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Vertical shear pelvic ring injuries: do transsacral screws prevent fixation failure?

Breann K. Tisano, MD[a,*], Drew P. Kelly, MD[b], Adam J. Starr, MD[a], Ashoke K. Sathy, MD[a]

Abstract

Objectives: To determine the frequency of fixation failure after transsacral-transiliac (TS) screw fixation of vertical shear (VS) pelvic ring injuries (OTA/AO 61C1) and to describe the mechanism of failure of TS screws.

Design: Retrospective cohort study.

Setting: Level 1 academic trauma center.

Patients/Participants: Twenty skeletally mature patients with unilateral, displaced, unequivocal VS injuries were identified between May 1, 2009 and April 31, 2016. Mean age was 31 years and mean follow-up was 14 months. Twelve had sacroiliac dislocations (61C1.2) and eight had vertical sacral fractures (61C1.3).

Intervention: Operative treatment with at least one TS screw.

Main Outcome Measurements: Radiographic failure, defined as a change of >1 cm of combined displacement of the posterior pelvis compared with the intraoperative position on inlet and outlet radiographs.

Results: Radiographic failure occurred in 4 of 8 (50%) vertical sacral fractures. Posterior fixation was comprised of a single TS screw in 3 of these 4 failures. The dominant mechanism of screw failure was bending. All of these failures occurred early in the postoperative period. No fixation failures occurred among the sacroiliac dislocations. There were no deep infections or nonunions.

Conclusions: This is the first study to describe the mechanism of failure of TS screws in a clinical setting after VS pelvic injuries. We caution surgeons from relying on single TS screw fixation for vertically unstable sacral fractures. Close radiographic monitoring in the first few weeks after surgery is advised.

Level of Evidence: Level IV.

Keywords: fixation failure, iliosacral, pelvic fracture, transsacral, vertical shear

1. Introduction

VS[1] pelvic ring injuries (OTA/AO classification 61C1.2 and 61C1.3)[2] typically result from high-energy trauma and can be difficult to treat. A systematic review within the last decade found 44% of all pelvic ring malunions and nonunions occurred after VS injuries.[3] Clinical series focused exclusively on VS injuries are sparse in the literature owing to their relative rarity,[4–8] but they may be grouped with other vertically unstable pelvic ring injuries.[1,9–12] Such injuries can lead to a host of problems related to poor outcomes including chronic low back pain, limb length discrepancy, gait impairment, sitting difficulty, sexual dysfunction, and bowel or bladder incontinence.[3,13–17]

Iliosacral (IS) screws (which cross 1 sacroiliac [SI] joint and end in the sacrum)[18,19] and TS screws (which cross both SI joints)[20,21] are common fixation options used to treat posterior pelvic ring injuries. Fixation failure and nonunion are known complications of percutaneous IS screws[18–21] and the fixation method most likely to result in uneventful union is unknown. At least 2 previous studies have shown good results with no fixation failures in patients with VS SI joint dislocations treated with IS screws,[5,7] but one of these investigations showed that IS screws were more likely to result in fixation failure when used to treat vertical sacral fractures than with SI dislocations.[7] Since that time, TS screws have become more popular for a number of reasons, with some authors speculating that a longer fixation pathway crossing the cortex of the contralateral SI joint and ilium may provide more robust fixation than screws that end in the cancellous bone of the sacral body.[14,22,23] A biomechanical cadaver study has demonstrated no difference in displacement or load to failure between single IS fixation or IS and supplemental TS fixation of VS sacral fractures.[24] To our knowledge, this has not been previously studied in a clinical population.

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[a] *Department of Orthopaedic Surgery, University of Texas Southwestern Medical Center, Dallas, Texas,* [b] *Department of Orthopaedic Surgery and Rehabilitation, University of Oklahoma College of Medicine, Oklahoma City, Oklahoma*

[*] *Corresponding author. Address: Department of Orthopaedic Surgery, University of Texas Southwestern Medical School, 1801 Inwood Rd., Dallas, TX 75390. E-mail address: breann.tisano@phhs.org (B. K. Tisano).*

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The purpose of this study was to determine the frequency of fixation failure after transsacral (TS) screw fixation of VS pelvic ring (OTA/AO 61C1) injuries and to describe the mechanism of failure of TS screws.

2. Methods

This investigation was reviewed by our institutional review board and approved as exempt. No outside funding was used.

A coding query was used to identify all patients treated with percutaneous IS or TS screws by 2 surgeons at an academic level I trauma center between May 1, 2009 and April 31, 2016. Hospital charts and radiographic studies were used to identify skeletally mature patients with unilateral, displaced, unequivocal VS injuries. Bilateral, anterior posterior compression, lateral compression, combined pelvic ring mechanism, jumper's type (sacral U, H, or lambda), and combined pelvic ring and acetabulum fractures were excluded. Fractures lost to follow-up prior to union were also excluded.

Surgical treatment consisted of percutaneous reduction with a pelvic reduction frame[25] and percutaneous screw fixation of the posterior ring. All patients had at least 1 TS screw, with some having a second TS or IS screw. The screws were all 6.5 or 7.3 mm cannulated stainless steel or titanium. Both screw quantity and diameter were determined at the time of surgery upon subjective assessment of the size of bony corridor available.

Various methods of treatment of the anterior ring injury were employed according to surgeon preference for each injury. On the side of the posterior ring injury, patients were instructed to remain foot flat weight bearing, where partial weight is born through the flat foot to minimize the joint reactive forces at the hip required by lifting the foot for non-weightbearing status. This was continued for 12 weeks after surgery and then advanced to weight bearing as tolerated.

Intraoperative and follow-up anteroposterior, inlet, and outlet radiographs were reviewed. Screw position, length, number, and any evidence of bending or breaking were recorded. The main outcome measure was fixation failure, defined as a change of 1 cm or more of combined vertical displacement (superiorly and posteriorly) of the posterior pelvis on final inlet/outlet radiographs compared with immediate postoperative position.[5,26] Two observers independently measured displacement of the pelvic ring according to the method described by Henderson,[26] the only difference being we used inlet/outlet radiographs for measurements whereas Henderson used anterior-posterior and inlet radiographs. One observer (AKS) was a fellowship-trained orthopaedic traumatologist and contributed to the care of these patients. The other observer (DPK) was an orthopaedic trauma fellow and was not involved in patient care. Differences of 0.5 cm or more were resolved by consensus. Nonoutcome demographic and clinical variables that may contribute to risk of fixation failure were collected as well, including patient age, gender, body mass index, mechanism of injury, anterior ring injury morphology, and anterior ring fixation method.

3. Results

A total of 372 pelvic fracture patients treated with percutaneous screws by 2 surgeons were identified during the 7-year review period, 344 of whom were excluded for 1 or more reasons related to fracture morphology: bilateral, anterior posterior compression, lateral compression, combined pelvic ring mechanism, jumper's type (sacral U, H, or lambda), or combined pelvic ring and acetabulum. A 4-year-old patient who underwent percutaneous fixation of a VS injury was excluded due to skeletal immaturity. Displaced, unilateral, unequivocal VS pelvic ring injuries were identified in 27 skeletally mature individuals. One patient died from acute hepatic failure 8 days after injury. Six others were lost to follow-up prior to union, leaving 20 (74%) patients available for analysis.

Table 1

Demographic and clinical characteristics of the overall sample

Characteristic	Overall sample (N = 20)
Patient demographics	
Age, years, M ± SD	31 ± 13
Male, % (n)	55% (11)
Female, % (n)	45% (9)
BMI, kg/m^2, M ± SD	30 ± 6
Length of follow-up, months, M ± SD	14 ± 12
Mechanism of injury	
Motor vehicle collision, % (n)	75% (15)
Fall, % (n)	20% (4)
Crush, % (n)	5% (1)

Note. BMI = body mass index; M = sample mean; SD = standard deviation.

As summarized in Table 1, mean age was 31 (range 17–59) years, 11 (55%) patients were male, and mean body mass index was 30 (range 20–41). Mean follow-up was 14 months. Mechanisms of injury were as follows: 15 (75%) motor vehicle collisions, 4 (20%) falls, and 1 (5%) crush injury. One surgeon fixed 14 (70%) fractures, and another surgeon fixed the other 6 (30%).

Twelve (60%) posterior ring injuries involved dislocations of the SI joint (61C1.2), and 8 (40%) comprised vertical fractures of the sacrum (61C1.3). Seventeen (85%) anterior ring injuries involved fractures of 1 or more rami, and 3 (15%) were purely symphyseal. All posterior ring injuries were fixed with at least 1 partially threaded cannulated 6.5- or 7.3-mm stainless steel or titanium TS screw, and 11 (55%) posterior ring injuries were fixed with more than 1 screw. Of the 12 patients with SI dislocations, 5 were treated with 1 screw and 7 with 2 screws. Of the 8 sacral fractures, 4 had 1 TS screw and 4 had 2 screws (all of which were combined TS and IS screw configuration). Anterior fixation constructs were as follows: 11 (55%) INFIX devices, 3 (15%) external fixators, 2 (10%) medullary ramus screws, 2 (10%) plate and screw constructs, and 2 (10%) without fixation (Table 2).

Table 2

Injury pattern and surgical fixation methods

	Overall sample (N = 20)
Posterior ring injury pattern	
SI dislocation, % (n)	60% (12)
Vertical sacral fracture, % (n)	40% (8)
Anterior ring injury pattern	
Pubic rami fracture (1 or more), % (n)	85% (17)
Pure symphyseal diastasis, % (n)	15% (3)
Anterior fixation	
INFIX device, % (n)	55% (11)
External fixator, % (n)	15% (3)
Medullary ramus screw, % (n)	10% (2)
Plate and screw construct, % (n)	10% (2)
None, % (n)	10% (2)

Table 3

Patients with reduction loss following TS +/− IS screw fixation

Age	Sex	BMI	Anterior injury	Anterior fixation	Posterior injury	Transsacral screw	Combined vertical displacement (mm)			Mode of failure
							On admission	Immediate postoperative	After displacement	
58	M	33	rami x2, symphysis	External fixator	Sacral fracture	S1 TS	13	0	24 at 2 wks	TS bent
51	M	34	symphysis	Plate	Sacral fracture	S1 TS	18	0	12 at 7 wks	TS bent
20	F	20	rami x4	INFIX	Sacral fracture	S2 TS	23	5	27 at 3 wks	TS cut out
31	M	23	rami x4	INFIX	Sacral fracture	S1 TS, S2 IS	21	9	25 at 6 wks	TS bent, IS cut out

Surgical reduction was to within 1 cm or less of combined vertical displacement in all patients. No patient underwent revision of posterior fixation. According to our radiographic criteria, reduction loss occurred in 4 (50%) of the 8 vertical sacral fractures (Table 3) but none of the SI dislocations. Each case of reduction loss was identified on the first set of postoperative x-rays (at 2, 3, 6, and 7 weeks after injury). Among those with reduction loss, 3 TS screws bent (Figs. 1–3) and 1 TS screw cut out. Three of the 4 patients with reduction loss were fixed with a single TS screw, and the other was fixed with a single TS screw combined with an IS screw. In this dual screw configuration, the TS bent and the IS cut out. All 4 of these patients went on to heal without further displacement or surgery. There were no deep infections or nonunions.

4. Discussion

It is clear from previous studies[5,7] as well as the current investigation that VS injuries with an SI joint dislocation behave differently from those through a sacral fracture. A single screw (IS or TS) combined with appropriate anterior fixation is likely adequate for a well-reduced SI dislocation. Similar to previous reports, we had no fixation failures of SI dislocations.

In contrast, vertically unstable sacral fractures have higher fixation failure rates. There may be several reasons for this. This could be because of inherent instability of the fracture itself (as opposed to an SI dislocation, where the undulations of the joint can be interdigitated and compressed) or because IS screws lack cortical purchase medial to the fracture. There has been a trend over the last 10 to 20 years to use longer screws that have a transsacral-transiliac pathway.[20] These TS screws are attractive because they traverse 3 dense cortices on each side of the fracture.[14,22,23] The purpose of this paper was to evaluate the rate of secondary displacement using TS screws in vertically unstable sacral fractures. This is the first series to our knowledge specifically dedicated to TS screw fixation of VS injuries. It is also the first study to specifically illustrate the mechanism of failure of TS screws in this setting.

We found that sacral fractures fixed with a single TS screw can still fail, albeit in a different manner (bending of the screw as opposed to cutout/loosening with IS screws[5,22]). Three of the 4 failures only had a single TS screw. Our study is not powered to comment on whether 2 TS screws or 1 TS screw combined with an IS screw is sufficient fixation. We know from a previous analysis at our institution that 2 IS screws can fail in vertically unstable sacral fractures at a rate of 13%.[5] We have shown here that a single TS screw can fail. Logic would then dictate that the surgeon strive for at least 2 screws, with 1 or both being TS. The ability to do this is, however, constrained by the anatomy of the patient's sacrum. With sacral dysmorphism, it is often not possible to place a TS screw in the S1 corridor. In these situations, an obliquely oriented IS screw into the S1 body combined with a TS screw in the S2 corridor may be the best configuration of posterior screw placement.[27] Occasionally, even an oblique IS screw into the S1 body may not be possible, depending on the sacral anatomy. When dysmorphism is not present, it is often possible to place TS screws in both the S1 and S2 corridors. Iliolumbar fixation has also been described in conjunction with IS/TS screws for vertical sacral fractures.[28] It is likely that increasing comminution of the sacral fracture would call for increasing amounts of posterior fixation. Future, multicenter collaborative studies could help answer the question of the optimal posterior fixation construct.

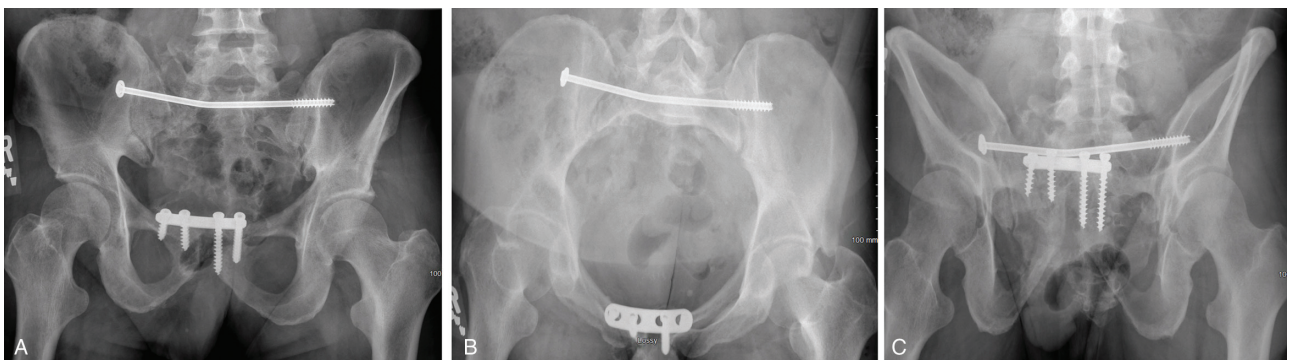

Figure 1. AP (A), inlet (B), and outlet (C) pelvis radiographs for a 51-year-old male show obvious bending of the transsacral screw and loosening of the symphyseal plate and screw construct at final follow-up.

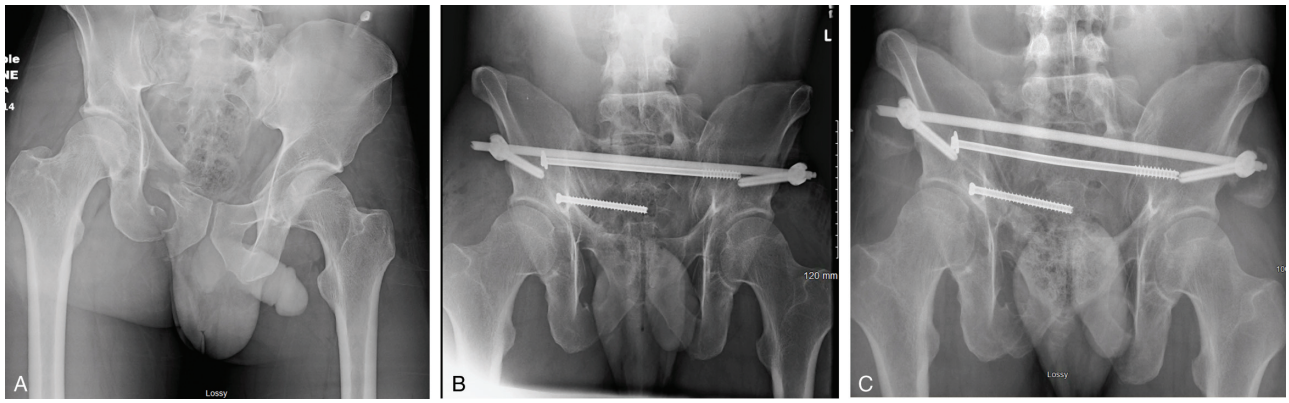

Figure 2. Injury (A), immediate postoperative (B), and 6-month follow-up (C) outlet pelvis radiographs of a 31-year-old male demonstrate slight bending of the transsacral screw and partial cut-out of the iliosacral screw with cranial translational displacement of the right hemipelvis following surgery.

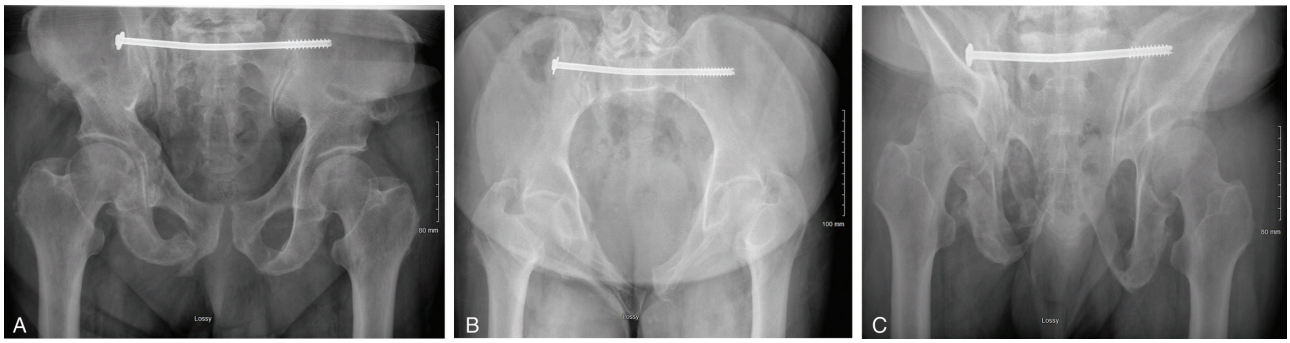

Figure 3. Pelvic radiographs of a 58-year-old male demonstrating bending of the transsacral screw on AP, inlet (B) and outlet (C) views at final follow-up.

It is important to note that while these radiographic failures do not meet our fixation standards, we do not believe these necessarily represent clinical failures. Even when loss of reduction occurred with screw bending, the TS screw construct allowed for eventual bony union without the need for revision posterior fixation. We essentially describe a phenomenon whereby the TS screw bends in the early postoperative period (leading to some loss of reduction) but then resists further displacement and ultimately results in bony union. This is in contrast to historical controls where IS screw cut-out led to catastrophic loss of reduction, necessitating revision posterior fixation to achieve union.[5] We continue to use percutaneous TS/IS screw fixation for these difficult injuries due to the many benefits of percutaneous screw fixation (i.e., no infections or wound complications). We strive for TS screw fixation whenever possible.

All cases of reduction loss in this series occurred early in the postoperative period and were identified on the first set of postoperative x-rays (at 2, 3, 6, and 7 weeks after injury). While we have no way to document compliance with weight-bearing status in this cohort, we recommend avoidance of premature weight bearing after fixation of these highly unstable injuries. Although TS screws may provide stronger fixation, they still will not withstand weight-bearing forces prior to fracture union, especially if only 1 screw is used. The caveat should be noted that, though the intent of the foot flat weightbearing utilized here is to minimize joint reaction forces at the hip, the force transmission across the sacrum is not known and could inadvertently contribute to bending of TS screws. We also recommend close radiographic monitoring with consideration for radiographs at 1 and 2 weeks after surgery. We used 6.5/7.3 mm cannulated screws in this study. Our finding that bending is the predominant mechanism of failure has implications for improvements in implant design. Larger diameter screws may be useful in vertical sacral fractures (within the constraints of patient anatomy).

The strength of our study is strict inclusion criteria resulting in a homogenous cohort of unequivocal VS pelvic ring injuries treated with at least 1 TS screw posteriorly. Limitations include the relatively small cohort size of 20 patients, despite analysis at an academic level 1 trauma center over the course of 7 years. This is a testament to the rarity of these injuries. Different treatment methods were used to address anterior ring injuries in this group. This could be a confounding variable, but we do not feel it detracts from the validity of our findings. Our average follow-up period of 14 months was short, but all fractures were followed to union. Other weaknesses of the study include its retrospective nature and that our primary outcome is a radiographic measure, with the clinical significance being limited by lack of correlation with functional outcomes.

5. Conclusions

SI dislocations heal reliably after reduction and fixation with a single TS screw. It is more challenging to achieve durable fixation

for vertical sacral fractures. We have highlighted the mechanism of failure of TS screws. We caution surgeons from relying on single TS screw fixation for vertically unstable sacral fractures. While this is likely adequate for well-reduced SI dislocations, we recommend striving for 2 TS screws for vertically displaced sacral fractures. The surgeon must then decide if additional supplemental fixation adjuncts are necessary. Close radiographic monitoring in the first few weeks after surgery is advised.

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