Pelvic Fixation

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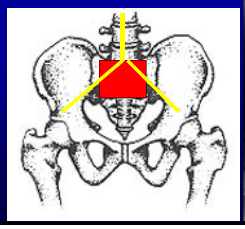
Disclosures

- Consultant - DePuy Synthes Spine, Zimmer Biomet, Amendia, Stryker
- Stock - Innovative Surgical Solutions, Vivex
- Royalties - Zimmer Biomet

Rationale for Lumbo-pelvic Fixation

- Stronger mechanical construct
  - Unload / protect sacral screws
  - Decrease risk of L5-S1 pseudarthrosis
  - Control sacro-pelvic alignment



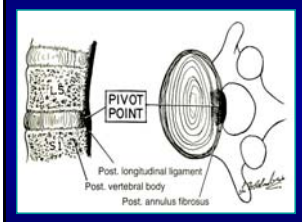
Biomechanical Analysis of Lumbosacral Fixation

David H. McCord, MD, Bryan W. Cunningham, BS, Yasahiro Shono, MD, Jordan J. Myers, PA, and Paul C. McAfee, MD

S236 Spine • Volume 17 • Number 8S • 1992

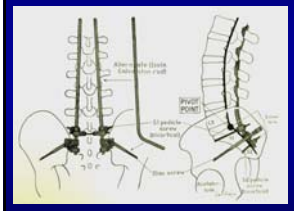
- *In vitro* bovine study evaluating multiple instrumentation types and fixation locations
- 10 total fixation constructs studied
  - Tested until failure in flexion

McCord et al. Study



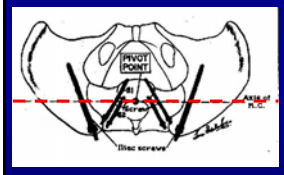
- Introduced concept of the **pivot point.**
  - "At the intersection of the middle osteoligamentous column and the lumbosacral intervertebral disc".

McCord et al. Study



- Location of failure
  - Occurred at the caudal bone-metal interface.
  - 2 constructs that withstood greatest load prior to failure
    - Both **iliac fixation** constructs.

McCord et al. Study



- Key was fixation **ANTERIOR to center of rotation (pivot point).**
  - Greatest flexion moment resistance.
  - **Stiffness of construct proportional to distance of instrumentation anterior to pivot point.**

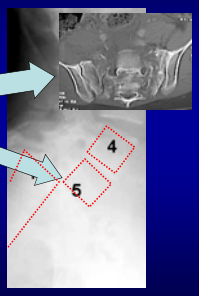
Indications

Grade II or higher L5–S1 spondylolisthesis
Long-segment fusions to the sacrum (L2 or above to S1)
Spinal deformity (scoliosis or kyphosis)
Lumbar fractures
Trauma
Osteomyelitis
Neoplasm
Lesions that destroy the sacrum
Neoplasm
Osteomyelitis
Fractures
Treatment of L5–S1 pseudoarthrosis

Indications

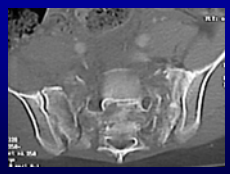
Why instrument to the pelvis?

- Bypass incompetent lumbo-sacral articulation
- Biomechanical strengthening of lumbo-sacral constructs



Sacral/Pelvic Ring Injuries

- Bypass compromised sacrum
  - Denis type II, III fractures
  - Transverse fractures (Roy Camille type IV)
  - Tumor / infection reconstruction



Biomechanical Strengthening of Lumbo-Sacral Constructs

- Long constructs
- Deformity correction / spondy
- Revision pseudarthrosis
- Poor bone quality

Contemporary Fixation Techniques

- Traditional Iliac Screw Method
- Modified Iliac Screw Method
- S2 Alar Iliac Screw Method

IDEAS AND TECHNICAL INNOVATIONS

Pelvic fixation for adult scoliosis

PUBMED search

Sacropelvic fixation should be considered in any patient with **a long construct ending in the sacrum**.

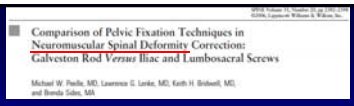
Patients with associated risk factors for loss of distal fixation or **high risk for pseudarthrosis** at L5–S1.

Those undergoing **three column osteotomies** or vertebral body resections in the low lumbar spine.

Current pelvic fixation techniques with **iliac screws**, multiple screw/rod constructs, and **S2-alar-iliac screws** are all viable techniques for achieving pelvic fixation.

Growing evidence that **pelvic fixation may become the standard for obtaining long fusions in adult scoliosis.**

Indications and techniques should be individualized to the patient and based on surgeon preference and experience.


Comparison of Pelvic Fixation Techniques in Neuromuscular Spinal Deformity Correction: Galveston Rod *Versus* Iliac and Lumbosacral Screws

- 20 patients with the Galveston technique, 20 patients with an iliac screw undergoing posterior spinal fusion (T2/T3-pelvis) for neuromuscular spinal deformity.
- **Statistically improved post-op PELVIC OBLIQUITY in the patients with an iliac screw** (4.4°) versus those with the Galveston technique (7.3°) (P 0.04).
- There were **13 patients with the Galveston technique versus 6 with an iliac screw who had RADIOLUCENT HALOS** more than 2 mm around the pelvic anchor devices at latest follow-up (P 0.05).
- **Galveston technique group had 4 BROKEN RODS and 2 REOPERATIONS**.
- **Iliac screw group had 1 broken screw and NO reoperations**.
- The iliac screw technique avoids complex, lumbosacral 3-dimensional rod bends and yields minimal implant complications.

Outcome and Complications of Long Fusions to the Sacrum in Adult Spine Deformity

Luque-Galveston, Combined Iliac and Sacral Screws, and Sacral Fixation

- Group 1: (11 patients) smooth L-rod and segmental sublaminar wires (Luque- Galveston technique).
- Group 2: (36 patients) posterior Isola segmental instrumentation & combined iliac and sacral screws.
- Group 3: (12 patients) Isola segmental instrumentation & bicortical sacral screws.
- 26 late complications. Pseudarthrosis developed in 10 patients, requiring revision surgery: 4 (36%) in the Group 1, 5 (14%) in Group 2, and 1 (8.5%) in Group 3.
- The **Luque-Galveston fixation technique has an unacceptably high rate of PSEUDARTHROSIS**, and this method is not recommended for adult deformities.
- **Recommend using iliac fixation for adult spinal deformity.**
- **But…..Higher rate of painful hardware, requiring removal.**

Pseudarthrosis in Long Adult Spinal Deformity Instrumentation and Fusion to the Sacrum: Prevalence and Risk Factor Analysis of 144 Cases

Yongjung J. Kim, MD,* Keith H. Bridwell, MD,* Lawrence G. Lenke, MD,* Seungchul Rhim, MD,† and Gene Cheh, MD*

- The overall **prevalence of pseudarthrosis** following long adult spinal deformity instrumentation and fusion to S1 was **24%.**
- Thoracolumbar kyphosis, osteoarthritis of the hip joint, thoracoabdominal approach
- (vs. paramedian approach), positive sagittal balance 5 cm at 8 weeks postoperatively, older age at surgery (older than 55 years), and **INCOMPLETE sacropelvic fixation** significantly increased the risks of pseudarthrosis to an extent that was statistically significant.
- **SRS outcomes scores at ultimate follow-up were adversely affected when pseudarthrosis developed.**

Traditional Iliac Screw Placement

Journal of Spinal Disorders & Techniques
Vol. 15, No. 3, pp. 199–205
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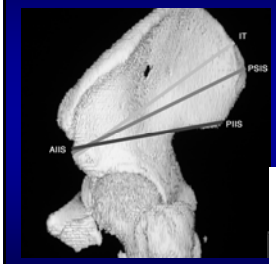
Anatomic and Radiographic Considerations for Placement of Transiliac Screws in Lumbopelvic Fixation

Thomas A. Schildhauer, *Patrick McCulloch, Jens R. Chapman, and *Frederick A. Mann

- Analyzed CT in 40 patients with additional cadaveric evaluation
  - Determined intra-iliac length, inner width, cortical thickness
  - Determine radiographic measures to safely insert iliac screws

Iliac Trajectories



- Evaluated 3 trajectories
- Mean length PSIS to AIIS
  - 141 mm in males
  - 129 mm in females

TABLE 1. *Transiliac bony canal length at various screw paths for male and female patients*

	Male		Female	
	Average ± STD	Min–Max	Average ± STD	Min–Max
L_{IT}/mm	133.6 ± 14.1	117.1–168.2	119.6 ± 15.4	74.7–152.2
L_{PS}/mm	141.1 ± 9.7	126.9–166.7	128.7 ± 12.1	95.1–151.8
L_{PP}/mm	86.3 ± 7.9	70.9–106.8	99.7 ± 29.4	0.0–120.9

L_{IT}, the length between the IT and AIIS; L_{PS}, the length between the PSIS and AIIS; L_{PP}, the length between the PIIS and AIIS.

Iliac Trajectories

- 2 iliac constrictions noted
  - Anterior joint surface of the sacroiliac joint.
  - Narrowest part of the iliac wing, just anterior and superior to the greater sciatic notch.

TABLE 2. *The distance between the posterior starting point and the first (D_1) and second (D_2) narrowing*

	*	Male		Female	
		Average ± STD	Min–Max	Average ± STD	Min–Max
D1/mm	IT	40.2 ± 6.8	22.3–51.9	33.4 ± 13.5	17.5–88.0
	PS	32.8 ± 8.9	18.0–51.8	27.1 ± 8.6	13.7–46.4
	PI	30.3 ± 13.4	6.2–54.6	26.2 ± 9.6	0.0–40.0
D2/mm	IT	87.9 ± 5.6	79.4–102.7	83.1 ± 8.0	56.3–100.8
	PS	86.3 ± 7.9	70.9–106.8	84.1 ± 9.9	44.1–96.6
	PI	60.3 ± 13.6	42.7–99.7	52.8 ± 19.8	0.0–101.2

*The posterior starting point of the bony canal toward the AIIS. IT, iliac tubercle; PS, PSIS; PI, PIIS.

Iliac Trajectories

- Goal would be to engage the inner cortical bone for better purchase at BOTH constriction points.
- **Suggested screw diameter of 8 mm in males and 6 - 7 mm in females.**
- Smaller than previous studies reported.

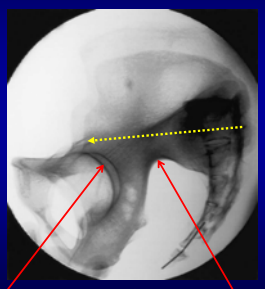
TABLE 3. *The inner width of the ilium at first (IW_1) and second (IW_2) narrowing*

	*	Male			
		Average ± STD	Min–Max	<8 mm	<6 mm
IW1/mm	IT	12.4 ± 2.4	8.9–18.1	0/27	0/27
	PS	12.3 ± 2.6	6.8–18.9	1/27	0/27
	PI	9.3 ± 3.6	2.6–16.9	11/27	4/27
IW2/mm	IT	12.6 ± 3.6	7.1–20.4	2/27	0/27
	PS	15.4 ± 3.9	8.3–22.1	0/27	0/27
	PI	12.0 ± 5.8	3.9–23.7	10/27	5/27
	*	Female			
		Average ± STD	Min–Max	<8 mm	<6 mm
IW1/mm	IT	9.8 ± 2.8	4.9–15.7	7/28	2/28
	PS	9.2 ± 3.0	3.7–16.8	9/28	2/28
	PI	8.1 ± 3.8	0.0–16.6	13/28	6/28
IW2/mm	IT	8.2 ± 3.2	3.7–19.3	16/28	4/28
	PS	10.9 ± 2.8	6.0–20.0	2/28	0/28
	PI	9.0 ± 4.3	0.0–16.1	8/28	4/28

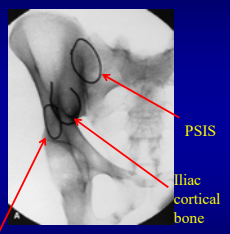
*The posterior starting point of the bony canal toward the AIIS. IT, iliac tubercle; PS, PSIS; PI, PIIS.

Radiographic Guidance

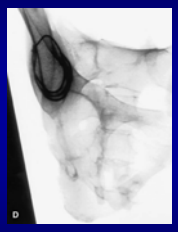
- Typically need two views
  - Lateral
  - Obturator oblique-outlet
- Lateral view
  - Direct screw above sciatic notch and acetabulum
  - Be sure to wig-wag to get clear view



Radiographic Guidance



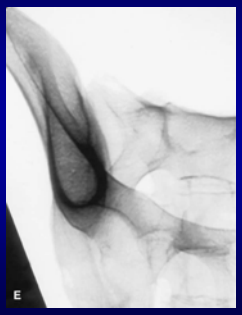
AP view



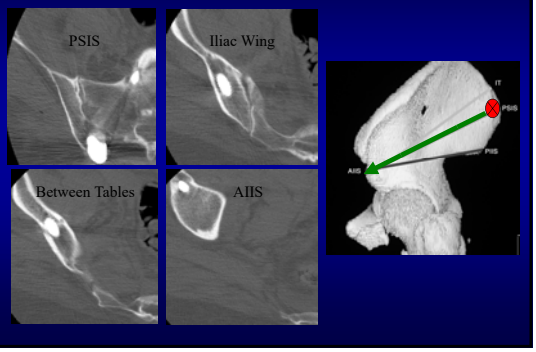
Obturator oblique–outlet view - Superimposes PSIS, iliac cortical rim above the sciatic notch, and AIIS

Radiographic Guidance

- Obturator oblique–outlet view known as a "teardrop"
  - "safest and intraosseous when directed along the teardrop figure on its **medial border**"
  - PSIS to AIIS trajectory

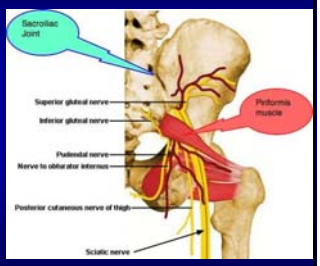


Iliac Screw Trajectory



Intraoperative Complications

- Vascular injury
  - Superior gluteal artery
- Neurological injury
  - Sciatic nerve
  - Superior gluteal nerve
- Screw malposition
  - Cortical breech
  - Acetabular breech



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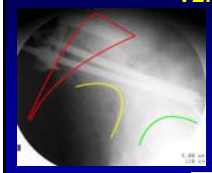
INTRAOPERATIVE COMPLICATIONS – VERIFY PLACEMENT



Lateral View

Iliac Oblique

Obturator Oblique

Modified Iliac Screw Technique - Vaccaro

Neurosurg Focus 36 (3):E10, 2014
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Unilateral versus bilateral iliac screws for spinopelvic fixation: are two screws better than one?

Rajiv Saigal, M.D., Ph.D.,[1] Darryl Lau, M.D.,[1] Rishi Wadhwa, M.D.,[1] Hai Le, B.S.,[2] Morsi Khashan, M.D.,[2] Sigurd Berven, M.D.,[2] Dean Chou, M.D.,[1] and Praveen V. Mummaneni, M.D.[1]

- 46 patients underwent unilateral and 26 bilateral iliac screw fixation in adult spinal deformity.
- 41% (n = 19) of the unilateral cases and 50% (n = 13) of the bilateral cases were treated with **reoperation** (p = 0.48).
- In addition, 13% (n = 6) of the unilateral and 19% (n = 5) of the bilateral cases developed L5–S1 **pseudarthrosis** (p = 0.51).
- There were **no sacral insufficiency fractures**. 13% (n = 6) of the unilateral and 7.7% (n = 2) of the bilateral cases developed postoperative **infection** (p = 0.70).
- Retrospective single-institution study, single versus dual pelvic screws led to comparable rates of reoperation, iliac screw removal, postoperative infection, pseudarthrosis, and sacral insufficiency fractures.
- **Bilateral pelvic screws provided NO ADDED CLINICAL BENEFIT in most cases (vs unilateral.**

Clinical Biomechanics

Biomechanical effects of the extent of sacrectomy on the stability of lumbo-iliac reconstruction using iliac screw techniques: What level of sacrectomy requires the bilateral dual iliac screw technique?

Bin-Sheng Yu [a,*], Xin-Ming Zhuang [a], Ze-Min Li [a], Zhao-Min Zheng [a], Zhi-Yu Zhou [a], Kar-Neng Zou [a], William W. Lu [b,*]

- Biomechanical testing was performed on a material testing machine for evaluating the stiffness of the L3-iliac fixation construct in compression and torsion.
- **Single iliac screw technique** was found to effectively restore the local stability in **under 50% S1 sacrectomy.**
- However, it could not provide adequate stability for further resection of one-side sacroiliac joint in torsion and total sacrectomy in compression.
- **Dual iliac screw technique** could **restore the stability to the intact condition after total sacrectomy in both compression and torsion.**

Effect of Iliac Screw Insertion Depth on the Stability and Strength of Lumbo-Iliac Fixation Constructs

An Anatomical and Biomechanical Study

Zhao-Min Zheng, MD, PhD,* Bin-Sheng Yu, MD, PhD,* Hui Chen, MD,* Darwesh M. K. Aladin, MPhil,† Kai-Bo Zhang, PhD,* Jia-Fang Zhang, MD,* Hui Liu, PhD,* Keith D. K. Luk, FRCSE, FRCSG, FRACS, MCh(Orth), FHKAM(Orth),† and William W. Lu, PhD†

- 2 groups were tested (short screws - 70 mm and long screws - 138 mm).
- Biomechanical testing was performed on a material testing machine under 800 N compression and 7 Nm torsion loading modes for stiffness evaluations.
- Pullout testing was performed for all the iliac screws to measure the maximum pullout force.
- Longer iliac screws resisted significantly greater axial pullout force.
- BUT…….Under PHYSIOLOGICAL, torsional, and compressive loading conditions, the mechanical stability of lumbo-pelvic fixation construct with **short iliac screws WERE COMPARABLE with that of the long SCREWS.**
- Therefore, the use of short iliac screws, which are only about half the length of the long iliac screws, could reduce the implantation risk without significantly compromising on the stability of the construct.

Minimally Invasive Percutaneous Iliac Screws
Initial 24 Case Experiences With CT Confirmation

Michael Y. Wang, MD, Seth Williams, MD,† Praveen V. Mummaneni, MD,‡ and Jonathan D. Sherman, MD§*

Clin Spine Surg • Volume 29, Number 5, June 2016

- 24 patients had 47 screws placed for fixation at the lumbosacral junction.
- No cases required abor … open operation.
- All of the percutaneous … rified by postoperative computed tomography … tion.
- There were no hardwa…
- Iliac screw placement … lhood of bony violation.
- **MIS technique offers … tion without the soft-tissue exposure tradit… -tion.**
- The technique **relies on high-quality intraoperative fluoroscopic imaging.**

Spine
SURGERY

Should Symptomatic Iliac Screws Be Electively Removed in Adult Spinal Deformity Patients Fused to the Sacrum?

Brian A. O'Shaughnessy, MD,* Lawrence G. Lenke, MD,† Keith H. Bridwell, MD,† Woojin Cho, MD, PhD,† Lukas P. Zebala, MD,† Michael S. Chang, MD,‡ Joshua D. Auerbach, MD,‡ Charles H. Crawford, MD,¶ and Linda A. Koester, BS†

- Of 395 consecutive walking patients who had iliac screws placed during fusion to the sacrum for adult spinal deformity, **24 (6.1%) underwent elective removal.**
- Patients had a statistically significant improvement in hip / buttock pain after screw removal, and a low prevalence of complications after the procedure was observed.

Iliac Screws

Pros

- Pass pivot point
- Ease of insertion
- Safe technique

Cons

- Screw Prominence
- Often extensive soft tissue dissection
- Not inline with S1 screws (off-set connector needed)
- Screw loosening

S2 Alar Iliac Screw

- Alternative to the traditional iliac screw
- Advantages
  - Allows pelvic fixation without extensive muscle stripping or having to make a separate fascial incision
  - Instrumentation alignment (in-line with other screws)
  - Low profile
  - Multi-cortical fixation

SPINE Volume 34, Number 12, pp E439–E442
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An Anatomic Study of the S2 Iliac Technique for Lumbopelvic Screw Placement

Joseph R. O'Brien, MD, MPH,* Warren D. Yu, MD,* Rishi Bhatnagar, MD,*
Paul Sponseller, MD, MBA,† and Khaled M. Kebaish, MD†

- Cadaveric study
- To determine anatomic feasibility and course of S2 alar iliac screws in relation to the SI joint, vital structures, cortical breeches
- To determine length and trajectory of screws

A Comparison of Early Clinical and Radiographic Complications of Iliac Screw Fixation Versus S2 Alar Iliac (S2AI) Fixation in the Adult and Pediatric Populations

Haaris Ryan, B.A, Howard Place, MD, and Aki Puryear, MD

J Spinal Disord Tech • Volume 28, Number 4, May 2015

- 65 adult patients (43 IS, 22 S2AI) and 55 pediatric patients (40 IS/unit rod, 15 S2AI) in a consecutive series who underwent spinopelvic fixation.
- Adult cohort found an 18.6% **absolute risk reduction (ARR)** in **implant loosening** (P=0.029) and a 21.1% ARR (P=0.05) in **late pain** with the S2AI method.
- Pediatric population, the S2AI method demonstrated a 22.2% ARR (P=0.049) in both occurrence of **revision surgery secondary to spinopelvic implant failure and late pain**.
- Pooled cohort, the S2AI method had a 13% ARR (P=0.033) in **acute infections**, 18.1% ARR (P=0.003) in **implant loosening**, 14.5% ARR (P=0.009) in **revision surgery**, 18.7% ARR (P=0.015) in **late pain**, and a 10.8% ARR (P=0.031) in **delayed wound issues**.
- **The S2AI technique is associated with significantly less clinical and radiographic complications in both the pediatric and adult populations when compared with the iliac screws technique.**

Spine
BIOMECHANICS
Biomechanical Evaluation of S2 Alar-Iliac Screws
Effect of Length and Quad-Cortical Purchase as Compared With Iliac Fixation

- 7 human cadaveric spines (L2–Pelvis) were fixed at L2 proximally and the pubis distally.
- Pedicle screws were placed from L3–S1 with S2AI screw lengths of 65-mm, 80-mm, or 90-mm iliac screws. S2AI screws were tested with and without quad-cortical purchase.
- All the instrumented constructs significantly reduced range of motion compared with the intact spine.
- The L3–S1 construct was statistically significantly less stable than all instrumented constructs in flexion-extension.
- **There was statistically no significant difference between the S2AI screws of all lengths and the iliac screw constructs with offset connectors.**

- S2AI screws are biomechanically as stable as the test constructs using iliac screws in all loading modes.
- **65mm S2AI screws** were biomechanically equivalent to 90-mm iliac screws and 80-mm S2AI screws.
- Quad-cortical purchase did not statistically significantly improve the biomechanical strength of S2AI screws.

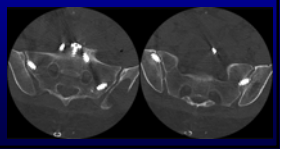
Anatomic Trajectory

- Starting point was 1mm inferior and 1mm lateral to the dorsal S1 foramen (*)
  - 40-50° relative to the horizontal line connecting the PSIS
  - 20-30° caudal to straight lateral
  - Typically only 10° from parallel to the lamina
  - Lateral fluoroscopy to stay above sciatic notch

S2 Alar Iliac Screw Characteristics

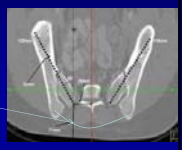
- **60% of screws violated the articular portion of the SI joint.**
- Average screw length was 84 mm (70-100mm)
- No screw intra-pelvic
- No risk to vascular or neural structures
- 3 screws (15%) violated posterior cortex of ilium
- All screws in-line with S1

- Medial aspect of ilium.
- Demarcation of articular & non-articular SI joint.
- Note penetration of the articular cartilage.



Sacral Alar-Iliac (SAI) Pathway

- Iliac Fixation
  - Starting on sacral ala
  - Deeper, within muscle envelope
  - In line with other spinal anchors
  - Ideal for pelvic obliquity correction mechanics
  - Good platform for de-rotation

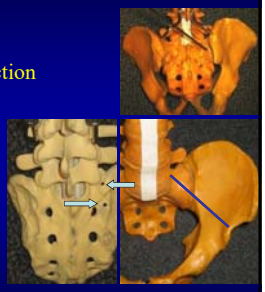


Starting Point Derived

- 25 ± 1 mm below S1 endplate
- 22 ± 1mm lateral to midline

Technique: SAI Start

- Lateral to Sacral foramen
- Fluoro finds major Alar projection
- ~ 40º laterally
- ~ 25-40º caudal
  - Varies w. pathology!
- Pass just above notch
- **Aim for AIIS**

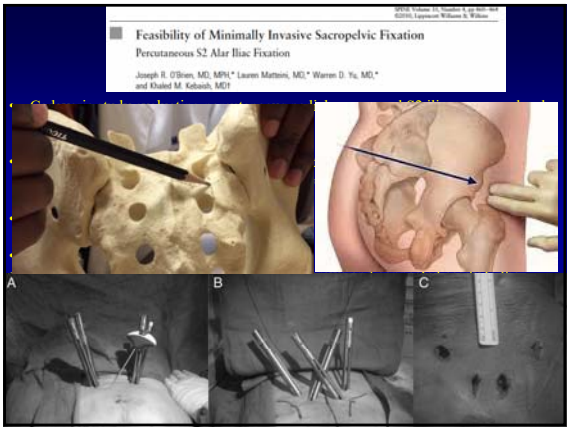


Technique

- Resistance increases at SI joint
- You can use an awl or a drill
- Continue till AIIS or lateral cortex

Technique

- SAI



Summary

- Many indications to consider iliac screw fixation
  - Bypass incompetent sacrum
  - Sacral Fractures / Pelvic Ring Injuries
  - Strengthen LS construct
  - Improve L5-S1 fusion rate

Summary

- Traditional Iliac Screw Placement
  - PSIS typical starting point (notch to recess screw head or modified technique).
  - Use lateral and obturator oblique-inlet view as needed.
  - Use long enough screw to traverse both iliac constrictions.
  - Use large enough screw to engage inner cortical bone.

Summary

- S2 Alar Iliac Screws
  - Appear to be viable alternative.
  - Lower prominence and in-line with other screws.
  - Fixation appears to be equivalent to traditional iliac screws.
  - 60% articular surface violation.

Thank you