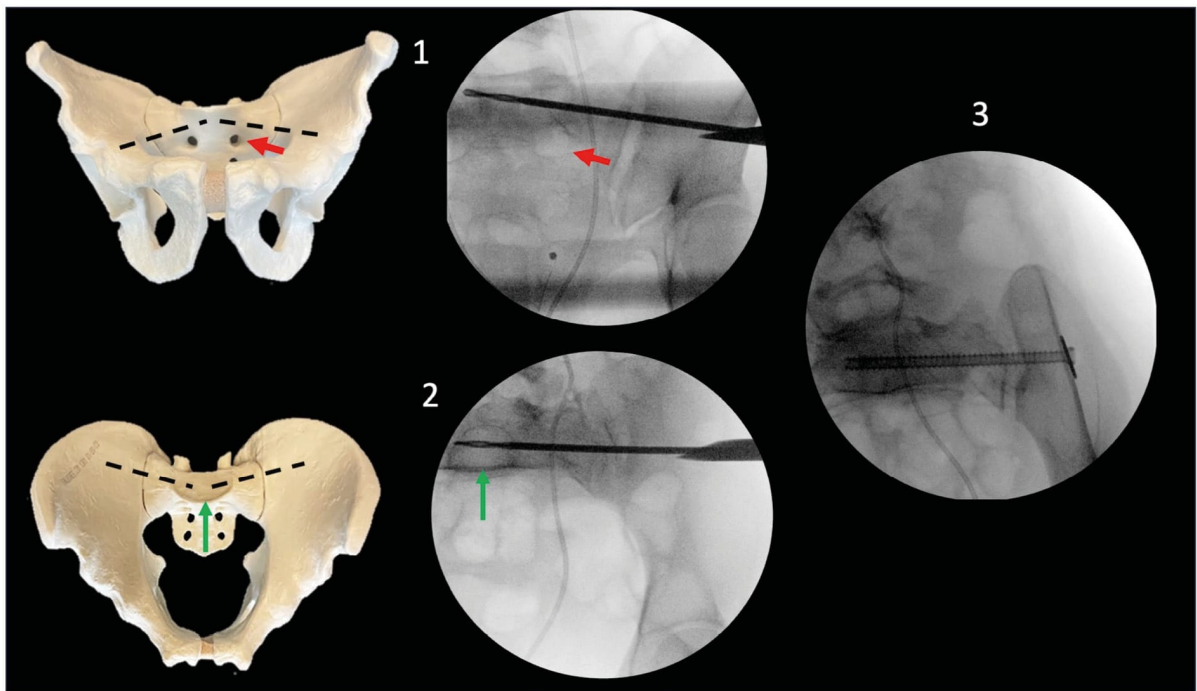


Figure 6 : Illustration of iliosacral screw fixation in S1. IS-1 trajectory in outlet view on dry bone and intraoperatively (1), left first sacral foramen (Red Arrow); IS-1 trajectory in inlet view on dry bone and intraoperatively (2), anterior wall of S1 (Green Arrow); Inlet-obturator view showing joint reduction and screw placement on the lateral cortex (3).

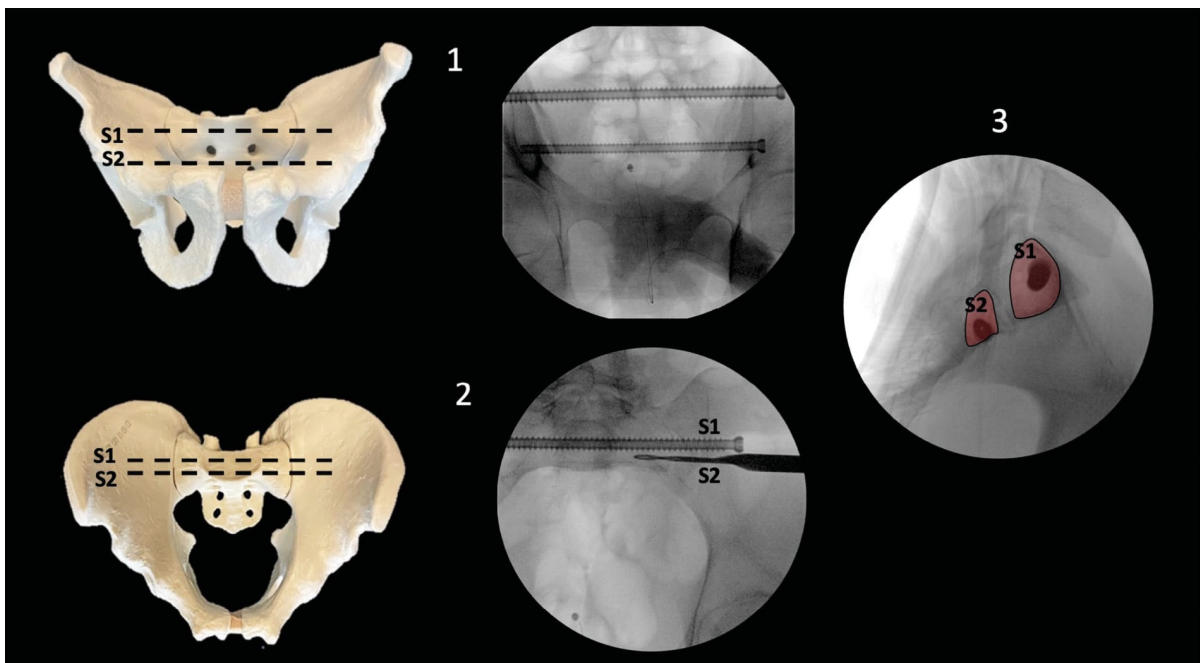


Figure 7 : Illustration of Trans Iliosacral (TIS) screw fixation in S1 and S2. TIS-1 and 2 trajectory in Outlet view on dry bone and intraoperatively (1); TIS-1 and 2 trajectory in Inlet view on dry bone and intraoperatively (2), note the more anterior position of the TIS-2 screw; Lateral view showing S1 and S2 vertebral bodies (separated by the first foramen), as well as proper screw positioning within the corridors (3).

Once the appropriate direction is identified, the guide wire is advanced using power equipment. When its tip reaches the level of the foramina, the lateral view allows verification that the wire is positioned posterior to the cortical density lines, thus limiting the risk of misplacement at this level that could lead to iatrogenic injuries of

the lumbosacral trunk. Similarly, along with the Inlet view, it helps ensure that the wire trajectory is not directed toward the spinal canal, which could cause cauda equina injuries. It is also recommended to maintain distance from the inferior aspect of the sacral foramina and anterior sacral landmarks. The guide wire is then advanced to the desired position. After checking the different views, the appropriate screw (usually 7.3 or 8 mm in diameter) is implanted using dedicated instrumentation. To improve fixation in the sacral wings, which often have poor bone quality, we prefer using fully threaded screws for all lesions. In cases of sacroiliac disruption, using a lag screw technique allows for compression [14] (Figure 4). The screw length can be verified using an ipsilateral and contralateral sacroiliac joint view (Inlet + three-quarter obturator).

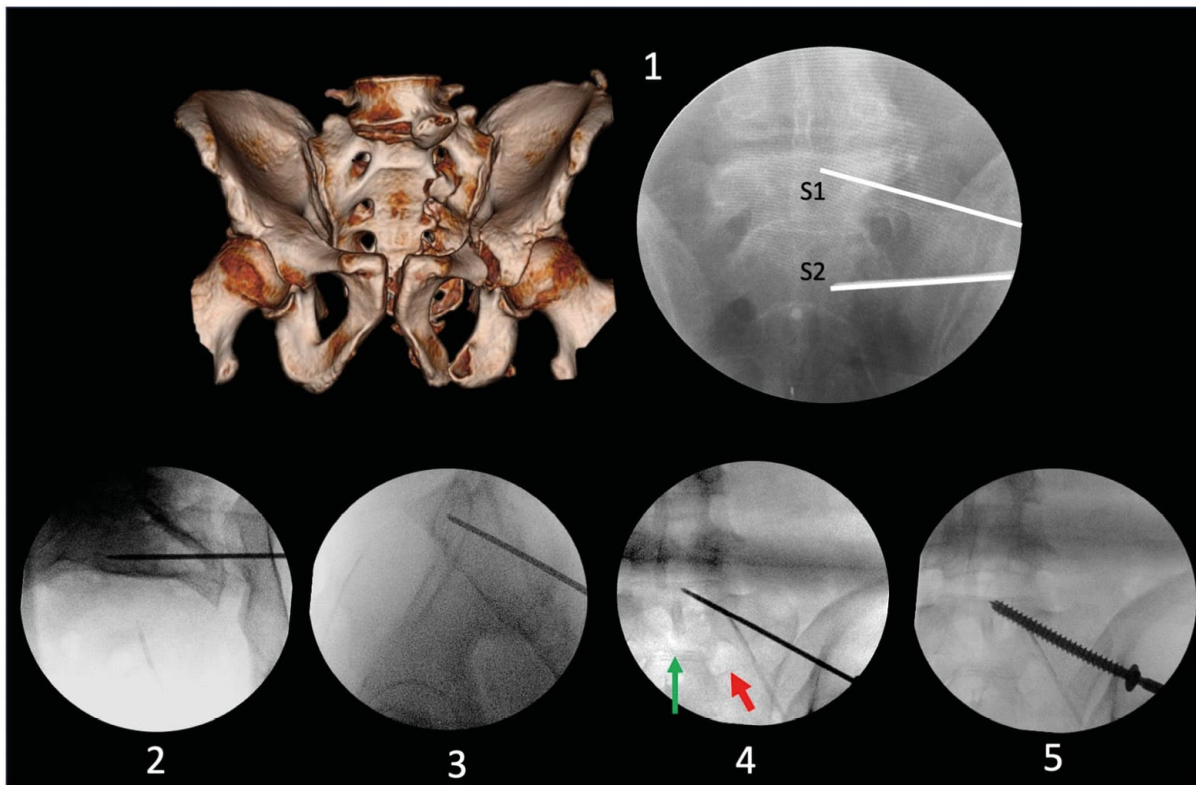


Figure 4 : Figure illustrating sacral dysmorphism. Note the particular direction of S1 and S2 corridors (1); Intraoperative images of left sacroiliac joint disruption fixation in sacral dysmorphism (2); Characteristic profile of dysmorphism (3); Characteristic outlet view showing visible S1-S2 disc (Green Arrow), as well as particularly visible foramina (Red Arrow), Compression using a fully threaded screw according to the lag screw technique (5).

The anatomical structures at risk for this technique are the superior gluteal pedicle, the lumbosacral trunk with the L5 nerve root, and the S1 sacral root for IS screwing, with the additional risk of S2 injury for TS screwing.

An injury to the superior gluteal pedicle will result in significant acute bleeding through the skin incision; compression hemostasis is recommended as the first-line treatment. In cases of arterial bleeding, radioembolization may be necessary. Furthermore, iatrogenic injury can lead to occult bleeding, potentially causing a compressive hematoma, hemoglobin drop, or compartment syndrome of the gluteal muscles.

L5 nerve root injury is a classic complication of this technique. Some authors have proposed intraoperative EMG monitoring. Tonetti et al. recommend placing a hand on the foot of the lower limb ipsilateral to the screw fixation to detect the slightest iatrogenic nerve irritation. The L5 nerve root is clinically examined pre- and post-operatively through motor assessment of the extensor hallucis longus muscle.

During IS or TS screw fixation, the S1 nerve root can also be injured. As with L5, pre- and post-operative clinical examination is recommended for its assessment. The S1 nerve root is clinically examined through motor assessment of the peroneus longus and brevis muscles, sensitivity of the lateral aspect of the foot, and the Achilles reflex.

Three-dimensional fluoroscopy and CT-guided computer-assisted navigation offers a promising solution to facilitate orthopedic procedures while reducing the risks of breach or misplacement. Several studies have highlighted the safety and effectiveness of these techniques. The advantages include decreased technical difficulty and potential reduction in radiation exposure. Despite its complex implementation and higher cost, surgical navigation remains an attractive tool.

Preoperative evaluation is essential to anticipate difficulties associated with posterior arch screw fixation. Pelvic version and sacral tilt can complicate the acquisition of Inlet and Outlet views. Analysis of sagittal CT scans preoperatively helps overcome these challenges by providing an estimate of the angles needed to obtain these views (Figure 8).

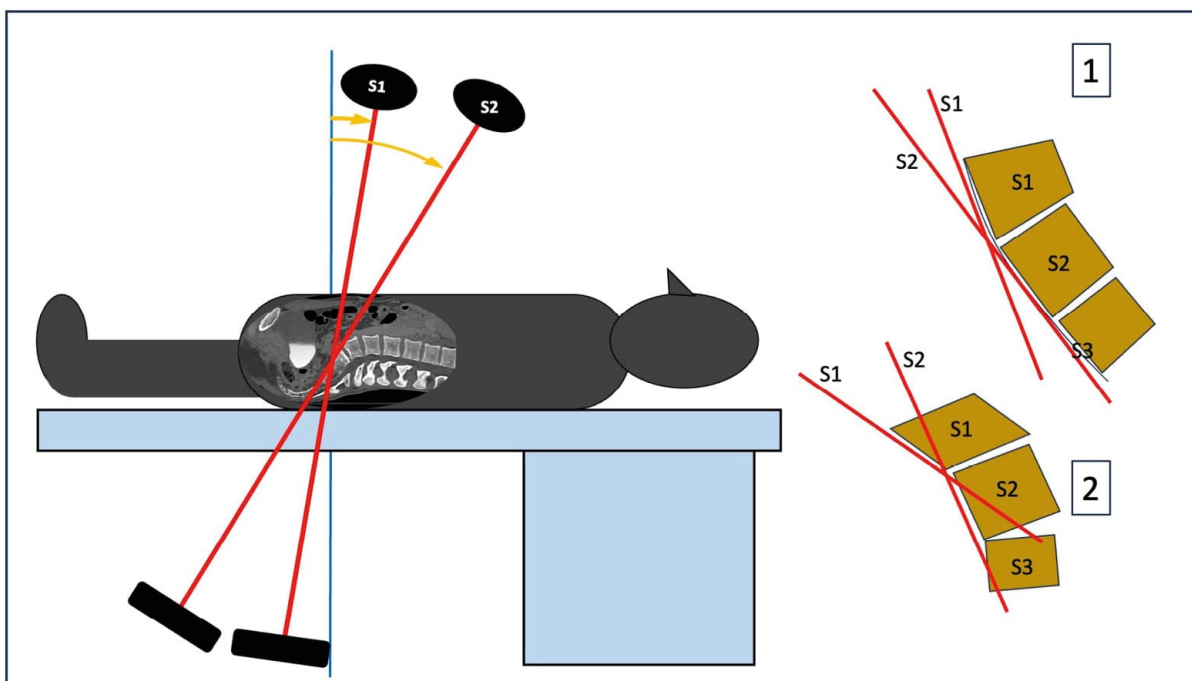


Figure 8 : Figure illustrating the performance of S1 and S2 Inlet views and possible variations. In the first case, the S1 Inlet tilt will be greater than the S2 Inlet (1); In the second case, the S1 Inlet is less pronounced than the S2 Inlet (2).

CT reconstructions with precise axial and coronal plane reformatting are also useful for more accurate measurement of the corridor size [15].

In the presence of sacral dysmorphism, careful analysis of preoperative CT scans, including axial and coronal reconstructions, is essential to minimize the risk of breach [16]. This type of dysmorphism requires a more ascending and anteriorly oriented screw trajectory. Positioning the patient on the side of the table or elevating them with a cushion helps avoid conflicts with the motor and operating table.

ANTERIOR COLUMN (AC) SCREW FIXATION

First described by Routt et al. in 1994, the use of intramedullary screws in the iliopubic ramus has demonstrated equivalence to plate fixation and superiority over non-operative treatment or external fixation. This technique is indicated for obturator ring fractures in pelvic ring injuries and anterior column fractures in acetabular fractures. Positive outcomes have expanded surgical indications, particularly in geriatric patients, with benefits for pain management and recovery of autonomy (Figure 9). This fixation can be performed either antegrade (from the gluteus medius pillar to the symphysis) or retrograde (reverse direction). The choice between these two techniques is not clearly established. However, for fractures closer to the symphysis (Nakatani I and II), retrograde fixation appears to offer an easier trajectory. Conversely, for lesions near the acetabulum, antegrade fixation seems more appropriate. The anatomy of the iliopubic ramus is highly variable, and certain corridors can be difficult to locate, even with reduced fractures. For fixation in cases of osteoporosis or early weight-bearing, bicortical purchase is recommended, particularly in the dense region of the acetabular roof [17]. The procedure is preferably performed in supine position, with a sacral cushion to avoid interference with the operating table. However, it can be performed prone when acetabular fracture requires posterior fixation. Surgical draping should extend to the edge of the table for the buttock and to the base of the penis or clitoris for the superior portion. The image intensifier is positioned facing the surgeon. For imaging views, the Outlet + three-quarter obturator view provides a "front view" of the obturator frame, thus guiding the trajectory in the cranio-caudal plane and allowing visualization of the entry point while monitoring for intra-articular hip penetration (Figures 3, 9, 10, 11). The orthogonal view, an Inlet view, helps manage trajectory convergence, avoiding medial neurovascular and urovisceral structures. (Figure 3) For antegrade AC screw fixation, the skin incision is typically made halfway between the greater trochanter and the pillar bulge on the iliac crest, approximately 6 cm posterior to the anterior superior iliac spine. In obese patients, the incision should be placed even closer to the iliac crest. The bone entry point is located in the gluteus medius pillar, typically 2-3 cm above the hip joint, identified using fluoroscopy (Figure 10). For retrograde fixation, the entry point can be at the homolateral rectus tubercle, or even contralateral in very medial fractures (Figure 11). It can also be lateral to the symphyseal meniscus depending on the case. This technique makes hip joint passage more challenging. Once reduction is achieved if necessary, the guide wire can be advanced through the corridor manually using a T-handle; this method helps limit misplacements by allowing the wire to work and flex along the cortical walls of the corridor. When bone density is high, power tool use may be necessary. Once the wire position in the corridor is confirmed, a 6.5- or 7.3-mm screw is typically used, with partial or full threading depending on the fracture pattern and proximity to the joint.

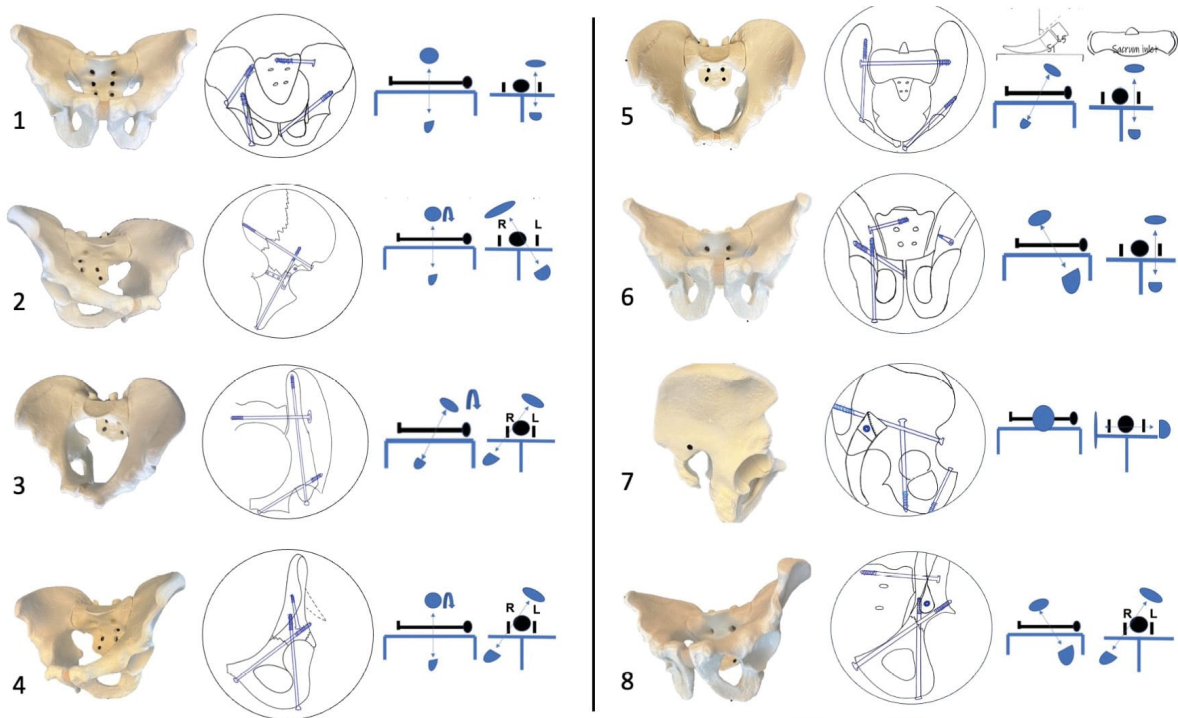


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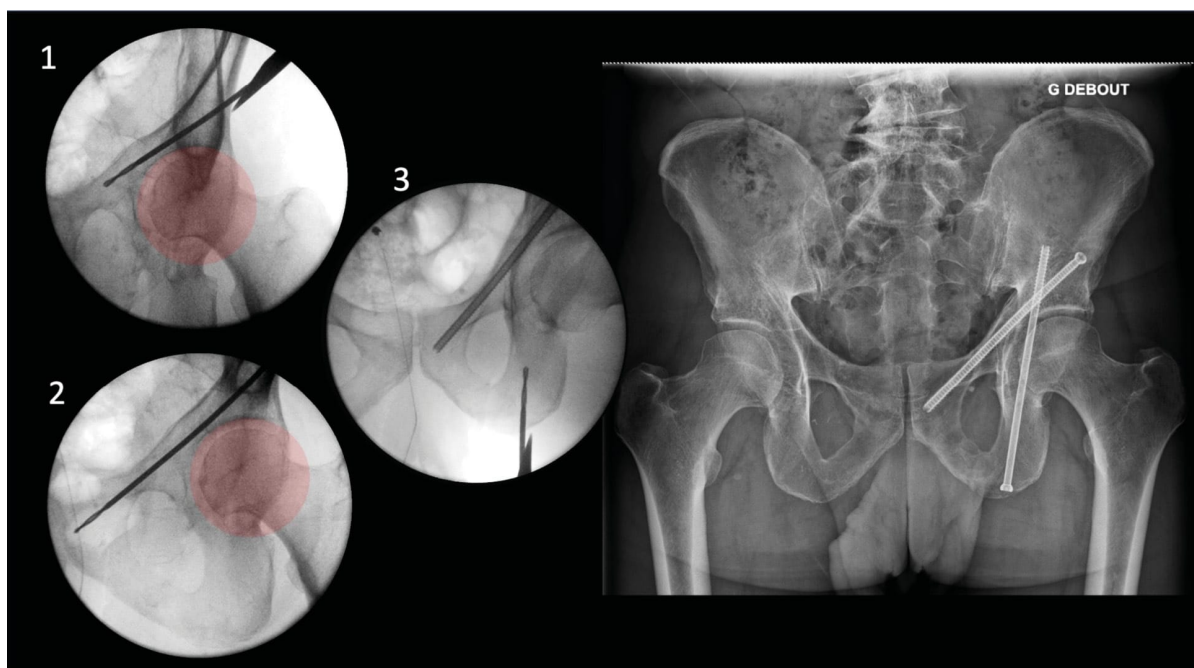


Figure 9 : Illustration of left anterior column (AC) antegrade screw fixation (1,2), and left posterior column (PC) retrograde screw fixation (3) in the management of an acetabular fracture.

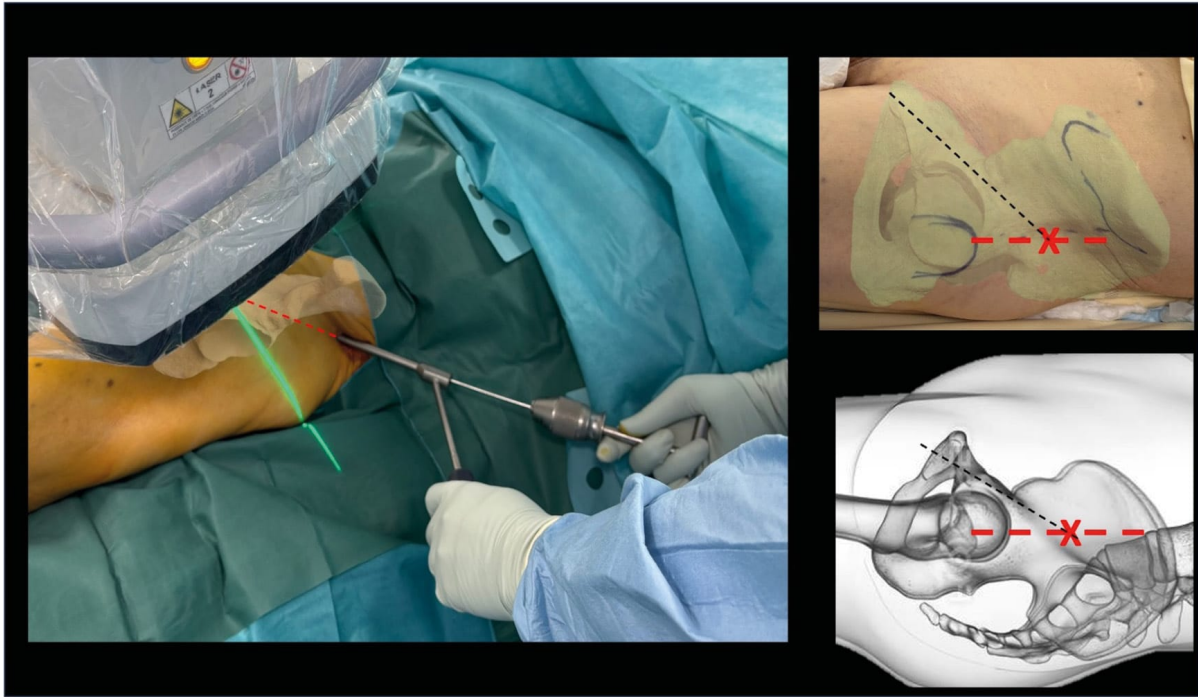


Figure 10 : Figure showing the entry point for anterior column antegrade screw fixation, guided by palpable landmarks (greater trochanter, gluteus medius pillar on the iliac crest).

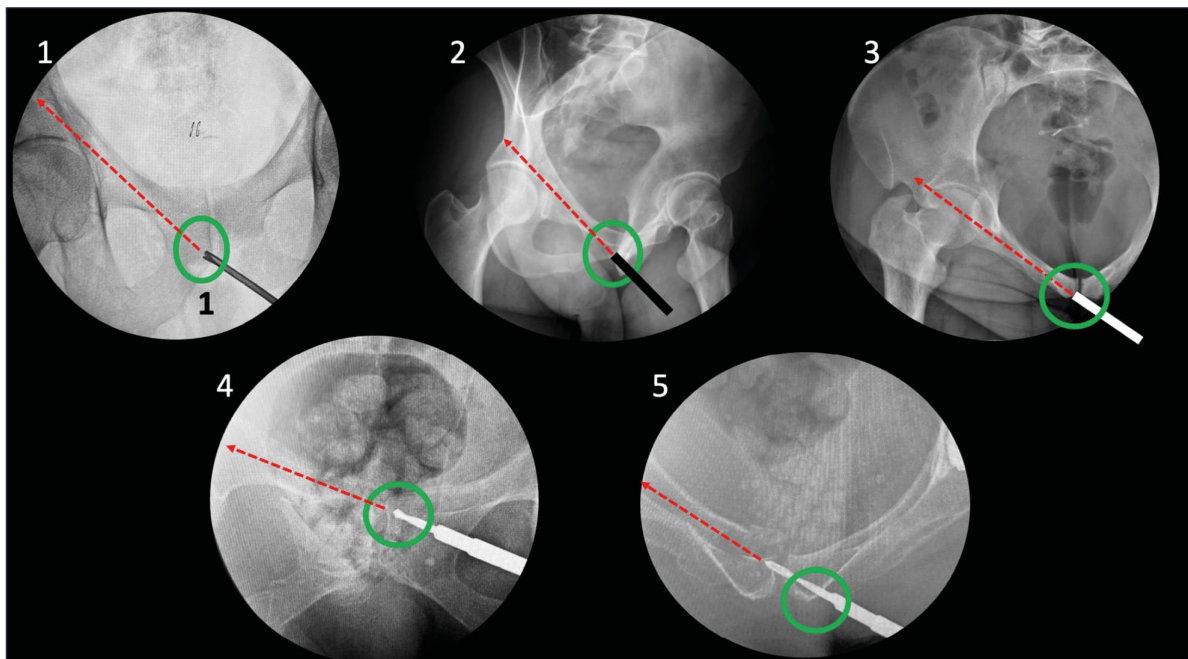


Figure 11 : Figure showing the entry point for anterior column retrograde screw fixation. On an anteroposterior view, the entry point is located at the inferior aspect of the symphysis (providing the best trajectory in the anterior wall) (1); Visualization of the trajectory on an Outlet view plus three-quarter obturator view (2); Visualization of the trajectory on an Inlet view (3); Special case of right anterior column screw fixation with contralateral starting point (4,5).

One of the main complications is injury to the external iliac vessels or femoral nerve, located at the superior portion of the branch. A breach at this level may also go unnoticed if the outlet view is insufficient (Figure 12). The structures at risk in antegrade CA screw fixation are the gluteal muscles and their neurovascular pedicles,

although this is a theoretical complication since no injuries have been reported in the literature. For retrograde CA screw fixation, the major risk is urogenital and thus differs between sexes. In women, the body and glans of the clitoris are the main structures at risk. It should also be noted that there is significant sensory nerve innervation that could be injured by this procedure. In men, the spermatic cords and corpus cavernosum are the main structures at risk. The spermatic cords can be easily palpated and identified before the procedure. To limit potential injury to these structures, it is recommended to perform clinical mapping when possible and careful dissection while protecting the procedure using a dedicated cannula.

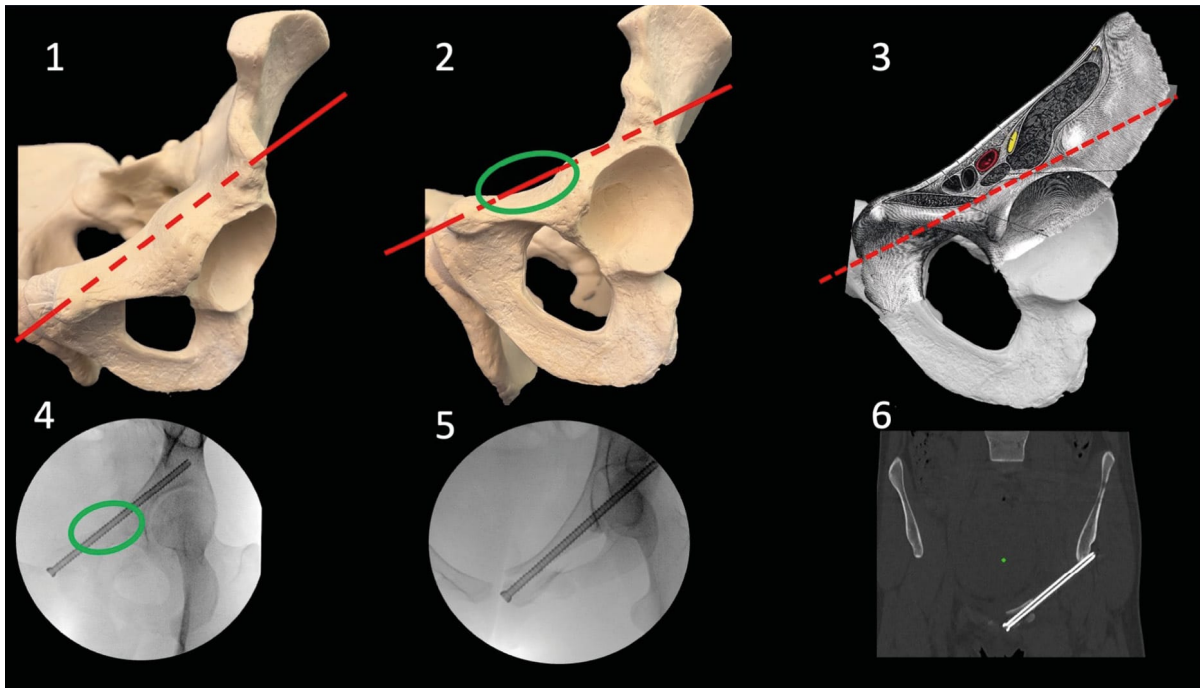


Figure 12 : Figure showing the risk with an Outlet + Left Obturator view with insufficient Outlet, concealing the false route at the iliopectineal eminence level (1, 2), reminder of the related anatomical structures (3); Clinical illustration (4, 5, 6).

Certain anatomical features, such as the parabolic shape of the iliopectineal branch or external genital and abdominal anatomy, complicate this procedure. Many authors have described techniques to facilitate screw insertion. Another difficulty may arise from fracture displacement itself, making the corridor inaccessible. Various percutaneous reduction maneuvers are then implemented, such as traction, using a reduction frame, joystick wire, pusher, or performing a small suprapubic approach. One of these techniques uses a Métaizeau nail as a guide wire. This device facilitates progression through the corridor, limits false passages thanks to its blunt tip, and allows catheterization of the displaced fragment using its curved end. This technique thus enables reduction.

Tips / Tricks: To incise at the optimal trajectory, we recommend, when beginning to gain experience, using a standard 2.0mm Kirschner wire through the skin to evaluate, under fluoroscopy, the ideal entry point and appropriate trajectory before making the scalpel incision. This approach helps avoid having to force through soft tissues in case of inadequate skin incision, which could complicate screw placement. In case of conflict with the contralateral thigh (extreme morphologies), one technique involves exploiting the creep (bending) of the guide wire. The radius of curvature thus generated allows for a trajectory that would be physically impossible to achieve with a straight wire (Figure 13). Using a curved wire or Métaizeau nail is an effective technique for finding the corridor when it is difficult or narrow (for example, to place the screw as far from the joint as possible), while limiting the risk of false passages [18]. Another technique involves using a cannulated drill bit at the entry point,

then inserting a pre-curved Kirschner wire. The progression of the wire, followed by the drill bit, is performed repeatedly inside the corridor (Figure 14).

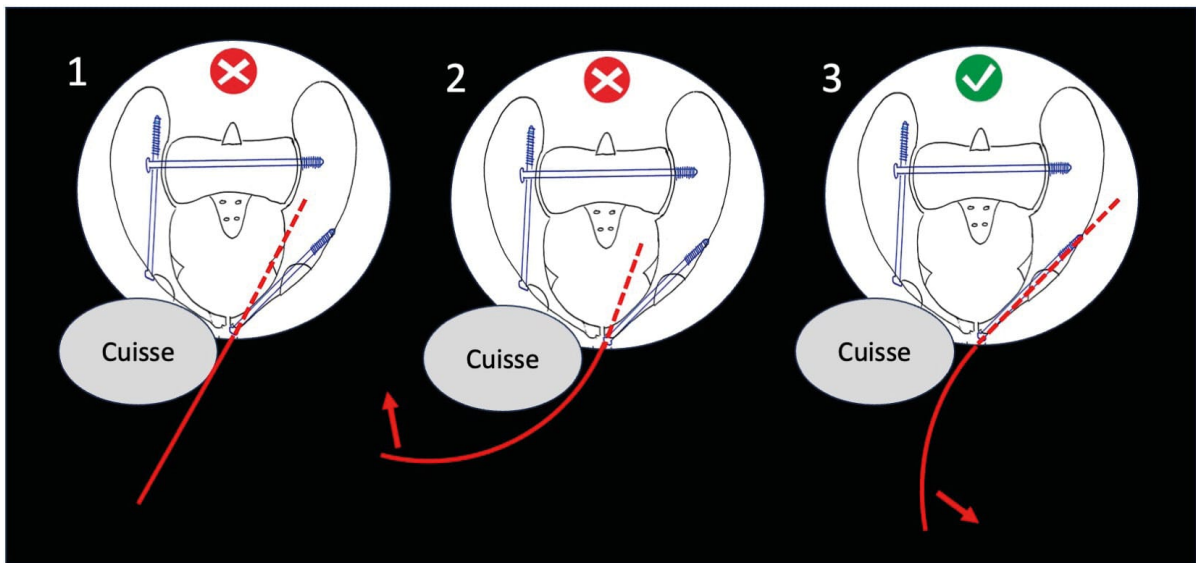


Figure 13 : Figure demonstrating the potential conflict with the contralateral thigh during retrograde AC (Anterior Column) screw fixation (1), resulting bending towards the lesser pelvis due to conflict (2); opposite bending technique enabling successful procedure (3).

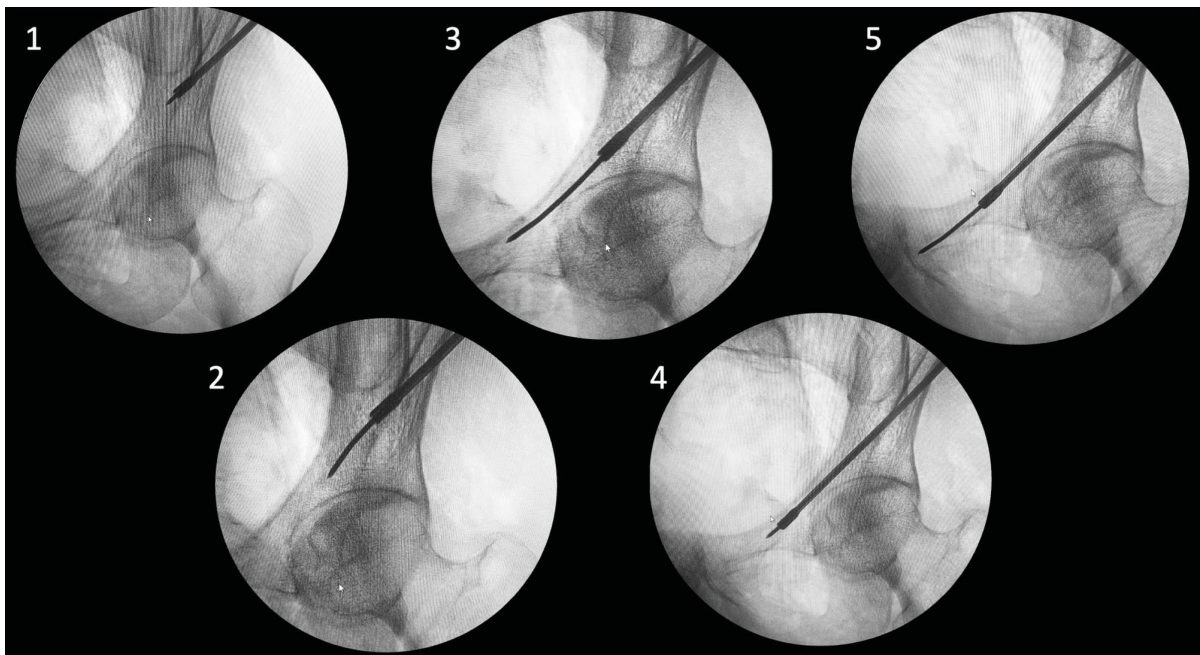


Figure 14 : Figure demonstrating the progressive drilling technique (here for left AC antegrade) using a cannulated drill bit and a curved guide wire.

POSTERIOR COLUMN (PC) SCREW FIXATION

The osseous corridor used for this technique is well-known to pelvic and acetabular surgery specialists. Long used in open surgery as a complement to plate osteosynthesis, posterior column screw fixation was described for

percutaneous acetabular surgery in the late 1990s. This method is indicated for acetabular fractures involving the posterior column, such as posterior column fractures, transverse fractures, anterior column fractures with posterior hemitransverse component, T-shaped fractures, and certain both-column fractures.

In this technique, the patient is positioned supine with the sacrum elevated on a cushion. Similar to anterior column (AC) screw fixation, there are antegrade and retrograde approaches. The antegrade fixation is not truly "percutaneous" as it requires a small iliac approach. However, retrograde fixation is performed using the classic percutaneous method. A high posterior column fracture will more readily accommodate antegrade fixation, while a fracture in the lower portion of the column is better suited for retrograde fixation, although both techniques are equivalent.

For the surgical field, it is necessary to include the ipsilateral lower limb during retrograde fixation, taking care to exclude the external genitalia. This allows positioning of the ischial tuberosity in the surgical field when the assistant places the hip in deep flexion. The image intensifier is positioned facing the surgeon.

Regarding imaging views, this technique requires an anteroposterior view, obturator oblique view, and iliac oblique view. The anteroposterior and obturator oblique views are used to guide the guide wire toward the ischial tuberosity. The iliac oblique view helps verify that the wire remains clear of the hip joint and the greater sciatic notch. The obturator oblique view ensures the wire is not medial to Kohler's line, i.e., intrapelvic. (Figure 3)

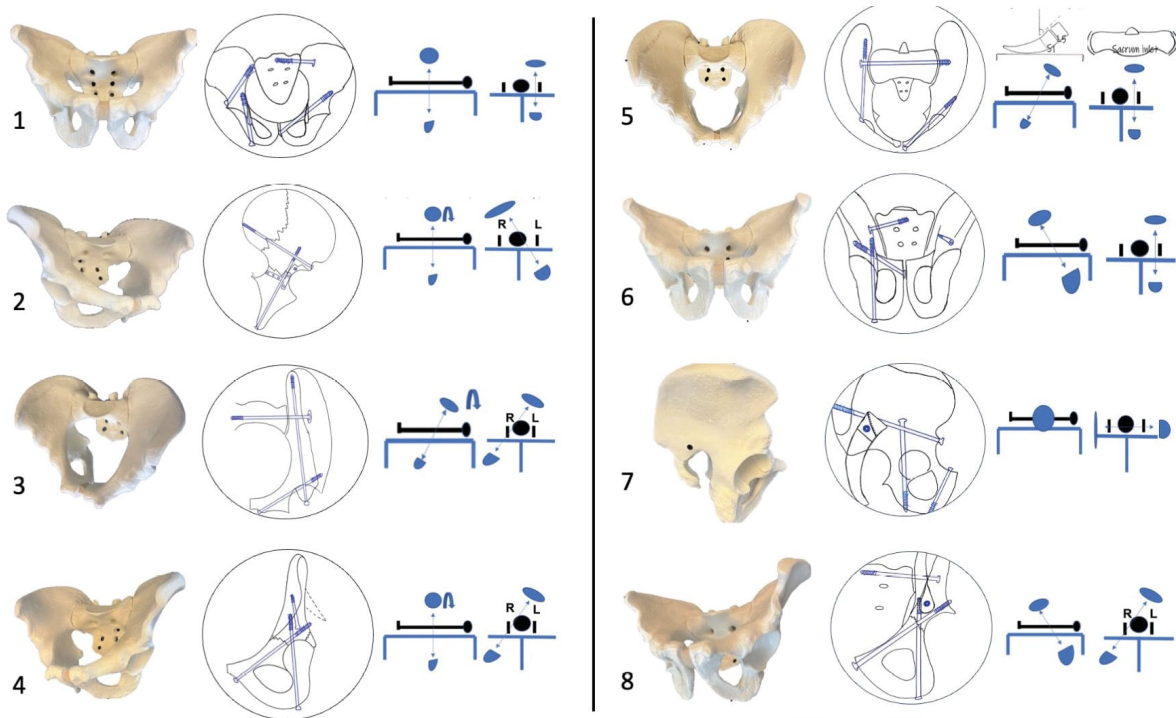


Figure 3 : Figure showing the main radiological views, with model representation, appearance of corridors and methods to obtain them. Anteroposterior view (1); Left alar oblique view (2); Inlet + Left obturator view (3); Left obturator oblique view (4); Inlet view (5); Outlet view (6); Lateral view (7); Outlet + Left obturator view (8).

For antegrade fixation, a small approach is necessary. This involves a mini-window in the iliac portion of the ilioinguinal approach. To obtain the best trajectory without soft tissue interference, a 2 cm skin incision is made, starting 4 fingerbreadths from the anterior superior iliac spine (ASIS). The iliacus muscle is subperiosteally stripped along the internal table of the innominate bone. The entry point is located approximately 2 cm lateral to the pelvic brim. The direction is obtained using the radiographic views. The use of a percutaneous trocar is imperative to preserve skin integrity and allow support against the thoracic cage to prevent guide wire bending.

For retrograde fixation, the hip is placed in deep flexion with the knee flexed, and the entry point is located in the medial half of the ischial tuberosity. Here too, percutaneous reduction techniques are described, but the difficulty in achieving perfect articular reduction leads to favoring this option for minimally or non-displaced fractures, or as a complement to conventional open osteosynthesis. Once the guide wire is in place and after verifying the absence of false passages on different views, measurement is performed. A lateral view may be useful for evaluating length, particularly in retrograde fixation. Indeed, the cortical density line of the innominate bone indicates the wire's exit point. A 6.5- or 7.3-mm screw is typically used, with partial or full threading depending on the fracture pattern and proximity to the joint (Figures 9 and 15).

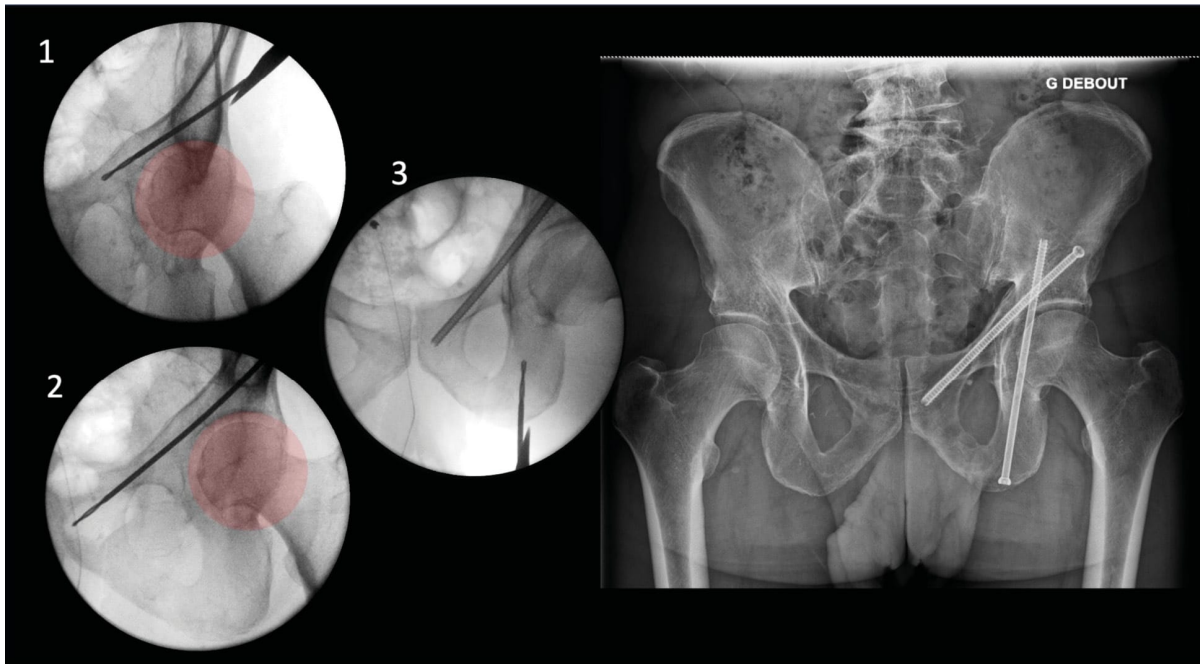


Figure 9 : Illustration of left anterior column (AC) antegrade screw fixation (1,2), and left posterior column (PC) retrograde screw fixation (3) in the management of an acetabular fracture.

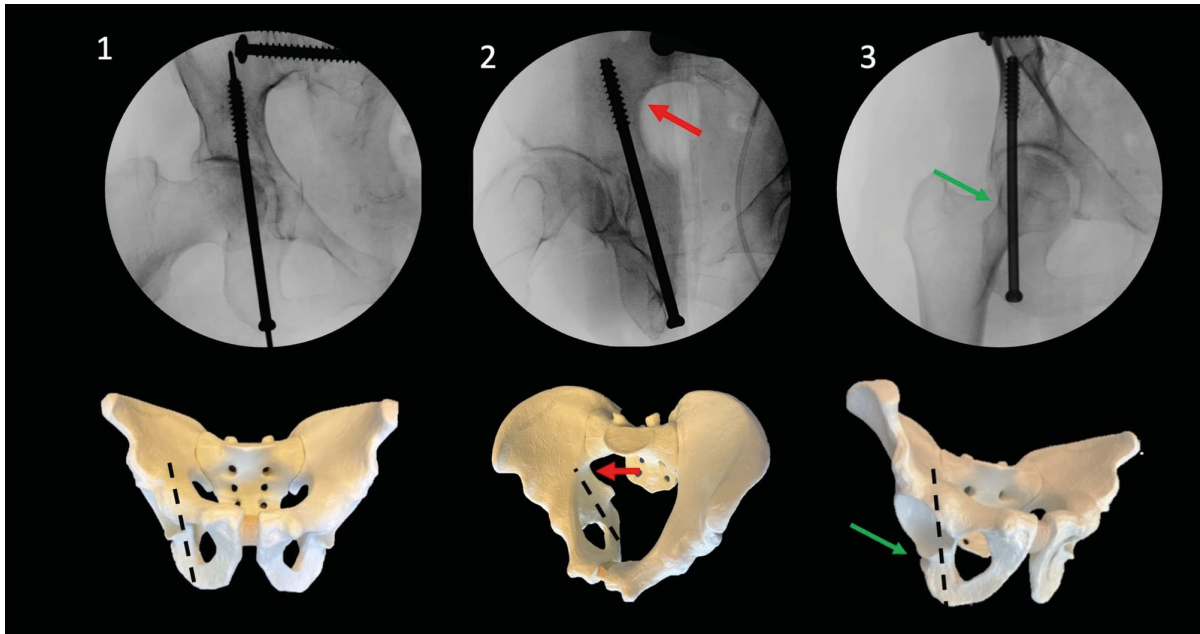


Figure 15 : Figure demonstrating the Posterior Column screw fixation technique (here right PC retrograde fixation). Anteroposterior view showing the starting point and trajectory (1); Three-quarter iliac wing view showing the entry point, hip joint, and greater sciatic notch (Red Arrow) (2); Three-quarter obturator view showing the lesser sciatic notch, with the Sciatic Nerve being the nearby hazard (Green Arrow) (3).

In addition to potential muscle damage associated with the iliac approach, the lateral femoral cutaneous nerve is exposed during the antegrade procedure. For both techniques, the neurological structures at risk include the sciatic nerve, the posterior femoral cutaneous nerve, as well as the cluneal nerve branches. These are responsible for cutaneous sensitivity of the inferior half of the gluteal region. Potential complications also include injury to the inferior gluteal artery, located lateral to the entry point, as well as the risk of fecal contamination of the wound from the patient's gastrointestinal tract.

SUPRA-ACETABULAR SCREW FIXATION (OR LC2) ---

The supra-acetabular screw corridor, also known as LC2, has been used for several decades in pelvic trauma for placing external fixator pins in "supra-acetabular" configurations. The supra-acetabular position is biologically superior to the iliac crest for controlling the posterior arch of the pelvic ring. Its use for internal fixation was first described in the early 1990s.

This technique is indicated for anterior column fractures, particularly in their high variants, iliac wing fractures located adjacent to the greater sciatic notch (LC2 fractures, lateral compression type 2, according to Young and Burgess classification, which gave it its name), as well as crescent fractures. More recently, it has been described for the placement of pedicle screws in Infix device fixation, or in retrograde trajectory lumbo-pelvic fixation techniques.

The hourglass-shaped bone corridor connects the anterior inferior iliac spine (AIIS) to the posterior superior iliac spine (PSIS). Several screw trajectories can utilize this corridor [19]. Here, we will detail the most commonly used trajectory, which offers maximum safety.

Regarding imaging views, the "teardrop" view is frequently recommended in the literature. To obtain it, position the fluoroscope in Outlet and obturator oblique views (Figure 3), then adjust the angles to clearly isolate the base of the teardrop from the acetabular roof. In this view, the rays are adjacent to the major axis of the corridor, and the bottom of the teardrop represents the apex of the greater sciatic notch (GSN). Although this view is recommended, the authors do not recommend it and do not use it in their practice. Indeed, the bulk of the image intensifier limits freedom of movement, which complicates its use. We prefer a method based on using two orthogonal views, which offers better freedom of movement [20] (Figure 16).

The AIIS entry point is visualized on a three-quarter wing view, which is very useful during the procedure to verify the absence of intra-articular breach and false passage through the greater sciatic notch, thus allowing trajectory management in the cranio-caudal plane. The guide wire progression within the corridor is monitored using an inlet view plus three-quarter obturator view (or "bottom wing" view according to Anglo-Saxon literature), which provides visualization of the internal and external tables of the corridor to manage trajectory convergence, as well as the AIIS. (Figure 16)

Finally, a true lateral view is useful to control the final screw length if the fracture requires complete corridor fixation. The "teardrop" view can potentially be performed at the end of the procedure for final verification.

The patient is typically positioned supine for antegrade fixation, but retrograde fixation can be performed in prone position if reduction requires posterior crest approach. Surgical draping has no particular requirements but must allow access to the root of the thigh.

For antegrade fixation, the starting point is located on the AIIS and thus not palpable. Typically, it is located two fingerbreadths caudally and one fingerbreadth medially from the Anterior Superior Iliac Spine (Figure 16). A teardrop view can be helpful to locate the skin incision. The entheses of the direct head of the rectus femoris muscle on the AIIS can make proper guide wire positioning challenging. The guide wire is placed at the entry point using a three-quarter wing view, and the trajectory is adjusted to pass above the acetabulum and above the GSN. A trajectory adjacent to the apex of the GSN will allow maximum screw length implantation while remaining in the safest zone.

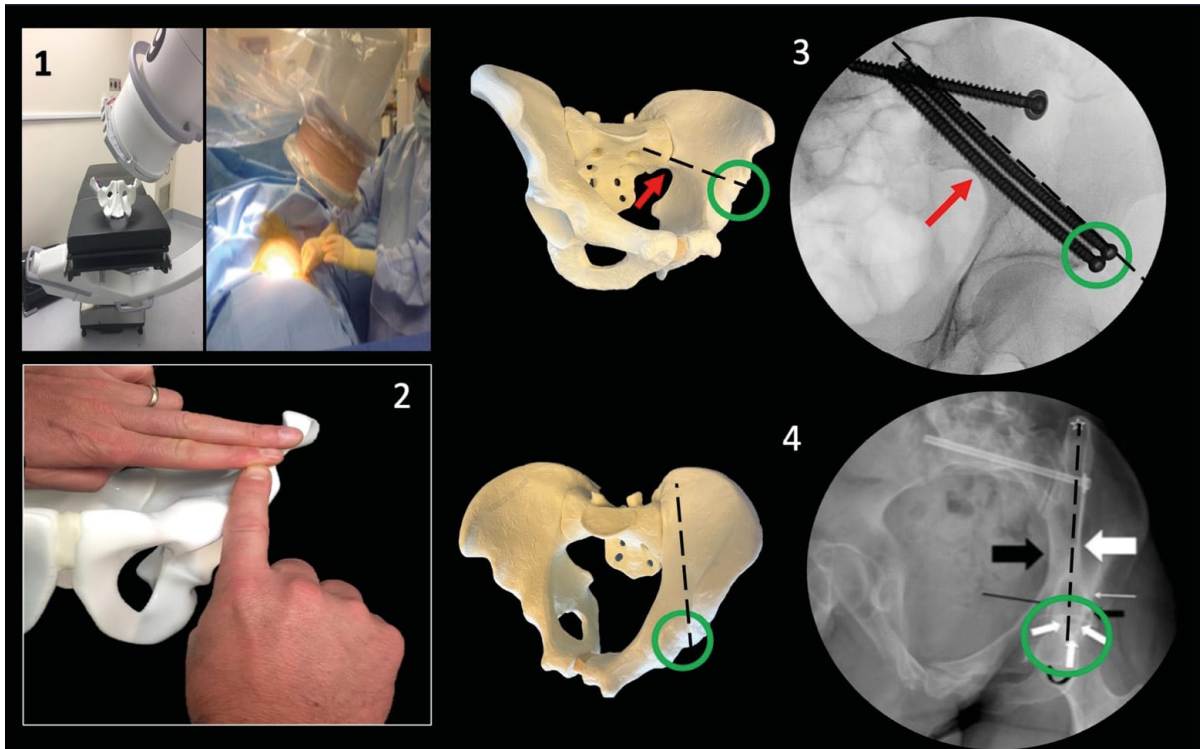


Figure 16 : Figure demonstrating the views for supra-acetabular screw fixation. Conflict between the image intensifier and operator's hands for the "teardrop" view (1); entry point relative to the ASIS (Anterior Superior Iliac Spine) (2); three-quarter iliac wing view showing the greater sciatic notch (Red Arrow) and the starting point in the AIIS (Anterior Inferior Iliac Spine) (Green Circle) (3); Inlet + Obturator view showing the corridor between the internal table (Black Arrow) and external table (White Arrow) and the starting point (Green Circle) (4).

Then, the image intensifier is positioned for inlet plus three-quarter obturator view to manage trajectory convergence. The guide wire is then advanced through the corridor, alternating between these two views to check for absence of false passages. Once the guide wire is advanced to the desired position, a teardrop view is performed to confirm proper positioning within the corridor. A lateral view verifies the length. Subsequently, a screw of the desired length is inserted.

For retrograde fixation, the patient is positioned prone, the posterior iliac spines are easily palpable clinically, and the procedure is the same as for antegrade fixation. A 7.3 mm or 8 mm screw is typically used, with partial or full threading depending on the fracture pattern and proximity to the joint.

Structures at risk during these procedures include the hip joint, lateral femoral cutaneous nerve (LFCN), femoral nerve, and femoral artery. The most exposed structure is the LFCN, considered the main hazard during external fixator implantation using the LC2 corridor, although no series report deficits in this context. However, post-operative deficit is reported in 30% of cases with the Infix technique, which also uses the LC2 corridor, with the majority of patients recovering spontaneously within six months. The use of dedicated protection sleeves should help prevent these complications.

TRANSVERSE SUPRA-ACETABULAR SCREW FIXATION

This corridor is described for acetabular fractures. The screw trajectory lies in the acetabular weight-bearing zone and terminates medially at the articular surface in the quadrilateral plate. Indicated in certain acetabular fractures, it provides support to the dome and allows for osteosynthesis of the previously reduced quadrilateral plate. The entry point is similar to that of an anterior column (AC) screw, but slightly more anterior on the gluteus medius pillar, approximately 1 cm above the joint. This point can be verified on an outlet view combined with an obturator oblique view. The cranio-caudal trajectory is evaluated on an anteroposterior view and must ensure passage above the articular surface. Finally, the corridor terminus is located at the quadrilateral plate, visible on an inlet view with slight obturator obliquity (Figure 3). To limit the risk of visceral and neurovascular pelvic injury at the end of the procedure, using the drill in reverse mode can be useful to palpate the internal table without risk of breaching it. Besides the risks of intra-articular breach, neurovascular and visceral risks are most concerning. Endopelvicly, there is a risk of digestive perforation or injury to the obturator pedicle. Exopelvicly, the superior gluteal pedicle is theoretically at risk.

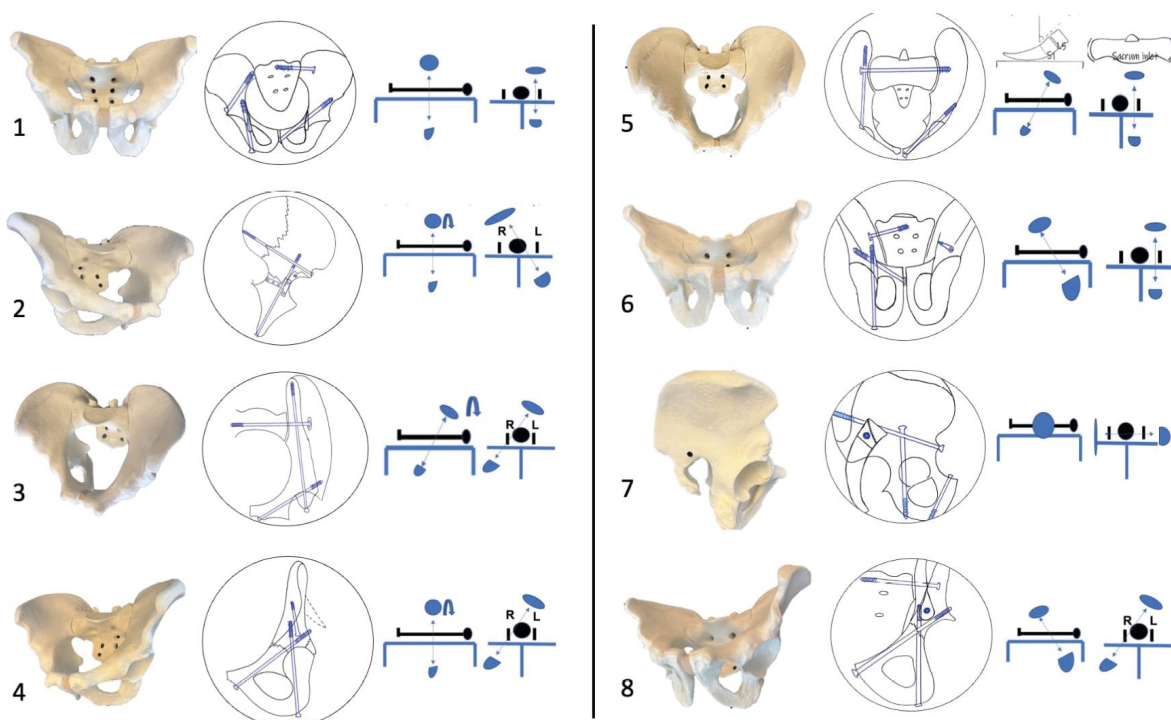


Figure 3 : Figure showing the main radiological views, with model representation, appearance of corridors and methods to obtain them. Anteroposterior view (1); Left alar oblique view (2); Inlet + Left obturator view (3); Left obturator oblique view (4); Inlet view (5); Outlet view (6); Lateral view (7); Outlet + Left obturator view (8).

THE "MAGIC" SCREW

Also called the "external-internal posterior column screw," this technique was described in the early 2000s. Its execution is complex and requires perfect mastery of bone anatomy. It is indicated in certain transverse fractures, as a complement to or replacement for a posterior column (PC) screw. Like the supra-acetabular screw, it allows for maintaining a previously reduced quadrilateral plate fracture. Its entry point is similar to that of a transverse supra-acetabular screw, visible on an outlet view plus obturator oblique view. Its anteroposterior direction requires an iliac oblique view; on this view, its trajectory must be directed toward the ischial spine, away from the

joint. The guide wire progression is also monitored through anteroposterior, obturator oblique, inlet, and outlet views (Figure 3). The same technique described for the supra-acetabular screw is strongly recommended at the end of the procedure to palpate the internal table of the posterior column. The iatrogenic risks are similar to those described for the supra-acetabular screw, with the additional potential risk of sciatic nerve injury.

RESULTS

To date, there are few studies reporting long-term outcomes of these techniques, due to the diversity of patient populations and surgical indications. However, several studies demonstrate good results for posterior pelvic ring injuries. Similar results are also observed for percutaneous fixation of the anterior arch of the pelvic ring. Stabilization techniques for unstable vertical shear injuries remain controversial, although trans-sacral fixation is recommended if a percutaneous approach is preferred.

Regarding percutaneous management of acetabular injuries, the number of studies is limited. Nevertheless, some authors report encouraging results, although more studies are needed to definitively evaluate these methods. The geriatric population appears to particularly benefit from these techniques, both for pelvic ring and acetabular fractures. Several authors have studied the impact of these techniques in this population with positive outcomes.

CONCLUSION

Percutaneous fixation techniques for pelvic ring and acetabular fractures offer promising results. They enable stable fracture fixation, thereby reducing postoperative complications and improving patients' functional recovery. These techniques minimize tissue trauma, reduce hospital stay duration, and accelerate return to daily activities, which is particularly beneficial for elderly patients who often have reduced recovery capacity and an increased risk of postoperative complications.

Beyond the percutaneous aspect discussed in this article, it is essential for all surgeons specializing in pelvic and acetabular surgery to thoroughly master these anatomical corridors and the necessary fluoroscopic views. Indeed, whether the screw is placed percutaneously or through an open approach, the technique, safe corridor, and fluoroscopic views remain identical.

However, it is essential to emphasize that these procedures require technical expertise and thorough knowledge of pelvic anatomy to ensure their effectiveness and safety. Iatrogenic risks, such as neurovascular injuries, must be considered and managed with extreme caution. Due to technical complexity and associated risks, these interventions require careful evaluation of indications and rigorous planning before implementation. Overall, while results show that percutaneous fixation techniques are an effective and safe option for treating certain pelvic ring and acetabular fractures, they should be performed by experienced surgeons in hospital environments with adequate support in case of complications.

REFERENCES

1. Tonetti J, van Overschelde J, Sadok B, Vouaillat H, Eid A. Percutaneous ilio-sacral screw insertion. Fluoroscopic techniques. *Orthop Traumatol Surg Res* 2013;99:965–72. <https://doi.org/10.1016/j.otsr.2013.08.010>.
2. Routt MLCJ, Simonian PT, Grujic L. Preliminary Report: The Retrograde Medullary Superior Pubic Ramus Screw for the Treatment of Anterior Pelvic Ring Disruptions: A New Technique. *J Orthop Trauma* 1995;9:35.
3. Starr AJ, Walter JC, Harris RW, Reinert CM, Jones AL. Percutaneous Screw Fixation of Fractures of the Iliac Wing and Fracture-dislocations of the Sacro-iliac Joint (OTA Types 61-B2.2 and 61-B2.3, or Young-Burgess “Lateral Compression Type II” Pelvic Fractures): *J Orthop Trauma* 2002;16:116–23. <https://doi.org/10.1097/00005131-200202000-00008>.
4. Starr AJ, Reinert CM, Jones AL. Percutaneous fixation of the columns of the acetabulum: a new technique. *J Orthop Trauma* 1998;12:51–8. <https://doi.org/10.1097/00005131-199801000-00009>.
5. Starr AJ, Borer DS, Reinert CM. Technical aspects of limited open reduction and percutaneous screw fixation of fractures of the acetabulum. *Oper Tech Orthop* 2001;11:218–26. [https://doi.org/10.1016/S1048-6666\(01\)80008-2](https://doi.org/10.1016/S1048-6666(01)80008-2).
6. Qoreishi M, Seyyed Hosseinzadeh HR, Safdari F. Clinical Results of Percutaneous Fixation of Pelvic and Acetabular Fractures: A Minimally Invasive Internal Fixation Technique. *Arch Bone Jt Surg* 2019;7:284–90.
7. Rommens PM, Boudissa M, Krämer S, Kisilak M, Hofmann A, Wagner D. Operative treatment of fragility fractures of the pelvis is connected with lower mortality. A single institution experience. *PLoS ONE* 2021;16:e0253408. <https://doi.org/10.1371/journal.pone.0253408>.
8. Benhenneda R, Letissier H, Dubrana F, Di Francia R. Immediate full weight bearing after pelvic percutaneous fixation by screw for simple acetabular and pelvic ring fractures in patients older than sixty five years. *Int Orthop* 2022;46:2413–21. <https://doi.org/10.1007/s00264-022-05504-z>.
9. Tolosano L, Rieussec C, Sauzeat B, Caillard G, Drevet S, Kerschbaumer G, et al. Fractures de fragilité pelvienne : première expérience de prise en charge opératoire. À propos d’une série grenobloise de 48 patients. *Rev Chir Orthopédique Traumatol* 2024;110:469–81. <https://doi.org/10.1016/j.rcot.2024.02.013>.
10. Rommens PM, Graafen M, Arand C, Mehling I, Hofmann A, Wagner D. Minimal-invasive stabilization of anterior pelvic ring fractures with retrograde transpubic screws. *Injury* 2020;51:340–6. <https://doi.org/10.1016/j.injury.2019.12.018>.
11. Hadeed M, Heare A, Parry J, Mauffrey C. Anatomical Considerations in Percutaneous Fixation of the Pelvis and Acetabulum. *J Am Acad Orthop Surg* 2021;29:811–9. <https://doi.org/10.5435/JAAOS-D-21-00066>.
12. Collinge C, Coons D, Aschenbrenner J. Risks to the superior gluteal neurovascular bundle during percutaneous iliosacral screw insertion: an anatomical cadaver study. *J Orthop Trauma* 2005;19:96–101. <https://doi.org/10.1097/00005131-200502000-00005>.
13. Pennal GF, Tile M, Waddell JP, Garside H. Pelvic disruption: assessment and classification. *Clin Orthop* 1980;12–21.
14. Maher M, Baldini TH, Parry JA, Mauffrey C. The potential biomechanical advantage of lag by technique screw fixation of the posterior pelvic ring. *Eur J Orthop Surg Traumatol* 2020;30:1045–8. <https://doi.org/10.1007/s00590-020-02665-8>.
15. Hadeed M, Woods D, Koerner J, Strage K, Chu X, Simon V, et al. Using Reformatted Axial Computed Tomography Images in Isolation Will Miss Narrow S1 Transsacral Screw Corridors. *J Orthop Trauma* 2022;36:292–6. <https://doi.org/10.1097/BOT.0000000000002295>.
16. Woods D, Koerner J, Strage K, Chu X, Simon V, Hadeed M, et al. Defining Sacral Dysmorphism: What Size Corridor Precludes Transsacral Screw Placement. *J Orthop Trauma* 2022;36:498–502. <https://doi.org/10.1097/BOT.0000000000002380>.

17. Tucker NJ, Stacey S, Kim YJ, DeLeon J, Richard R, Heare A, et al. Variables Associated With Loss of Fixation of Retrograde Rami Screws in Minimally Displaced Lateral Compression Type 1 Pelvic Ring Injuries. *J Orthop Trauma* 2024;38:215–9. <https://doi.org/10.1097/BOT.0000000000002756>.
18. David G, Rony L, Moullac D, Letissier H, Di Francia R. The “Metaizeau trick” to facilitate medullary pubic ramus screw insertion: A technical note. *Orthop Traumatol Surg Res OTSR* 2024;110:103879. <https://doi.org/10.1016/j.otsr.2024.103879>.
19. Giannoudis PV, Tzioupis CC, Pape H-C, Roberts CS. Percutaneous fixation of the pelvic ring: AN UPDATE. *J Bone Joint Surg Br* 2007;89-B:145–54. <https://doi.org/10.1302/0301-620X.89B2.18551>.
20. Tosounidis TH, Mauffrey C, Giannoudis PV. Optimization of technique for insertion of implants at the supra-acetabular corridor in pelvis and acetabular surgery. *Eur J Orthop Surg Traumatol* 2018;28:29–35. <https://doi.org/10.1007/s00590-017-2007-8>.