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# Sacropelvic fixation: An overview and update on current techniques

**Andrew Harris, and Khaled M Kebaish***

*The Johns Hopkins University, Department of Orthopaedic Surgery, Baltimore, MD, United States*

ABSTRACT

The lumbosacral junction presents several unique challenges for spine surgeons. Of the many techniques developed to meet the anatomic and biomechanical challenges the lumbosacral junction presents and to address historically high complication rates, only a handful are commonly used today. Originally described 10 years ago, the S2-alar-iliac technique is the newest of these techniques, and evidence supports its simplicity, efficacy, lower complication rates, and other advantages compared with other methods. This article discusses the general principles underlying sacropelvic fixation and summarizes the recent literature regarding current techniques.



## 1. Introduction

Sacropelvic fixation describes the instrumentation at the caudal end of a spinal construct that ends at the sacrum and pelvis. Thus, sacropelvic fixation serves as the foundation for long constructs in spinal deformity surgery and is used to treat high-grade spondylolisthesis, flat-back syndrome requiring osteotomy, deformities at the lumbosacral junction, pelvic obliquity, and sacral fractures, as well as in revision surgery for disc degeneration caudal to long fusion constructs.[1,2] The lumbosacral junction presents a unique set of anatomic and biomechanical challenges to achieving rigid osseous fusion, and many techniques have been developed to overcome the strong flexion moments and cantilever forces of this region, while attempting to maintain secure distal fixation in the setting of poor bone quality of the sacrum.[2] Historically, the earliest methods of sacropelvic fixation, such as cast immobilization with in situ fusion, Harrington instrumentation, and Luque instrumentation produced high rates of pseudarthrosis and instrumentation failure, which led to the development of newer techniques with lower complication rates.[2,3]

In the following sections, we will review anatomic and biomechanical considerations of the lumbosacral region. We will also describe the current indications for the procedure, the techniques used in current practice, and the recent evidence regarding sacropelvic fixation.

## 2. Anatomic principles

Understanding the anatomy and biomechanics of the lumbosacral junction is essential to selecting and implementing a stable construct. The sacrum consists of cancellous bone surrounded by a thin cortical shell. The smaller sized and proportionally larger pedicles limit screw length and make it challenging to fully engage the cortices when S1 pedicular screws are used.[4] Because of its position as a fulcrum at the caudal end of the spine, the lumbosacral junction can experience shear forces up to 100 N during bending.[5] These forces, along with the poor bone quality of the sacrum, contributed to the failure of earlier techniques for sacropelvic fixation.

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* *Corresponding author at:* The Johns Hopkins University, 601 North Caroline Street, Suite 5223, Baltimore, MD 21287, United States.
*E-mail address:* kkebais@jhmi.edu (K.M. Kebaish).

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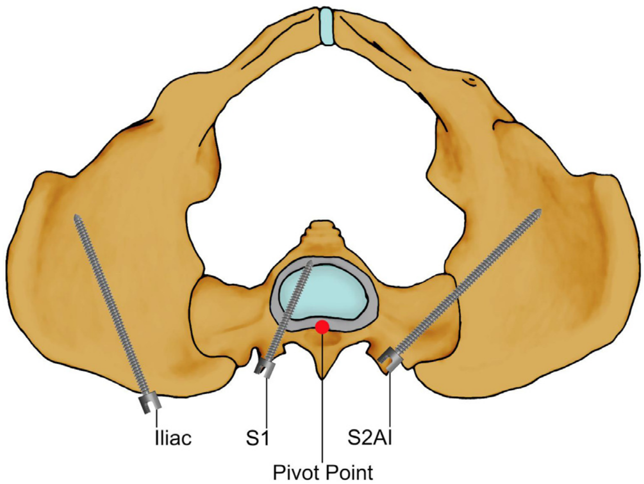


**Fig. 1 – Diagram showing the lumbosacral pivot point in the transverse and saggital planes, seen at the center point of the middle osteoligamentous column between L5 and S1 – An S1 screw, iliac screw, and S2 alar-iliac screw are all shown in reference to this point.**

### 2.1. *Lumbosacral pivot point*

The lumbosacral pivot point, first described by McCord in 1992, is defined as the center point of the middle osteoligamentous column between L5 and S1.[6] Fig. 1 shows this pivot point and its relationship to S1, S2, and iliac screws. McCord's pivot point is important because as fixation progresses anterior to this point, the stability of the construct increases.[1,5]

### 2.2. *Zones of sacropelvic fixation*

Sacropelvic fixation can be divided into 3 anatomic zones, as described by O'Brien et al[7] (Fig. 2, A and B). The zones are defined as follows: zone 1 includes the S1 vertebral body and the cephalad border of the sacral alae; zone 2 encompasses the region from the caudad sacral alae, through the body of S2, to the tip of the coccyx; and zone 3 is defined by the iliac bones.[7] These zones are important because the strength of the construct increases as fixation extends caudally from zones 1 to 3.[1]

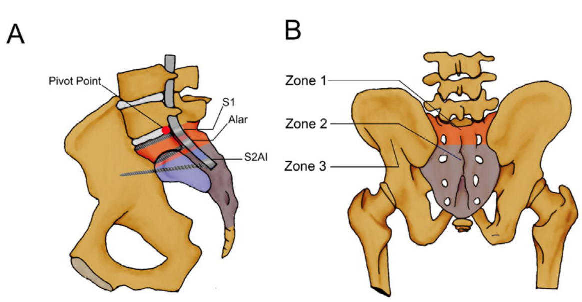


**Fig. 2 – (A and B) – Diagram showing the zones of sacropelvic fixation in the saggital plane (A) and posterior view (B), along with a schematic representation of where S1 screws, alar screws, and S2AI screws lie within these zones.**

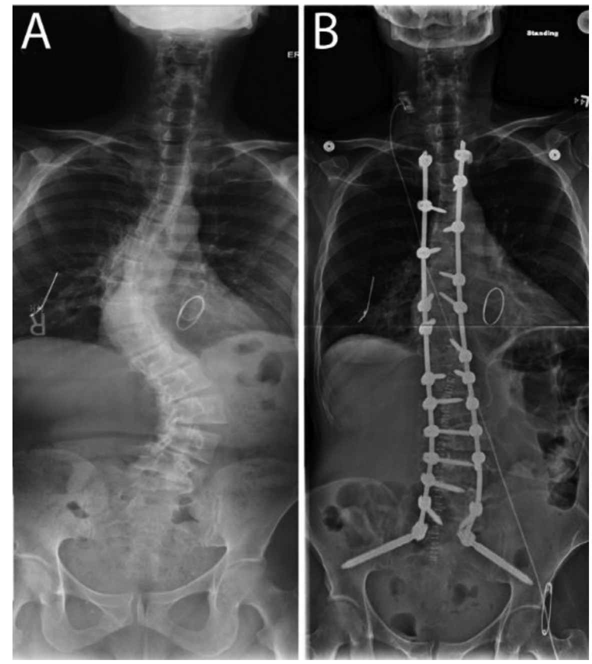


**Fig. 3 – Standing radiograph of a patient with a long spinal fusion construct with sacropelvic fixation using iliac screws before (A) and after (B) surgery.**

## 3. Indications for sacropelvic fixation

Long spinal fusion the sacrum is the most common indication for sacropelvic fixation and is the most widely studied.[1,5,8,9] The 2 accepted definitions of long spinal fusion are 1) a construct that crosses 4 levels and extends to L2; or 2) any construct that extends to the thoracolumbar junction or higher (Fig. 3).[5,9,10] Though the extent of distal fixation in long fusions is a critical decision and often debated, there is a consensus that when the sacrum is included, additional fixation in the ilium is necessary to reduce the risk of nonunion and instrumentation-related complications.[8,9,11]

Deformity at the lumbosacral junction is another common reason for sacropelvic fixation.[1,5] Conditions causing such deformity include adult degenerative scoliosis, kyphosis, and oblique takeoff at L5.[1] These conditions can be associated with severe lumbosacral instability, and instrumentation to the pelvis is necessary to prevent implant failure and pseudarthrosis.[1,8]

In cases of high-grade isthmic spondylolisthesis (grade 3 or higher),[12] major forces are placed on posterior implants, and sacropelvic fixation is necessary to reduce forces on the S1 screws.[5] When sacropelvic fixation is performed for this indication, care should be taken to protect the sacral screws with interbody cages at the L5 S1.[13,14]

Less common indications for sacropelvic fixation include sacral fracture with spinopelvic dissociation, fragility fractures of the sacrum, and instability after sacrectomy for tumors.[2,15,16] Sacropelvic fixation is also commonly indicated to correct pelvic obliquity in patients with neuromuscular scoliosis.[5,17]

## 4. Description of techniques

Over time, many different methods of sacropelvic fixation have emerged and evolved. Currently, only a few of these techniques are used. Here we will provide an overview of the techniques that are currently relevant.

### 4.1. *S1 Pedicular screws*

S1 pedicular screws can be placed either bicortically or tricortically through the sacral promontory. Bicortical fixation had been the standard technique. Tricortical fixation involves the screw passing through the dorsal and ventral sacral cortices, as well as the superior endplate cortex. Tricortical fixation has the advantage of doubling the insertional torque compared with bicortical fixation.[18] Still, the failure rates when using S1 bipedicular screws range from 44% to 70%.[6,14]

### 4.2. *Sacral alar screws*

Sacral alar screws are used for unicortical fixation into the cancellous bone of the sacral ala. These screws are highly resistant to pullout forces but are associated with high rates of pseudarthrosis at the lumbosacral junction.[19,20] The use of sacral alar screws for sacropelvic fixation is complicated by the narrow zone for safe insertion of sacral alar screws and the accompanying risk of injury to the surrounding internal iliac vessels and lumbosacral trunk and the risk of a breach to the sacroiliac joint.[21] Devices like the Tacoma plate or Chopin block allow sacral alar screws to be inserted through a plate for more accurate placement, but using such devices requires extensive soft-tissue dissection that is unnecessary with the availability of newer techniques.[22,23] Furthermore, sacral alar screws are placed dorsal to the lumbosacral pivot point, making them mechanically inferior to other methods. Although not recommended for primary sacropelvic fixation, sacral alar screws are still used as supplemental fixation to other constructs.[1,24]

### 4.3. *Iliac screws*

Iliac screws evolved from the Galveston rod technique and remain a common technique for long fusions to the sacrum. Iliac screws offer important advantages over Galveston rods, including a variable insertion point, greater pullout strength, and the ability to be inserted at any point along the ilium.[25] Iliac screws are readily connected to proximal fusion instrumentation; however, these connections can be bulky and cumbersome. As a result, implant prominence in larger constructs involving iliac screws can cause pain, requiring removal in 22% of patients at 2 years and 34% of patients at 5 years.[26,27] Still, this technique achieves solid fusion in 85% to 90% of patients.[27,28]

### 4.4. *S2-Alar-Iliac (S2AI) technique*

S2AI technique, first described in 2007,[29] is the most recently developed method of sacropelvic fixation. It involves using a single polyaxial screw inserted into the ilium through the sacral ala to achieve iliac fixation. Screw placement was described originally as an open procedure, but it has been shown that it can be safely achieved percutaneously.[30] This technique has several advantages compared with the methods described earlier. The lack of modular connectors, as well as screw placement that is in line with cephalad instrumentation decrease the complexity of the procedure and the risk of symptomatic implant prominence.[8,31]

Though the location and anatomic reference point for the optimal entry into the sacrum vary slightly among anatomic and radiographic studies,[32–36] the entry point preferred by the authors is at the midpoint of a line connecting the lateral borders of the S1 and S2 dorsal foramina (Fig. 4). After marking the entry point with an awl, a 2.5-mm drill is directed 40° lateral and 20°–30° caudal, depending on the amount of pelvic tilt and obliquity present.[8,37] The drill is aimed toward the anterior inferior iliac spine, maintaining the path of the drill within 20 mm cranial to the greater sciatic notch. A 3.2-mm drill or a pedicle finder can be used after crossing the sacroiliac joint to avoid drill bit breakage.[37] Fluoroscopy may be used to achieve a teardrop view to verify the anteroposterior trajectory is in the thickest part of the ilium and not in violation of the cortex. Lastly, an 8- to 10-mm polyaxial screw with a length of 80–100 mm is recommended (Fig. 5).[37,38] A schematic representation of final S2AI screw placement is shown in Fig. 6 in the transverse, coronal, and sagittal planes (Fig. 6, A–C).

Though rare, complications during insertion may include injury to the surrounding structures, including the superior gluteal artery and the sciatic nerve if the sciatic notch is violated. Rarely, if a steeper caudal angle of insertion is used,

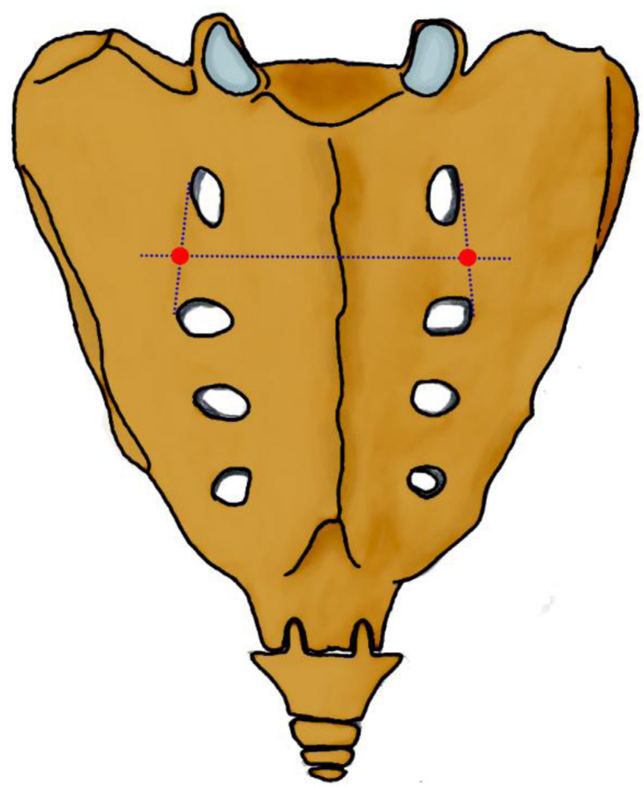

**Fig. 4 – A posterior view of the sacrum showing the entry point for S2AI screw placement, at the midpoint of a line connecting the lateral border of the S1 and S2 dorsal foramina.**

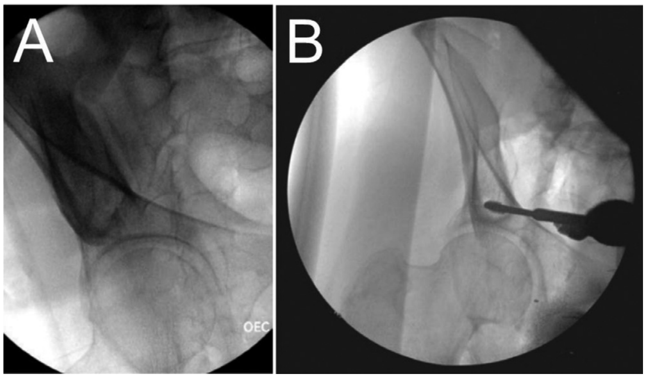


**Fig. 5 – A, Iliac oblique view demonstrating S2 alar iliac screw trajectory. B, Tear-drop view of the drill pointed in the correct trajectory.**

acetabulum violation may occur. Familiarity with sacropelvic anatomy is critical. These complications can be avoided by aiming screws toward the anterior inferior iliac spine, and correct screw choice and measurement will ensure that the cortex is not violated medially or laterally. Some surgeons prefer to use fluoroscopy to guide screw placement, though free-hand techniques are safe and reliable in experienced hands.[39,40]

## 5. Review of recent evidence

As the practical and theoretical advantages of the S2AI technique have become apparent since its development in 2007, numerous studies have examined the biomechanical and clinical outcomes associated with S2AI and other methods of sacropelvic fixation, both in adults and children.

Biomechanically, S2AI fixation has been tested most commonly against iliac screw fixation. In an initial cadaveric study, O'Brien et al.[41] demonstrated that quad-cortical purchase of S2AI screws through the ilium did not improve biomechanical stability compared with iliac screws. S2AI screws have also been shown to produce fixation strength equivalent to that of iliac screws in subsequent cadaveric studies.[42–44]

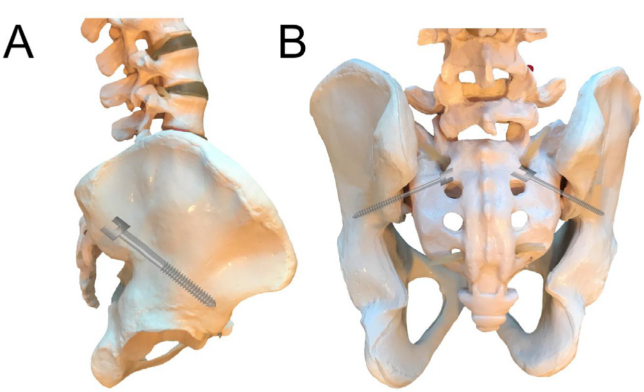


**Fig. 6 – A, Schematic representation of S2AI screw from a lateral (A) and posterior (B) view showing opacified bony anatomy revealing the desired screw placement.**

Recent studies examining clinical outcomes after sacropelvic fixation in adults have compared the S2AI technique with other methods of sacropelvic fixation. In 2014, a retrospective review of 65 adult and 55 pediatric patients found absolute risk reductions of 19% for implant loosening and 21% for late pain with S2AI fixation compared with iliac screws in adults.[45] In a pooled cohort analysis of both adult and pediatric patients in the same study, the authors found a 13% absolute risk reduction for acute infections, along with an 18% reduction in implant loosening, 15% reduction in revision surgery, 19% reduction in late pain, and 11% reduction in delayed wound healing.[45] The advantage of lower implant prominence of the S2AI technique has also been shown in retrospective studies. In 2016, Ishida et al.[31] analyzed data from 100 patients with iliac or S2AI screws and found that symptomatic screw prominence occurred in 11% of the patients with iliac screws and 1.4% in the patients with S2AI screws. In a recent retrospective review of 63 patients, also published by Ishida et al.,[46] the S2AI technique was associated with a lower reoperation rate (22%) compared with iliac screws (59%), along with a similar rate of proximal junctional kyphosis. Most recently, Smith et al.[47] further demonstrated the efficacy of S2AI fixation, showing high rates of fusion (up to 95%) in patients treated with this technique.

Different methods of sacropelvic fixation have been well studied in children. Ilyas et al.[45] reported an absolute risk reduction of 22% for both late pain and revision surgery for implant failure with S2AI fixation compared with iliac screws in a cohort of 55 pediatric patients. Two studies have also reported on patients who have received sacral-alar-iliac (SAI) fixation with at least 2 years of follow-up. One reported a failure rate of 24% with iliac screws compared with 7% with SAI screws,[48] and another showed better correction of pelvic obliquity using SAI fixation compared with other techniques.[36] Similarly, 2 pediatric studies with at least 5 years of follow-up have also been performed. One study confirmed the safety and efficacy of SAI fixation,[49] and another found fewer implant-related complications in patients with SAI fixation compared with iliac screw fixation and unit rods, along with less loss of curve correction in the SAI group.[50]

It has been postulated that the sacroiliac joint articular cartilage is often penetrated during S2AI fixation, potentially causing degenerative changes and/or pain. In a preliminary anatomic study, O'Brien et al.[32] demonstrated that S2AI screws violated the articular cartilage of the sacroiliac joint in 60% of cases, raising the concern that sacroiliac joint complications may occur after S2AI fixation. Recently, 2 smaller studies reported that sacroiliac joint complications are not seen with S2AI fixation. In 2017, a radiographic study with 12-month follow-up indicated that the S2AI technique was not associated with sacroiliac joint degeneration or screw-related complications.[51] A similar radiographic study of 23 patients with an average of 16-month follow-up reported only 1 patient with sacroiliac pain.[52]

There have been few reports that S2AI fixation is inferior to other methods. One study of 45 patients and minimum 6-month follow-up showed a higher failure rate with S2AI screws (35%) compared with iliac screws (12%),[53] which is inconsistent with several other studies.[31,42–45,47,48] In response to this, another group of authors proposed a modified version of the iliac screw technique and published a case series of 10 patients with 12-month follow-up and biomechanical proof-of-concept in 2018;[54,55] however, there have yet to be any larger or long-term studies of this technique, or comparison with S2AI fixation.

## 6. Conclusion

Sacropelvic fixation is an important technique with several applications in spinal surgery. The anatomy of the sacrum and principles of the pivot point and zones of sacropelvic fixation are important for understanding the interplay of anatomy and forces that have caused historically high complication rates with the procedure. As surgical techniques and instrumentation design and materials continue to evolve, complication rates have declined. Sacropelvic fixation can now be accomplished with minimal soft-tissue disruption and can even be placed percutaneously. The most recently developed and widely accepted technique for sacropelvic fixation, the S2AI technique, is effective and has reduced complications compared with other methods in both adults and children, and is now well studied with 5-year outcomes.

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