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Zone 2 sacral fractures managed with partially-threaded screws result in low risk of neurologic injury

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ABSTRACT

Background: Zone 2 sacral fractures account for 34% of sacral fractures with reported neurological deficit in 21–28% of patients. The purpose of this study was to examine the risk factors for neurological injury in zone 2 sacral fractures. The authors hypothesized that partially thread iliosacral screws did not increase incidence of neurologic injury.

Methods: A retrospective review of consecutive patients admitted to a level 1 trauma center with zone 2 sacral fractures requiring surgery from September 2010 to September 2014 was performed. Patients were excluded if no neurologic exam was available after surgery. Fractures were classified according to Denis and presence/absence of comminution through the neural foramen was noted. Fixation schema was recorded (sacral screws or open reduction and internal fixation with posterior tension plate). Any change in post-operative neurological exam was documented as well as exam at last clinic encounter.

Results: 90 patients met inclusion criteria, with zone 2 fractures and post-operative neurological exam. No patient with an intact pre-operative neurologic exam had a neurological deficit after surgery. 86 patients (95.6%) were neurologically intact at their last follow-up examination. Four patients (4.4%) had a neurological deficit at final follow-up, all of them had neurological deficit prior to surgery. 81 patients were treated with partially threaded screws of which 1 (1.2%) had neurological deficit at final follow-up.

Fifty-seven fractures (63.3%) were simple fractures and 33 fractures (36.7%) were comminuted. All four patients with neurological deficit had comminuted fractures. The association between neurologic deficit in zone 2 sacral fracture and fracture comminution was found to be statistically significant (p-value = 0.016). No nonunion was observed in this cohort.

Conclusions: The use of partially threaded screws for zone 2 sacral fractures is associated with low risk for neurologic injury, suggesting that compression through the fracture does not cause iatrogenic nerve damage. The low rate of sacral nonunion can be attributed to compression induced by the use of partially threaded compression screws. There is a strong association between zone 2 comminution and neurologic injury.

Introduction

Sacral fractures occur in 23–45% of all pelvic ring injuries, and when found to be unstable, require operative stabilization [1–3]. Sacral fractures are classified according to Denis: extra foraminal (Zone 1), involving the neural foramina (Zone 2) or involving the neural canal (Zone 3) [3]. Zone 2 sacral fractures are reported to range between 34 and 47.5% of all sacral fractures. Denis originally described the influence of fracture zone on neurological deficit and prognosis, with zone 2 fractures characterized by injury to the L5 through lower sacral nerve roots. Other authors reported the incidence of neurologic damage to be as high as 21–28% of the patients with most patients recovering at least one functional level [4,5].

Several fixation methods for of zone 2 sacral fractures have been examined: posterior plating [6,7], triangular fixation using pedicular screws [8] and sacroiliac or trans-sacral screws [9–13]. Percutaneous fixation with trans-sacral or sacral screws has become a popular method of fixation owing to, low complication rates and good clinical outcomes [12,13]. In addition, the

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biomechanical properties of the sacral screws show 80–85% return of pelvic biomechanical rigidity after instrumentation [14,15].

One potential concern with partially threaded screws is the potential for compression and narrowing of the neural foramen particularly through comminuted fractures, which may result iatrogenic neurologic injury [16,17]. Fully threaded screws represent an alternative to partially threaded screws as a means to avoid this potential complication [18,19].

The purpose of this study was to define the incidence of post-operative neurologic injury and identify risk factors for neurological deficit after zone 2 sacral fractures. The authors hypothesized that partially threaded posterior screws (trans-sacral, sacral) would not result in iatrogenic neurologic injury, and that fracture comminution through the neural foramen would predict injury-related neurologic compromise.

Methods

Following institution IRB approval, a retrospective review of all pelvic ring fractures and fracture dislocations fixed at a single level 1 trauma academic center from September 2010 to September 2014 was performed using CPT and ICD-9 codes. Patient inclusion criteria included: age > 18 years at the time of injury and closed zone 2 sacral fracture according to Denis. Exclusion criteria were: lack of neurological examination after surgery, patients that did not have neurologic examination prior to surgery and had a neurologic deficit after surgery, open fractures, and any patient transferred after fixation to an outside facility.

We extracted patient demographic data including age and gender; as well as injury profiles (mechanism of injury, abbreviated injury score (AIS) and the injury severity score (ISS)). Neurological status at arrival, first available neurologic exam after surgery and last clinical follow-up neurological examination were obtained from consult, post-operative, in-patient progress, and clinic notes, respectively. Further data collection included: comminuted vs simple fractures, the surgical intervention of open vs closed reduction, and posterior tension band plate fixation versus percutaneous screws, as well as screw type (partially threaded vs fully threaded), and screw number.

Neurologic deficit at final follow up was defined as motor strength of less than five (out of five) of the injured extremity.

Statistical analysis

Statistical analysis was performed by an experienced biostatistician (A.H.) using SPSS © 23.0 (Chicago, IL, USA). Categorical data are presented as count (percent). Continuous data are presented as mean (±standard deviation). The data were divided to patients with intact and deficient neurological examination at final follow-up. All the collected variables were compared between these two study groups. Comparisons between continuous variables were done by the Wilcoxon–Mann–Whitney rank sum test. Comparisons between categorical data were done with chi-square test or the Fisher exact test. The later test was used if expected count was less than five in any cell. All *p*-values reported are two-sided.

Results

Initial data review included 100 patients with zone 2 sacral fractures. After reviewing the patients' data, seven patients were excluded because of lack of neurological examination at follow-up. These included one patient that died shortly after admission, five patients that were transferred intubated and followed at another hospital and one patient that had an above knee amputation the same side as the sacral fracture. Three additional patients were excluded because they did not have a neurological examination prior to surgery and had a neurologic deficit after surgery.

The study population included 90 patients, mean age was 39.10 (±15.03). Of the 90 patients, 36 patients (40.0%) were male and 54 patients (60.0%) were female. The most common cause of injury was motor vehicle accident – 52 patients (57.8%) followed by fall from height – 12 patients (13.3%). There was no statistically significant difference in the demographic characteristics between neurologically intact and deficient patients (Table 1).

Of the 90 patients, 86 (95.6%) had no neurological deficit at any time point. Four patients (4.4%) had a neurological deficit at final follow-up. None of the four patients with final neurological deficit had an intact examination at time of admission. These four patients presented with weak but present initial motor exam defined as 2–3/5 motor strength in the tibialis anterior, extensor hallucis longus, flexor hallucis longus or gastrocnemius–soleus complex. No patient presenting with an initially intact neurologic exam developed a neurologic deficit following operative fixation (Table 2).

Table 1
Demographic and injury related data.

	Neurologically intact PostOp (*N* = 86)	Neurological deficit PostOp (*N* = 4)	*P*-value
Age	39.21 (±15.22)	36.75 (±10.43)	0.887
Gender			
Male	34 (39.5%)	2 (50.0%)	
Female	52 (60.5%)	2 (50.0%)	0.676
Mechanism of injury			
Assault	1 (1.2%)	00 (00%)	
Crush Injury	5 (5.8%)	00 (00%)	0.931
Fall from height	12 (14.0%)	00 (00%)	
Fall from horse	2 (2.3%)	00 (00%)	
MCC	5 (5.9%)	00 (00%)	
MVC	48 (55.8%)	4 (100.0%)	
Pedestrian vs MV	10 (11.6%)	00 (00%)	
Tornado	3 (3.5%)	00 (00%)	
AIS–Abdomen	2.38 (±0.61)	3.33 (±1.53)	0.226
AIS–Extremities	3.02 (±0.88)	3.25 (±0.96)	0.595
AIS–Injury severity score	22.34 (±10.62)	30.5 (±8.34)	0.087

AIS = Abbreviated Injury Score; MVC = Motor vehicle collision; MCC = motor cycle collision; MV = motor vehicle.

Table 2
Pelvic injury and surgery related data.

	Neurologically intact PostOp (*N* = 86)	Neurological deficit PostOp (*N* = 4)	*P*-value
Side of zone 2 fracture			
Left	42 (48.8%)	2 (50.0%)	
Right	33 (38.4%)	2 (50.0%)	0.886
Bilateral	11 (12.8%)	0 (00.0%)	
Fracture pattern			
Simple	57 (66.3%)	0 (0.0%)	
Comminuted	29 (33.7%)	4 (100.0%)	0.016
Fixation method			
ORIF and plate	5 (5.8%)	2 (50.0%)	
CRPP and screw	81 (94.2%)	2 (50.0%)	0.001
Type of screws			
Sacroiliac screws	35 (43.2%)	0 (00.0%)	
Trans-sacral screws	46 (56.8%)	2 (100.0%)	0.506
Number of screws			
1 screw	48 (59.3%)	2 (100.0%)	
2 screws	25 (30.9%)	0 (00.0%)	0.717
3 screws	5 (6.2%)	0 (00.0%)	
4 screws	3 (3.7%)	0 (00.0%)	
Type of screw threads			
Partially threaded	80 (98.8%)	1 (50.0%)	
Fully threaded	1 (1.2%)	1 (50.0%)	0.049

Table 3
Neurological examination of patients with neurological deficit.

	First available examination				Last follow-up examination			
	TA	EHL	FHL	GS	TA	EHL	FHL	GS
Patient 1	3	3	4	4	4	1	5	5
Patient 2	2	2	NA	NA	2	2	5	5
Patient 3	3	NA	NA	3	4	1	4	5
Patient 4	3	3	3	3	4	4	4	4

NA = Not available. TA = Tibialis anterior, EHL = Extensor hallucis longus, FHL = Flexor hallucis longus, GS = Gastrocnemius-Soleus.

Of the four patients with deficit at final follow-up all had Tibialis Anterior (TA) and extensor halucis longus (EHL) motor strength of less than five (out of five). Two patients had either flexor hallucis longus or Gastrocnemius-soleus complex with strength of four or less (of five). One patient also experienced a sensory deficit. Most patients had some recovery of their initial examination (see Table 3).

Correlation of associated injuries and neurologic deficit after sacral fracture was performed using the abbreviated injury score (AIS, Table 1). For the entire patient cohort the mean AIS – abdomen was 2.43 (±0.689). The mean ISS for the entire patient cohort was 22.72 (±10.63). There was a statistical trend for higher ISS in neurologically deficient patients (p-value = 0.087).

Fifty seven patients (66.3%) had simple pattern fractures (Fig. 1) and 33 patients (36.7%) had comminuted fractures (Fig. 2). All four patients with neurological deficit had a comminuted fracture pattern. Of the 86 patients without neurological deficit, 29 patients (33.7%) and 57 (66.3%) had comminuted or simple fracture patterns, respectively. The association between comminuted fractures and neurological deficit was found to be statistically significant. (p-value = 0.016, Table 2).

Of patients with comminuted fracture those with neurological deficit were more commonly fixed open reduction and internal plate fixation (two patients 50.0%) than patients that were neurologically intact (five patients, 5.8%). This difference was found to be statistically significant (p-value = 0.001).

Sacroiliac screws alone were used to fix the sacral fractures of 35 patients (42.16%). In 48 patients (58.84%), trans-sacral screws were used for fracture fixation, either combined with sacroiliac screws or as sole fixation. No statistically significant difference was found between these two groups (p-value = 0.506, see Table 2). Percutaneous screw fixation was performed in 83 patients and partially threaded screws were used in 81 (97.6%) of these. Only one (1.2%) of these 81 patients had neurological deficit at final follow-up, but this deficit was present pre-operatively. There were no nonunions recorded in this cohort.

Discussion

The data presented supports a higher incidence of neurologic injury with comminuted zone II fractures than simple fractures. Surgical fixation with partially threaded sacral and trans-sacral screws did not result in iatrogenic neurologic injury even in communited fractures.

Previous works described the incidence of neurological injury after sacral fractures to be as high as 21–28% [2,5]. The most common injury pattern described was a sensory-motor deficit [5]. Zone 2 sacral fractures are mostly associated with sciatic-like nerve injury and drop-foot – injury to the L5-S1 nerve roots. In this series, the incidence of neurologic injury (4.4%) is lower than previously reported.

It has been reported that all patients show improvement of at least one grade of muscle function and 53% have complete

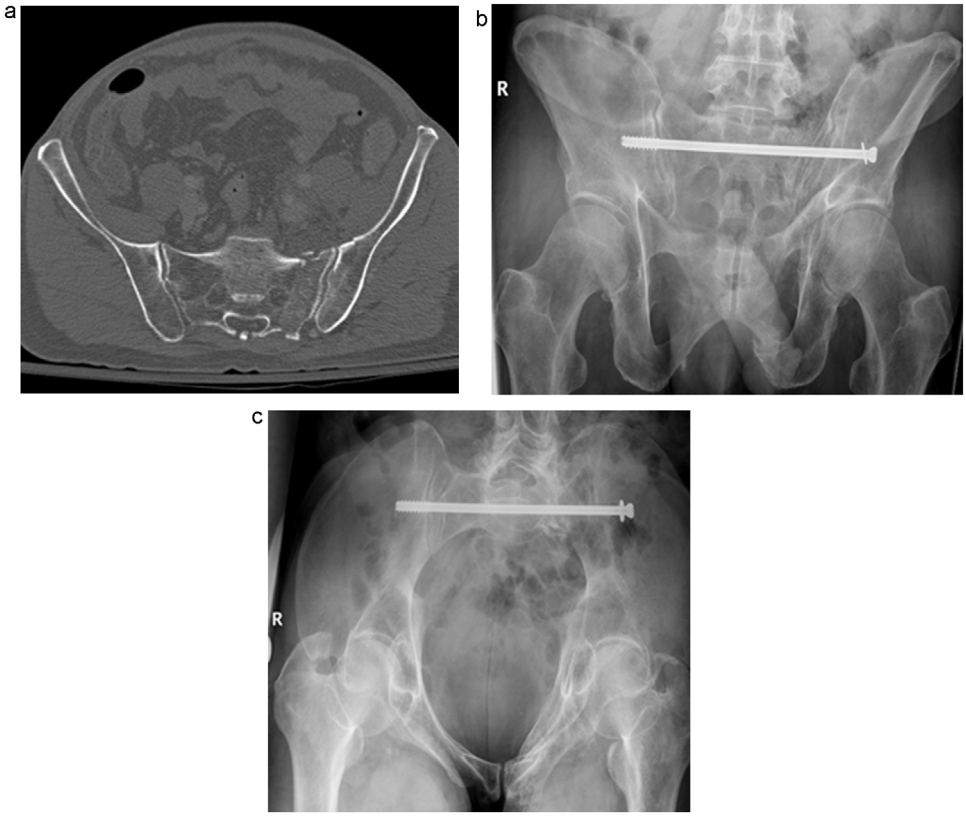

Fig. 1. A CT of a 54-year-old male that was injured falling from 10 feet. He had a zone two simple fracture – the foraminal involvement was not comminuted although some comminution exists in zone 1. He was treated by closed reduction and internal fixation using a transacral screw that produced fixation. (b) (c) present the six months follow-up pelvis outlet and inlet x-rays. Both compression across the fracture and union can be seen. At this time, he is neurologically intact and pain free.

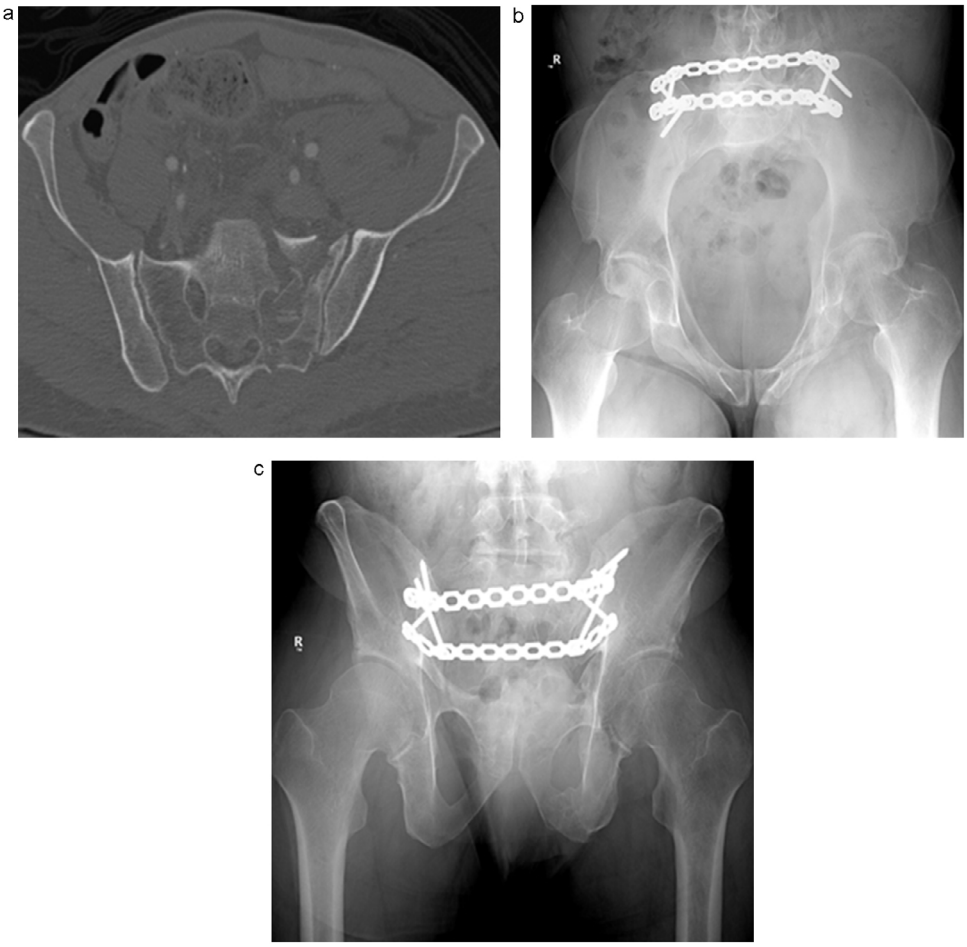

Fig. 2. A 39-year-old male that was injured in a motor vehicle collision. (a) an axial CT in which the comminution involves the neural foramin can be seen with a fragment in the foramina. He initially presented with motor function of three out of five in TA, EHL, FHL and GS. He was treated by open reduction, decompression laminectomy and internal fixation by two tension bands. (b) and (c) presents his inlet and outlet pelvis x-ray at 1 year follow-up. He recovered to four out of five in TA, EHL, FHL and GS but remained 0/5 in peroneal strength.

neurological recovery [5]. In our patient, cohort one patient had neurological recovery and that after he had sacral laminectomy and decompression during his open reduction and internal fixation (Fig. 2).

Vaccaro et al. and Routt et al. have suggested that zone 2 sacral fractures should be fixed using fully threaded sacral screws to avoid neuroforaminal compression generated by partially threaded screws and resultant iatrogenic nerve injury [16,17]. Concise scientific study of this assertion is lacking. Data presented in this cohort does not support these prior concerns as no patient with comminution developed a postoperative neurologic injury. Additionally, this series supports that surgical stabilization with partially threaded sacral and trans-sacral screws yielded 100% union rate.

Min et al. reported on 35 patients with Zone 2 sacral fractures that were treated with partially threaded sacral screws. They did not find any new neurological deficit that could be attributed to the compression screws [20]. They did not study other risk factors such as comminution and they had a small cohort of 35 patients that had Zone 2 sacral fracture.

Our data suggest that neurologic deficit is injury related and that it depends on the comminution of the fracture that is determined at injury. Strengthening this conclusion is the fact that neurologically injured patients had higher scores of abdomen AIS and ISS. This suggests that these were more severely injured patients. We did not recognize a single patient that had an intact neurological examination upon admission and had a neurological deficit after surgery.

Our study has several drawbacks; the first is that it is a retrospective study based on clinical records some of which some records might be incomplete or biased. Several patients were intubated upon arrival which makes it impossible to determine their neurological status at arrival. However, intubation upon arrival is inherent to a population of severely injured patients at a referral trauma center. These patients cannot be excluded if a true representation of the sacral fracture population is to be considered.

Further studies are required to confirm our results. More specifically, we would be interested in a randomized trail comparing the results between partially threaded and fully threaded screws, focusing both on neurologic status and union rate after surgical fixation of zone 2 sacral fractures.

Conflicts of interest

None declared.

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