S-1 alar/iliac screw technique for spinopelvic fixation

J. Mason DePasse, MD,1 Mauricio Valdes, MD,2 Mark A. Palumbo, MD,3 Alan H. Daniels, MD,3 and Craig P. Eberson, MD4

Divisions of 3Spine Surgery and 4Pediatric Orthopaedic Surgery, 1Department of Orthopaedics, Alpert Medical School of Brown University, Providence, Rhode Island; and 2Hedley Orthopaedic Institute, Phoenix, Arizona

Spinopelvic fixation provides an important anchor for long fusions in spinal deformity surgery, and it is also used in the treatment of other spine pathologies. Iliac screws are known to sometimes require reoperation due to pain resulting from hardware prominence and skin injury. S-2 alar/iliac (S2AI) screws do not often require removal, but they may provide inadequate fixation in select cases. In this paper the authors describe a technique for S-1 alar/iliac screws that may be used independently or as a supplement to S2AI screws. A preliminary biomechanical analysis and 2 clinical case examples are also provided.

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S PINOPELVIC fixation is essential for reinforcing long fusions to the sacrum in spinal deformity surgery. This instrumentation technique has also been applied in spinal trauma, tumor, and degenerative conditions.4,9,13 Although several methods for pelvic fixation have been described, iliac screw and S-2 alar/iliac (S2AI) screw fixation are currently the most commonly used methods.5,6,8 Traditional iliac screw fixation improves stability and fusion rate.10,14 However, the screw head can be prominent and the technique has been associated with symptomatic hardware and wound dehiscence.4,5 Compared with S2AI screws, iliac screws have been associated with higher rates of reoperation, surgical site infection, and symptomatic screw prominence.3 In a series of 67 patients, Tsuchiya et al. found that 34.3% required screw removal for symptomatic prominence, and they reported 7 cases of screw breakage.24

The S2AI screw trajectory was developed so that the screw head would sit below the posterior superior iliac spine (PSIS); recent literature has shown a decreased complication rate compared with iliac screws.3,6 However, S2AI screws do not always provide sufficient pelvic fixation. In a series of 20 patients, Guler et al. reported a 35% implant failure rate due to screw pullout and/or head-shaft disengagement.5

To avoid the complications associated with iliac screws and to supplement pelvic fixation, we describe an S-1 alar/iliac (S1AI) screw trajectory that may be used in addition to S2AI screws or independently if the patient’s anatomy limits the ability to place S2AI screws. We also present 2 clinical case examples demonstrating its implementation.

Surgical Technique: S1AI Trajectory

Preoperatively, the patient’s sacropelvic anatomy should be thoroughly reviewed on plain radiographs and/or CT. The availability of a wide range of screw diameter and length options, as well as a full complement of side-to-side connectors, should be confirmed.

The starting point for the S1AI screws is just lateral to the junction of the S-1 superior articular facet and the posterior sacral ala, which is in proximity to the entry point for S-1 pedicle screws. It is 3–5 mm above the superolateral corner of the S-1 foramen (Fig. 1). This entry site allows the S1AI screw heads to remain collinear with lumbar pedicle screws and S2AI screws, limiting the need for offset or side-to-side connectors. Figure 1 provides an image of a cadaveric specimen with the entry site marked with a pedicle probe; the white star in the figure indicates the S-1 foramen.

The trajectory of the screw path runs in a caudal and lateral direction through the ala and into the ilium. The surgeon should direct the S1AI screw 40°–50° laterally in the transverse plane, similar to S2AI screws.2,11 Fluoroscopic imaging (including anteroposterior and oblique pelvic radiographs) is used to identify the teardrop (PSIS—anterior inferior iliac spine [AIIS] corridor) and to confirm the screw is within the plane of the posterior ilium (Fig. 2).
Figure 3 upper provides comparison trajectories for traditional iliac screws, S1AI screws, and S2AI screws, while Fig. 3 lower compares the trajectories of the S1AI screw to the S-1 pedicle screw. Depending on the patient’s sacral anatomy, screws up to 10.5 mm in diameter and 100 mm in length may be placed. This determination can be made intraoperatively, or in select cases may be made on preoperative CT through assessment of alar thickness as well as the PSIS-AIIS corridor if cut angle reformatting is available. Polyaxial screws (with or without a favored angle head) are recommended for the S1AI and S2AI screws to minimize rod bending and contouring and to simplify seating of the rod.

Biomechanical Analysis

Biomechanical analyses comparing S2AI screws to traditional iliac screws have been performed, and have shown that there is no significant difference in stability and stiffness between constructs. To validate the feasibility of spinopelvic fixation utilizing S1AI screws only, a preliminary biomechanical analysis with a single cadaveric specimen was performed using methodology similar to that used by Burns et al.

An unembalmed human lumbopelvic specimen was stripped of all muscle tissue, though care was taken to preserve ligamentous tissue and intervertebral discs. Multiaxial pedicle screw instrumentation (Stryker) was placed from L-4 to L-5 bilaterally, then 8.5 × 80 mm screws were placed along the described S1AI trajectory bilaterally. All screw positions were confirmed with both direct ball-tipped probe palpation and visualization, and fluoroscopic imaging. The constructs were completed with titanium rods and set screws.

The cephalad end of the spine segment and the pelvis were then rigidly embedded utilizing a urethane potting compound (Smooth-On Inc.), and a custom apparatus applied pure moments about 3 principal anatomical axes with a biaxial servohydraulic load frame (Instron Corp.). As in the Burns et al. study, the torsional stiffness of the specimen was tested in flexion, extension, right lateral bending, and left lateral bending.

Measured torsional stiffness values (in Newton-me-
to degree \((\text{N-m/°})\) of the L4-pelvis construct with S1AI screws were: 8.84 N-m/° in flexion, 7.69 N-m/° in extension, 42.57 N-m/° in right lateral bending, and 29.56 N-m/° in left lateral bending. These values are similar to or greater than those measured by Burns et al. for their L-5 pelvis construct with L5–S1 pedicle screws and S2AI screws. The authors reported mean torsional stiffness of 9.38 ± 2.11 N-m/° in flexion, 8.39 ± 1.66 N-m/° in extension, 13.97 ± 3.03 N-m/° in right lateral bending, and 13.34 ± 1.88 N-m/° in left lateral bending.\(^1\)

Although this analysis utilizes only a single specimen, the torsional stiffness of the lumbopelvic construct with S1AI screws was similar in flexion-extension and greater in lateral bending as compared with S2AI constructs. Further biomechanical analysis is warranted; however, these preliminary data suggest that the biomechanical properties of spinopelvic fixation constructs with S1AI screws are similar to constructs with S-1 pedicle screws and S2AI screws.

Clinical Cases
Case 1
A 64-year-old woman presented with lower-extremity weakness and pain due to critical spinal stenosis and progressive sagittal and coronal deformity. Her plain radiographs on presentation are shown in Fig. 4. The patient was treated with lumbar decompression and fusion, with pedicle screw instrumentation from T-9 to L-5, S1AI screws, and a 4-rod construct (Fig. 5). S2AI screws were not used due to a large psoriatic plaque overlying the sa-
crum, limiting the caudal extent of the skin incision. At the 1-year follow-up, there was no evidence of hardware failure or screw loosening on plain radiographs (Fig. 6).

Case 2

A 58-year-old woman presented with severe back pain and progressive lumbar scoliosis with coronal imbalance resulting from a congenital L-5 butterfly vertebra (Fig. 7). The patient was treated with pedicle screw instrumenta-

Discussion

Spinopelvic fixation is a technique used for a wide range of spinal column pathology, most commonly in an-

FIG. 6. Case 1. One-year follow-up anteroposterior (left) and lateral (right) radiographs demonstrating no loosening or hardware complications.

FIG. 7. Case 2. Preoperative coronal CT image demonstrating coronal deformity associated with an L-5 butterfly vertebra.

FIG. 8. Case 2. Left: Anteroposterior radiograph demonstrating S1AI and S2AI screws and a 4-rod construct. Right: Lateral radiograph demonstrating T10–L5 pedicle screws, and S1AI and S2AI screws.

FIG. 9. Case 2. Left: Three-dimensional CT reconstructed image of the construct, demonstrating S1AI and S2AI trajectories. Right: Coronal CT image showing pedicle screw fixation into vertebrae and the ilium. Figure is available in color online only.
choring long constructs to the pelvis in adult deformity. Traditional iliac screws can result in skin complications that may require revision. In certain situations, S2AI screws may not provide sufficient fixation strength to prevent screw pullout, breakage, or rod-screw interface failure. We present a technique for S1AI screws that may be used independently or in combination with S2AI screws for additional fixation strength.

In general, S1AI screws cannot be used with standard S-1 pedicle screws. The S1AI screw uses a similar entry point and achieves fixation in the sacral ala and ilium instead of the pedicle and vertebral body, which achieves additional sacropelvic purchase. It is possible that the use of S1AI screws may increase stability for longer constructs and reduce the rate of nonunion, which would be especially important for patients with lumbopelvic dissociation or large deformity correction. Further biomechanical testing will be required for verification. S1AI screws may also function as an excellent salvage alternative for loss of S-1 pedicle fixation or in cases of broken S-1 screws, which limit replacement of screws into the S-1 pedicle.

As noted in the technique description, it is important to use intraoperative fluoroscopy for placement of S1AI screws due to the risk of penetrating the inner table and entering the pelvis. The S1AI screw, similar to the S2AI screw, must be angled toward the teardrop of the ilium or apex of the acetabulum, which requires a significant degree of caudal angulation. Placement that is too horizontal is most likely to result in violation of the anterior cortex of the ilium and penetration into the iliacus muscle.

Although future biomechanical and clinical study will be required, S1AI screws provide a viable alternative to S-1 pedicle screws and strong supplemental fixation to S2AI screws.

References

Disclosures
Dr. Palumbo reports being a consultant to Stryker. Dr. Daniels reports being a consultant to Stryker, Globus, and Orthofix.

Author Contributions
Conception and design: Valdes, Palumbo, Daniels, Eberson. Acquisition of data: DePasse, Valdes, Daniels. Analysis and interpretation of data: DePasse, Valdes. Drafting the article: DePasse. Critically revising the article: DePasse, Palumbo, Daniels, Eberson. Reviewed submitted version of manuscript: Palumbo, Daniels, Eberson. Study supervision: Eberson.

Correspondence
J. Mason DePasse: Warren Alpert Medical School of Brown University, Providence, RI. jmdепasse@gmail.com.