Pelvic Fixation in Adult Deformity: Does the SI Joint Need to Be Fused?

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Learning Objectives: After participating in this CME activity, the spine surgeon should be better able to:
1. Explain the rationale for adding additional sacroiliac joint fusion to standard spinopelvic fusion constructs.
2. Describe biomechanical implications that result from additional sacroiliac joint fusion, including potential complications stemming from biomechanic changes.

Key Words: Adult, Biomechanics, Deformity, Fixation, Pelvic, Sacroiliac joint

As average life expectancy increases in the developed world, so too do rates of adult spinal deformities due to age-related degeneration. Long fusions are the standard of care in many adult spine deformity diseases. However, fixation ending at S1 is highly susceptible to failure due to the predominance of cancellous bone in the sacrum, complex regional anatomy, and the force of the load on the lumbosacral junction. In long constructs that end with S1 screws, rates of pseudoarthrosis at L5-S1 and S1 screw failure rates range between 30% and 40%, along with high rates of revision surgery and complications. To address this issue, pelvic fixation has become a popular technique to improve outcomes of long deformity constructs. By effectively resisting flexion and cantilever forces, this approach is highly efficient in enhancing rigidity at the lumbosacral junction, providing enhanced protection against strain for screws in S1, and minimizing the likelihood of pseudoarthrosis at L5-S1.

Currently, the iliac screw (IS) and the S2-alar-iliac (S2AI) screw are the 2 most commonly used methods of pelvic fixation. Fusion rates across the lumbosacral junction have improved significantly to near 90% using these 2 techniques. ISs historically were placed from the posterior superior iliac spine in the direction of the acetabulum toward the anterior superior iliac spine and typically connected to the main rods using lateral connectors. More modern instrumentation techniques featuring a start point placed at the inner table of the ilium have reduced IS-related complications such as wound dehiscence over screw heads and postoperative pain resulting from the superficial nature of the screws. S2AI screws, in contrast to the IS, are started at the S2 ala and traverse the sacroiliac joint (SIJ) into the ilium. The advantages of S2AI screws include less prominence, more in-line placement obviating the need for lateral connectors, and better fixation as the screws’ threads cross 3 separate sets of cortical bone.

The clear benefits of spinopelvic fixation in deformity constructs have been tempered by questions regarding pelvic screw-based complications and failure rates. Martin et al performed a review of spinopelvic fixation at 13 academic centers to determine acute failure rates, with acute failure defined as reoperation within 6 months of the index procedure. A total of 779 cases were included with a 5% rate of revision surgery and complications. The authors, faculty, and staff have no relevant financial relationships with any ineligible organizations regarding this educational activity.

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of failure. Modes of failure included slippage of the rods or displacement of the set screws from the tulip head, screw shaft fracture, screw loosening, and/or fracture of the sacrum. The authors reported a roughly 4% increase in failure rate for ISs compared with S2AI, although this difference was not significant. A different multicenter evaluation of adult deformity patients reviewed an overall long-term failure rate of 35% and 12% for S2AI screws and ISs, respectively. The time of failure was reported occurring between 8 and 709 days after the index procedure. Furthermore, with evidence of solid fusion across L5-S1, radiographic screw loosening of pelvic instrumentation has been found to occur in 10% to 30% of patients. The implications of no fusion occurring across the SIJ, and that motion across these joints still occurs after fixation. Given that traditional spinopelvic screws are not fusion devices and generally do not limit SIJ motion, loosening and resulting pain would be predictable. Additionally, concerns regarding high rates of SIJ pain and dysfunction after spinopelvic fusion have arisen.

Significant SIJ pain has been identified in 16% to 53% of patients after lumbar fusion, with highest incidence among those with spinopelvic fixation. Studies have identified evidence of SIJ degeneration via a CT scan in 75% of patients after lumbar fusion, compared with 38% of control patients. The nociceptive and proprioceptive innervation of the SIJ is thought to be key foundational elements for the development of postoperative pain after lumbar fusion extending to the pelvis.

Given these factors, interest has arisen in using additional fusion technology across the SIJ to supplement traditional pelvic fixation, reduce failure, and improve sacroiliac (SI)-related clinical symptoms for patients undergoing long fusions to the pelvis. Our objective in this review is to report on the current biomechanics of pelvic fixation, pelvic instrumentation failure, and SIJ dysfunction. Additionally, we examine the benefits and potential consequences of adding fusion across the SIJ to address these concerns.

### Important Biomechanical Concepts in The Setting of Spinopelvic Fusion

#### Sacroiliac Joint Is a Mobile Joint

A key factor in the outcomes of pelvic fusion in long deformity constructs is the mobility of the SIJ. Using a roentgen stereophotogrammetric method, whereby small radio opaque markers are introduced into the bone of interest to serve as landmarks resulting in highly accurate measurement of micromotion, Egund et al determined that when exposed to symmetric forces the sacrum mainly rotated about a transverse axis at most approximately 2 degrees. Jacob and Kissling analyzed SIJ movement using plain-light stereophotogrammetry, which uses surface markers instead of implanted bone markers. Rotational movement about the horizontal axis, which corresponds to a “nutation” movement, was found to be greatest with a mean value of 1 degree and range between 0 and 4.4 degrees. Translation along the axis of rotation was found to be low with an average of 0.7 mm. Most recently, Nagamoto et al examined SI motion in 13 healthy volunteers and 20 patients with degenerative lumbar spine disorders (DSDLs), which included adult spinal deformity, in neutral position, maximal trunk flexion, and maximal trunk extension. Findings in healthy patients echoed previously...
established SIJ motion parameters. However, joint motion in patients with DSDL was found to be significantly greater than in healthy volunteers, particularly in women with DSDL compared with healthy men. Notation movement of the SIJ in healthy men averaged to 0.52 during trunk extension, compared with 1.62 for DSDL women. This implies that a stiffer lumbar spine leads to more compensatory motion at the SIJ. Further, Nagamoto and colleagues elucidated a significant negative correlation between cross-sectional area of trunk muscles in relation to SIJ motion, suggesting loss of trunk muscle strength in DSDL patients contributes to increased SIJ motion.\textsuperscript{47} Overall, the SIJ is mobile and exhibits increased motion in patients experiencing spinal deformity disorders.

**Biomechanical Consequences of S2AI Screws**

Given the importance of SIJ movement within the context of spinopelvic fusion, understanding how various spinopelvic fusion constructs impact SIJ movement is vital. Cunningham et al\textsuperscript{29} evaluated lumbosacral and SIJ range of motion (ROM) with 3 fusion constructs including S1-2 sacral screws without instrumentation across the SIJ, sacral alar iliac screws (S2AI), and S1 iliac screws. These were done under unilateral and bilateral configurations across 21 cadaveric lumbo pelvic spines. With flexion-extension motion, S1-2 sacral reconstruction resulted in a 147\% $\pm$ 2716\% increase in SIJ ROM, presumably due to the stiffening of the lower lumbar spine and compensatory stress on the SIJ. Comparatively, S2AI screws resulted in minimal reduction of SIJ motion to 88.36\% $\pm$ 30.85\% of the intact state. Axial rotation analysis resulted in the most substantial changes elucidated by the study. Both S1-2 sacral reconstruction and sacral iliac constructs resulted in increased motion of the SIJ; however, S2AI screws decreased SIJ axial rotation motion to 72.63\% $\pm$ 35.39\% of the intact state, although this was not a significant decrease in motion compared with the intact spine. Cunningham and colleagues postulate that S2AI screws are able to slightly limit SIJ motion due to S2AI screws crossing the joint directly. This results in compression of the SIJ, although it is important to recall this decrease was not significant compared with the intact spine. Although S2AI screws are biomechanically as stable as LS constructs and may slightly limit SIJ motion,\textsuperscript{48} the decrease in motion is not significant and fusion of the SIJ is unlikely to occur.

Persistent motion at the SIJ after pelvic fixation impacts other spinopelvic parameters. Pelvic incidence (PI) is primarily interpreted as a fixed value that describes sacral orientation.\textsuperscript{49} However, studies have shown that PI can change during long deformity constructs.\textsuperscript{50} This is primarily due to the stiff lumbar spine placing increased stress on the SIJ. The addition of pelvic fixation to deformity constructs also results in PI changes.\textsuperscript{51-53} Most recently, Wei et al\textsuperscript{54} analyzed a cohort of 68 adjacent segment disease (ASD) patients undergoing pelvic fixation with S2AI screws and found that 36.8\% of patients exhibited a PI change greater than 6 degrees. Patients deemed to have a high preoperative PI (>$\geq$60 degrees) exhibited the largest percentage of 6-degree change at 66.7\%. Thus, S2AI screws do not limit SIJ motion enough to prevent changes in PI.

**Rationale for Adding SIJ Fusion to Deformity Constructs, Which Include Pelvic Fixation**

As we stated previously, lumbar fusion with pelvic fixation leads to surprisingly high rates of postoperative SIJ pain and incidence of pelvic screw loosening, with literature indicating ranges of 12\% to 33\% and 4\% to 27\%, respectively.\textsuperscript{22,28,36,55,56} It is postulated that after long deformity fusion involving the sacrum, the SIJ becomes the next segment upon which increased stress is placed. Mechanical studies of lumbar ASD have identified increases in intradiscal pressures and increased motion at the adjacent segments as a root cause of subsequent ASD development.\textsuperscript{57-59} It is likely that these same pathologic developments are the root cause of SIJ dysfunction. In fact, Ivanov et al\textsuperscript{41} determined that fusion in the lumbar spine resulted in increased motion and stress at the SIJ, and increased fusion levels resulted in increased stress at the SIJ. This increased motion ultimately results in hastened degeneration and pain for patients. As identified earlier, patients undergoing deformity correction procedures will likely already be experiencing higher than normal SIJ motion. Ha et al\textsuperscript{40} demonstrated the relationship between long fusion and SIJ motion by noticing accelerated radiologic SIJ degeneration in patients with fusions extending to the sacrum compared with those ending at L5. Therefore, there has been recent interest in the concept that by adding reinforced SIJ fusion to deformity constructs, surgeons may be able to limit postoperative motion at the SIJ and lower rates of SIJ pain and screw complications.

**Options for Sacroiliac Joint Fusion in The Setting of Deformity Constructs**

**Open Fusion**

Open fusion of the SIJ was first described in 1921.\textsuperscript{60} After its initial introduction, further reports of noninstrumented fusion techniques followed that required significant periods of immobilization with casting and bracing.\textsuperscript{61} In the 1980s, development of instrumented techniques followed that negated requirements for long immobilization.\textsuperscript{62} However, despite advancements in open technique widespread adoption was limited due to the inherent risks involved with long incisions, bone harvesting, prolonged hospital stay, and potential damage to pelvic structures.\textsuperscript{63-65}

Ledonio et al\textsuperscript{66} described an open technique that involves exposure of the superior capsule of the SIJ, followed by resection of the cartilage using a series of curettes and rongeurs. A bone graft is then harvested from the inner table of the ilium and subsequently packed into the joint space. Fusion is achieved with a 3-hole 4.5-mm reconstruction plate fixed with a 6.5-mm cancellous screw on the sacral side and 2 cortical screws on the iliac side.

**MIS SIJ Technique**

Minimally invasive surgical (MIS) techniques for SIJ arthrodesis began to surface in the early 2000s, with instrumentation primarily involving threaded screws and cages that rely on autologous bone graft.\textsuperscript{53,67} The effectiveness of MIS SIJ fusion has been validated in the literature, displaying high fusion rates, significant improvements in postoperative outcomes, and low complication rates.\textsuperscript{68-72}
MIS techniques primarily involve a transsacral percutaneous approach. Al-Khayer et al. were one of the first to publish outcomes of such a technique in a case series of 9 patients treated with a transsacral percutaneous approach using hollow screws. They noted the ideal insertion point and screw direction would result in the screw being placed from the ilium, perpendicular to and across the SIJ, through the sacral alar, to the body of S1 vertebra, ending midpoint between the S1 neural foramina and L5/S1 disc. The technique describes a percutaneously placed guide wire that is advanced across the SIJ to the body of the S1 vertebrae. Following this, a 10-mm cannulated drill is advanced over the guidewire and inside a 10-mm guide tube until it is in the body of the S1 vertebrae. after removal of the guidewire, a 10-mm HMA screw packed with bone matrix is placed in the prepared tunnel and tightened. Patient-reported outcome (PRO) analysis resulted in a statistically and clinically significant improvement in visual analog scale (VAS) and Oswestry Disability Index (ODI) values. Khurana et al. explored a similar technique, also using hollow screws, in 15 patients treated with percutaneous SIJ arthrodesis. Outcome assessment revealed significant improvements in 36-Item Short Form Health Survey (SF-36) scores. Khurana and colleagues reported no complications with any of the cases, with all cases obtaining solid fusion at final follow-up.

Another option that uses similar technique as hollow screws is the use of triangular titanium implants (iFuse Implant System). The efficacy and utility of triangular titanium implants in treating SIJ dysfunction has been demonstrated in the literature, with prospective trials identifying larger improvements in pain and quality of life compared with nonsurgical management. Darr et al. reported on 5-year clinical and radiographic outcomes in 103 subjects who underwent SIJ fusion via triangular titanium implants and found significant improvements in PROs at final follow-up. SIJ pain and ODI scores at 5 years decreased significantly by a mean of 54 points and 26 points, respectively. Radiographic analysis elucidated high rates of bony bridging at 87% at 5 years. The authors obtained robust long-term improvements in pain, disability, and quality-of-life measures. Additionally, Cher et al. examined 11,388 cases between 2009 and 2014 using iFuse internal inventory management and complaint databases and determined a 4-year revision rate of 3.54%. They noted that the revision rate improved over time, decreasing from 9.7% in 2009 to 1.4% in 2014. The observed revision rate is slightly higher than revision rates seen for total hip replacement. However, the rate of SIJ revisions is lower than those reported for lumbar stenosis surgery (decompression or arthrodesis) and lumbar disc replacement, with rates of 10.6% and 11.2%, respectively.

This technique has been specifically used in combination with traditional pelvic fixation in deformity constructs. Recent developments for triangular titanium implants include consideration specifically for large deformity constructs that involve spino-pelvic fusion to reinforce traditional pelvic fixation. The iFuse Bedrock Granite system, which received FDA clearance in 2022, is one such example. This new device uses similar design from their previous titanium triangular implants, however incorporates a tulip head that is compatible with a variety of pedicle screw system rods. The Bedrock Granite system acts as foundational support at the base of the spine fusion construct. There are no current studies available detailing initial outcomes of this new implant design in the setting of SIJ dysfunction or deformity constructs; however, clinical trials evaluating the addition of this device alongside traditional pelvic fixation are underway.

Studies comparing outcomes of MIS technique to traditional open fusion have showed improved outcome measures with MIS technique. Smith and colleagues compared outcomes of 149 open SI fusions to 114 MIS SI fusions and found MIS was associated with significantly shorter operative times, estimated blood loss, and hospital stay. PRO analysis identified a significantly lower VAS pain rating for the MIS group compared with the open group, by an average of 3.5 points at 12 months postoperatively. After controlling for age, sex, and other assorted parameters, pain score improvement was found to be 3 points higher for the MIS cohort. Ledonio et al. corroborated these findings after their comparison of 36 open and 27 MIS SIJ fusions, elucidating significantly lower estimated blood loss, operative time, and hospital stay in the MIS cohort. There were no complications reported for the MIS cohort, but there were 3 complications in the open group, which included pulmonary embolism and implant failure. Overwhelming support of MIS technique in the literature has resulted in widespread adoption of MIS technique as the standard, with open technique for SIJ dysfunction treatment falling out of favor. Lorio et al. conducted a survey on use of MIS technique for SIJ fusion among 121 International Society for the Advancement of Spine Surgery (ISASS) and Society for Minimally Invasive Spine Surgery (SMISS) members between 2009 and 2012. Results of the survey showed the percentage of MIS procedures increased from 39% in 2009 to over 87% in 2012. The percentage of open procedures decreased, from 60.56% in 2009 to 12.15% in 2012. This trend is likely to have strengthened since the Lorio and colleagues report, establishing MIS as the standard among surgeons.

**Technique for Adding Triangular Titanium SIJ Fusion Devices to S2AI Screw Constructs**

As previously mentioned, addition of triangular titanium implants (iFuse Implant System) alongside traditional S2AI pelvic fixation has been proposed to improve stability across the SIJ. Martin et al. provided a technical description in their review of 21 lumbosacral fusion procedures with concomitant bilateral SIJ fusion performed at a single institution. A standard open posterior approach with midline incision and subperiosteal exposure is performed. After exposure, pedicle screws and S2AI screw are placed via standard technique with the S2AI screws being placed as caudally as possible into the radiographic teardrop target. Placement of the triangular implants begins with establishing a starting point 2 to 3 mm proximal to the S2AI screw on the sacral ala. Martin and colleagues stress that more proximal starting points should be avoided, as this increases the chances of a cephalad breach of the implant. Once the appropriate starting point is defined, a cannulated drill is passed over the guide pin and progressed until the SIJ is breached. Subsequently, a navigated broach is used to create a tract for the implant. The technique calls for the flat side of the triangular broach to be turned toward the S2AI screw, which ensures the implant is placed as close as possible to the S2AI...
screw and as low as possible in the teardrop target. Finally, an appropriately sized implant is passed over the guide pin and impacted to the correct depth. The positioning is verified with intraoperative imaging.

Although Martin et al did not examine clinical outcomes, they did demonstrate the technical feasibility of additional reinforcement of the SIJ alongside traditional pelvic fixation. No operative complications were reported. Three implants were initially malpositioned, which required correction. None of these instances resulted in a breach of more than 1 to 2 cm. Three possible reasons for initial incorrect placement were discussed. First, the bony corridor for implant placement is wider at the caudal aspect and narrows substantially in the proximal and cephalad directions. Second, Martin and colleagues note that the slope of the SIJ combined with the hard bony cortex of the ilium promotes ventral breaches into the pelvis. Lastly, the drill bit is flexible; therefore, it may bend once it leaves the drill guide. Improperly placed implants were salvaged either by placing a new guide pin more lateral and caudal to better access the wider portion of the teardrop target or by shortening the implant and reinserting into the same trajectory.

Although we examined the fusion dowel technique in an open deformity setting in detail, other options are available to the surgeon including hollow screws, open bone grafting, and lateral transiliac percutaneous dowels.

**Biomechanical Consequences of SIJ Fixation**

**SIJ Fusion Devices “Protect” the S2AI Screws**

SIJ arthrodesis does have unique biomechanical consequences that are important to discuss. Galbusera et al conducted a cadaveric analysis comparing pedicle screw fixation with 3 separate sacropelvic constructs, which included ISS, S2AI screws, and laterally placed triangular titanium SIJ fusion implants. Moments of 7.5 Nm in flexion, extension, lateral bending, and axial rotation combined with a 500 N compressive load were simulated and biomechanical data were obtained. Galbusera and colleagues determined that the triangular SIJ fusion implants demonstrated a reduction in SIJ ROM relative to the intact spine model. This finding has been replicated by other biomechanical studies examining the impact of triangular fusion implants across the SIJ.

De Andrada Pereira et al examined 8 human pelvis specimens that underwent pure moment (7.5 Nm) and compression (400 N) tests under 4 construct conditions. The conditions included an intact specimen, L2-S1 pedicle screws, and rods with an LS-S1 interbody, LS-S1 construct with S2AI screws, and lastly the same S2AI construct with additional laterally placed triangular titanium SIJ fusion implants. Compared with the intact specimen, both S2AI and S2AI with additional SIJ fixation significantly decreased SIJ ROM in extension and in combined flexion-extension. Adding SIJ fusion devices reduced the mean S2AI screw-bending moment in all directions of load by 19%, implying that SIJ fusion devices “protect” the S2AI screws. In terms of rod strain, additional SIJ fixation slightly reduced LS-S1 rod strain during right axial rotation by 6%; however, it significantly increased rod strain in extension by 6%. Rod strain at S1-S2AI was not significantly impacted by addition of SIJ fusion devices, despite a slight increase.

Panico et al also examined the use of triangular titanium SIJ fusion implants as supplements to traditional S2AI pelvic fixation for T10-S1 constructs in cadaver specimens. Their findings largely echoed those previously discussed, identifying further reduction in SIJ motion by 15% to 25% with the addition of the triangular implants to S2AI screw constructs. Panico and colleagues also corroborated the finding that triangular implants have a protective effect on the S2AI screws. Therefore, the primary takeaways of additional SIJ fusion in the setting of S2AI deformity constructs include reduction in S2AI screw bending and potentially increased in rod strain on extension, with some additional reductions in SIJ ROM.

**SIJ Fusion Devices May Affect Proximal Junctional Failure Rates**

Advancements in technology and techniques have provided spine surgeons to correct severe spinal malalignment, however, proximal adjacent pathology in the form of proximal junctional kyphosis (PJK) and proximal junctional failure (PJF) remains problematic. Clinically, PJK is the development of minimally symptomatic kyphosis above a fusion construct. There is no standard radiographic definition of PJK; however, that of Glattes et al appears to be the most widely used. Glattes et al defined PJK as a sagittal Cobb angle between the uppermost instrumented vertebra (UIV) and the 2 levels above the UIV of 10 degrees or greater and at least 10 degrees greater than the preoperative measurement. PJF is a more severe manifestation of PJK that involves structural failure and mechanical instability, often requiring reoperation. Literature has shown that fusion to the sacrum increases the incidence of PJF/PJK. Yagi et al reviewed 157 patients with adult scoliosis treated with long instrumented spine fusion and found that fusion to the sacrum was a significant risk factor for the development of PJK. Bridwell et al examined clinical and radiographic data of 90 patients treated surgically for idiopathic/degenerative scoliosis and determined that PJK ≥ 20 degrees is associated with fusion to the sacrum.

Although there is currently no literature examining long-term outcomes of patients treated with concomitant SIJ fusion reinforcement and long deformity constructs, it is thought that increased rates of PJF/PJK may be an undesired consequence. As noted earlier, extension of fusion constructs to the pelvis already shows an association with increased rates of PJF/PJK. Therefore, a stiff spine combined with substantially reduced motion at the SIJ, in effect lengthening the fusion construct, may place increased strain at the mobile proximal junction, contributing to increased motion and increased rates of degeneration at proximal segments. The current ongoing SI Joint Stabilization in Long Fusion to the Pelvis (SILVIA) study, to analyze long-term outcomes of patients treated with SIJ fusion during deformity correction procedures, will ideally provide more information on proximal segment disease.

**SIJ Fixation Impacts the Hip Joint**

Complications distal to the fusion construct are also concerning reinforced SIJ fusion in the setting of
deformity constructs. A relationship between additional SIJ fixation in the setting of lumbosacral fusion and the development of hip pain has already been observed. It is postulated that with increased fixation of the SIJ, the hip joint becomes the next target of ASD, which results in increased progression of osteoarthritis. Kozaki et al reviewed 118 patient radiographs after spinal fusion, separating patients into 2 groups based on presence or absence of hip osteoarthritis determined by a decrease in measured joint space over 12 months. Logistical regression of patients found to have progression of hip osteoarthritis elucidated presence of SIJ fixation as a statistically significant factor. In a follow-up study exploring the biomechanics behind this association, Kozaki and colleagues compared contact pressure of the hip joint in a L4-S1 fusion model with or without SIJ fixation. After undergoing 400 N compressive loads at L4, and 10 Nm bending moments to stimulate flexion, extension, left lateral bending, and axial rotation, they determined the average and maximum contact stresses of the hip joint were highest for the model that included additional SIJ fixation. A third study by Kozaki et al further clarified this relationship after comparing the changes in hip joint moment before and after spinal fusion in 9 patients. Kozaki and colleagues determined hip joint flexion-extension and abduction-adduction moments increased after spino-pelvic fixation surgery involving the SIJ. The discoveries by Kozaki et al validated the idea that after increased fixation of the SIJ, the hip joint becomes the next adjacent segment that bears increased mechanical load resulting in increased motion and progressive degeneration. This should be a consideration for clinicians when considering possible SIJ fusion with deformity constructs in patients. For patients already suffering from arthritis, close discussion and planning with joint replacement surgeons are required.

**Conclusion**

More robust SI fixation involving multiple points of fixation and a biologic fusion has been shown to provide increased protection of S2AI screws and reduced axial rotation at the SIJ. Potential benefits of this include lower rates of clinical SIJ dysfunction and/or pelvic screw failure. However, these benefits likely come with a cost. The impact that strengthened SIJ fixation has on the progression of hip osteoarthritis has also been elucidated. Biomechanical questions that are still unanswered include the impact that SIJ fixation in the deformity setting has on proximal ASD in the form of PJK and PJF and whether increased fixation will result in new sacral insufficiency fractures. Literature examining outcomes of SIJ fusion devices in the setting of long deformity constructs is limited. Further study comparing clinical outcomes, including PROs, between traditional deformity constructs and deformity constructs using additional SIJ fusion devices is required to better understand the benefits and risks of strengthened SIJ fixation. The SILVIA study, a multicenter randomized controlled trial comparing deformity constructs using S2AI screws and S2AI screws with additional triangular titanium implants, is a promising endeavor that will surely provide more clarity and clinical guidance for the spinal community.

**References**

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1. The clear benefits of spinopelvic fixation in deformity constructs have been tempered by
   A. decreased surgeon use of spinopelvic fixation.
   B. decreased PRO scores.
   C. questions regarding pelvic screw–based complications and failure rates.
   D. advancements in nonsurgical treatment options.

2. In patients with degenerative spinal deformity disorders (DSDL), comparison to healthy volunteers, joint motion was
   A. significantly reduced compared with healthy volunteers.
   B. comparable to healthy volunteers.
   C. significantly greater, particularly in women with DSDL compared with healthy men.
   D. primarily affected in men with DSDL.

3. Which one of the following statements best describes the effect of S2AI screws on SIJ motion compared with other constructs?
   A. S2AI screws significantly decrease SIJ motion compared with the intact spine.
   B. S2AI screws result in significant fusion of the SIJ.
   C. S2AI screws slightly limit SIJ motion but do not significantly decrease it compared with the intact spine.
   D. S2AI screws are biomechanically less stable than iliac screw constructs.

4. In a study by Wei et al of patients with ASD who underwent pelvic fixation with S2AI screws, A. S2AI screws completely prevented any changes in PI.
   B. 68.8% of patients exhibited a PI change greater than 6 degrees.
   C. patients with a low preoperative PI (<30 degrees) exhibited the largest percentage of 6-degree change.
   D. patients with a high preoperative PI (>60 degrees) exhibited the largest percentage of 6-degree change.

5. Which one of the following is postulated to be a root cause of subsequent dysfunction of the SIJ after long deformity fusion involving the sacrum?
   A. decreased intradiscal pressures
   B. reduced motion at adjacent segments
   C. increased stress at the SIJ due to decreased motion and fusion in the lumbar spine
   D. improved biomechanical stability of the SIJ

6. What trend regarding surgical techniques for SJ dysfunction treatment has been observed in recent years according to a survey conducted by Lorio et al?
   A. increased SIJ ROM in extension and combined flexion-extension.
   B. had no effect on the bending moment of S2AI screws.
   C. slightly decreased L5-S1 rod strain during right axial rotation.
   D. reduced S2AI screw-bending moment in all directions of load and slightly increased rod strain in extension.

7. Compared with S2AI screws alone for treatment of SJ dysfunction, the addition of SJ fusion devices
   A. increased SIJ ROM in extension and combined flexion-extension.
   B. no different in SIJ ROM in extension and flexion-extension.
   C. significantly reduced compared with healthy volunteers.
   D. had no effect on the bending moment of S2AI screws.

8. In a cadaveric study by Panico et al, the use of triangular titanium SJF fusion implants as supplements to traditional S2AI pelvic fixation for T10-S1 constructs resulted in
   A. no significant effect on reducing SIJ motion.
   B. increase in SIJ motion by 15% to 25%.
   C. 15% to 25% reduction in SIJ motion.
   D. increased rod strain on extension without affecting S2AI screw bending.

9. Concomitant SJF fusion reinforcement and long deformity constructs are thought to
   A. reduce risk of adjacent segment degeneration.
   B. decrease rates of PJK or PJF.
   C. increase rates of PJK/PJF.
   D. enhance stability of the spine.

10. In a study by Kozaki et al of hip joint moments after spinopelvic fixation surgery involving the SJF, hip joint
    A. moments remained unchanged after surgery.
    B. moments decreased after surgery.
    C. flexion-extension and abduction-adduction moments increased after surgery.
    D. moments increased only in flexion-extension but decreased in abduction-adduction.
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