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Review Article

Posterior pelvic ring injury of straddle fractures: Incidence, fixation methods, and clinical outcomes

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ABSTRACT

Straddle fracture, a superior and inferior ramus fracture of both sides, is generally treated conservatively. However, posterior pelvic ring injury is often associated with straddle fracture, leading to unstable pelvic bone fracture that requires surgical treatment. The present study reports the clinical and radiological outcomes of straddle fracture with posterior pelvic ring injury.

This study included 73 patients (41 men, 32 women) with a straddle fracture injury. The injury mechanism, injury severity score (ISS), accompanying injuries, presence of posterior pelvic ring injury, and fixation methods for the pelvic fracture were analyzed, and outcomes were evaluated functionally and radiologically.

Of the 73 patients, 56 (77%) had a posterior pelvic ring injury and 7 died. In 43 patients, the posterior pelvic ring injuries constituted unstable pelvic injury and were treated surgically. The fixation method was determined based on the severity of the posterior pelvic injury. The patients' mean ISS was 24.7 points. Radiological evaluation of surgical outcomes in 43 patients revealed the outcomes as anatomic in 20, nearly anatomic in 14, moderate in 5, and poor in 4, whereas functional evaluation revealed the outcomes as excellent in 21, good in 9, fair in 7, and poor in 6.

Posterior pelvic ring fracture can accompany straddle fractures, which may lead to pelvic injury instability. Thus, special attention is required for patients with a straddle fracture.

1. Introduction

Pelvic fractures often cause severe bleeding and complications, both because the pelvis has a high-volume blood supply and because such fractures are often associated with injuries to the internal organs.[1,2] The most common cause of pelvic fractures is high-energy trauma, including traffic accidents and falls from a height. Previous studies have reported mortality rates of 8–19% due to severe intrapelvic bleeding or accompanying injuries and long-term complications, including gait disturbance, chronic pain, and arthritis.[3,4] In cases of unstable pelvic injuries, most patients present with both anterior and posterior pelvic ring injuries, which are associated with high mortality and morbidity.[5,6] Therefore, early fixation following injury is recommended, and clinicians should endeavor to minimize fracture complications using stable fixation techniques.[7]

Straddle fractures comprise bilateral fractures in the superior and inferior regions of the anterior pubis.[8] According to the Arbeitsgemeinschaft für Osteosynthesefragen - Orthopaedic Trauma Association classification used by many orthopedic specialists for fracture treatment and surgery, straddle fractures with an intact posterior pelvic ring are classified as 61A2.3.[9,10] The Tile system classifies fractures occurring at the arch of the anterior pelvic ring due to direct force as Type A2 and suggests conservative

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treatment in such cases.[11] However, in our own experience, straddle fractures often present a high incidence of posterior pelvic ring injury and accompanying injuries to the head, thorax, abdomen, and upper and lower extremities due to the injury dynamics. Moreover, genitourinary injuries to the bladder and urinary tract, which are located inside the pubis, are common and often require a multidisciplinary team approach.

Upon X-ray examination, a straddle fracture appears as a fracture of the anterior pubis bone. However, the incidence of accompanying posterior pelvic ring injuries and surgery requirements have not been reported. Therefore, this study aimed to identify the incidence of posterior pelvic ring injury in patients with straddle fracture, analyze fixation methods used for pelvic fractures, and investigate the clinical significance and importance of straddle fractures.

2. Methods

This study included 73 patients diagnosed with a straddle fracture who visited the level 1 trauma center between January 2014 and March 2017 and subsequently underwent treatment for the fracture. In addition, to qualify for inclusion, patients were required to attend follow-ups for >1 year. The study was approved by our institutional review board. Acute pelvic fracture was managed in accordance with the Advanced Trauma Life Support Guidelines.[12] The average age of the 73 patients (41 men, 32 women) was 47.4 years (range: 19–76 years). Young et al.'s classification was used to classify each fracture based on the mechanism of injury and to determine the treatment method.[13] Tile classification was applied to verify the presence of posterior pelvic ring injury.[11] Cases with accompanying sacrum fractures were subjected to the Denis classification, and the presence of sacroiliac joint dislocation was determined.[14] Depending on the method used to treat the sacral fracture and sacroiliac joint injury, posterior fixation was performed using either percutaneous sacroiliac cannulated screws or a sacroiliac plate penetrating the sacroiliac joint bilaterally via the posterior approach. Severity was evaluated using the injury severity score (ISS), and injuries associated with the pelvic fracture were also evaluated.

All patients with a straddle fracture underwent three-dimensional (3D) pelvic computed tomography (CT) and X-ray to identify the presence of posterior pelvic ring injury and to design an appropriate preoperative treatment plan. To this end, a 256-channel multi-detector CT (SOMATOM Definition Flash; Siemens, Berlin, Germany) was used to scan from the anterior superior iliac spine to the lesser trochanter, with a 2-mm slice thickness. A 3D bone model was then produced by reconstructing the axial, sagittal, and coronal two-dimensional CT images. Thereafter, the presence of pelvic bone fracture and degree of displacement were assessed and measured using a picture archiving communication system.[15,16]

In patients requiring fixation due to multiple accompanying injuries, hemodynamic instability, or displacement of ≥1 cm in the anteroposterior or longitudinal planes and those requiring surgery including pelvic packing due to active intrapelvic bleeding, the fracture was stabilized using temporary fixation via an external fixator in the anterior region. Plate fixation was then performed for the anterior pelvic ring; specifically, cannulated screws were used to fix the posterior pelvic ring after the patients' general condition had sufficiently improved. In patients with pelvic ring injury only and those whose general condition was not poor (lactate level <4 mmol/L, closed wound, ISS <15, and no active bleeding inside the pelvic cavity), the anterior pelvic ring was fixed using a plate and posterior pelvic ring was fixed using cannulated screws without temporary fixation using an external fixator. In patients presenting with bilateral sacroiliac joint and sacral dysmorphism, fixation was performed using a sacroiliac plate without cannulated screws in the posterior region. In patients with both straddle and posterior pelvic ring fractures presenting with a displacement of ≤1 cm, the intact leg was fixed under general anesthesia and a stress test was conducted to evaluate further displacement.[17] When a displacement of ≥2 cm was observed, the anterior region was fixed using a plate and posterior region using screws; in contrast, when the stress test did not result in further displacement, conservative treatment was provided. Patients with straddle fracture only also received conservative treatment (Fig. 1).

Patients were administered a thrombolytic agent to prevent thrombus formation after surgery and underwent treatment to alleviate their injury and improve their general condition. Patients were started on passive hip range-of-motion exercise 3 days after surgery, followed by and active hip exercises 10 days after surgery, except those who could not stand due to brain injury or accompanying trauma, in whom weight-bearing exercises were started using a crutch or walker. These were followed up periodically, and patients were subjected to bi-weekly radiography. Bony union was confirmed on X-ray, and full weight-bearing without a cane was encouraged from 12 weeks after surgery.

Radiological evaluation was performed based on Matta and Saucedo's method,[18–20] which defines cases of symmetrical pelvis with ≤4 mm sacroiliac joint displacement as anatomic, those with 4–10 mm displacement as nearly anatomic, those with 1–2 cm displacement as moderate, and those with ≥2 cm displacement as poor. Clinical evaluation of functional outcomes was performed using the Majeed pelvic score, which evaluates pain, work, sitting, sexual intercourse, walking aids, gait unaided, and walking distance in a comprehensive and systemic manner.[6,21,22] To this end, patients who had completed the follow-up period were contacted by phone or asked to visit the clinic to complete the Majeed pelvic score questionnaire.[6] They were then divided into two groups as working and not working before injury, and their functional outcome was scored out of 100 points (best score), graded as excellent (working >85, not working >70), good (working 70–84, not working 55–69), fair (working 55–69, not working 45–54), and poor (working <55, not working <45).

To analyze factors that may influence the functional outcomes, Fisher's exact test was used.[23] P-values <0.05 were considered statistically significant. Statistical Package for the Social Sciences (SPSS) version 18.0 (SPSS. Inc., Chicago, IL, USA) was used for the statistical analysis.

3. Results

3.1. Injury severity and demographics

Patients' mean ISS was 24.7 points (range: 4–59 points, standard deviation: 12.68 points). In total, seven patients died (9.59%). The injuries were caused by traffic accident in 47 cases (18 in-car, 29 pedestrian), falling from a height in 17, and direct blow by a heavy object in 9. Associated injuries comprised multiple fractures in other body parts in 47 cases, thoracic injury in 36, genitourinary injury in 17, abdominal organ injury in 42, and head injury in 25.

Complications occurring during treatment comprised respiratory disease such as pneumonia in seven cases, acute respiratory distress syndrome in two, deep vein thrombosis in five, pulmonary embolism in two, and sore coccyx in two. In addition, two cases of catheter-related bloodstream infections occurred. Causes of death were hypovolemic shock during the initial period of the hospital visit in three cases, disseminated intravascular coagulation in one, multiple organ failure in two, and sepsis in one case of extended hospitalization.

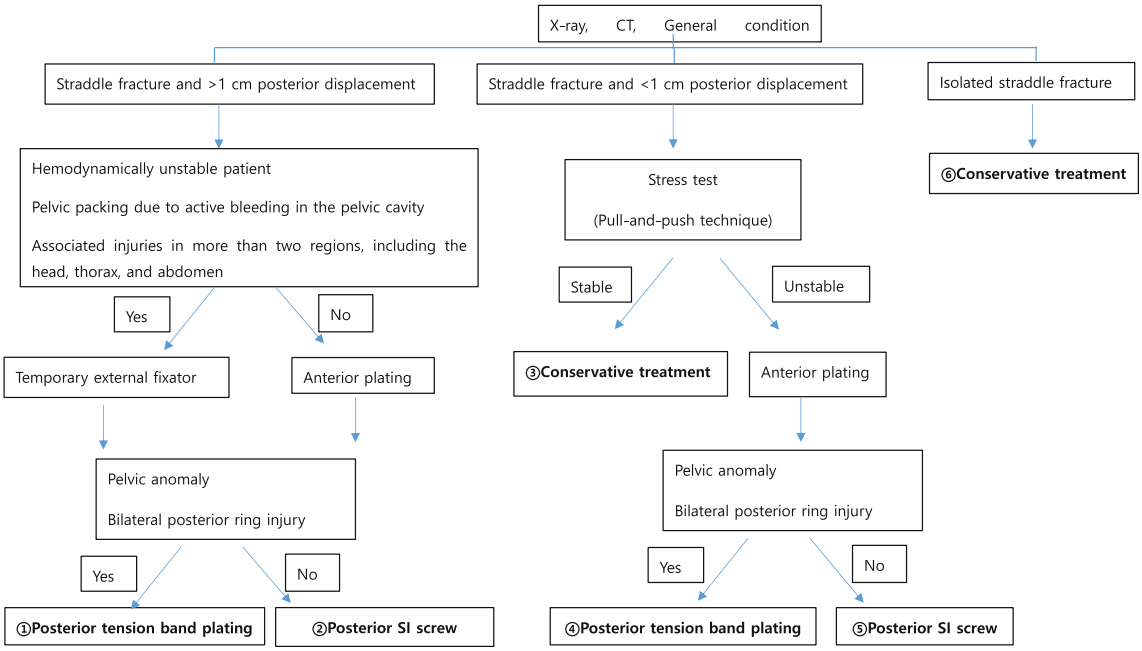

Fig. 1. Algorithm for treatment of straddle fractures.

3.2. Fracture classification

Of the 73 patients, 56 (76.7%) had either Tile classification type B or C (posterior pelvic ring injury); of these, 43 (76.8%) underwent fixation surgery. Sacral fracture occurred in 38 patients, and sacroiliac joint dislocation in 18 (Table 1).

3.3. Treatment outcome

3.3.1. (1) Straddle fracture posterior displacement ≥1 cm (27/66 cases; 40.9%)

Patients had simultaneous injuries in the anterior and posterior pelvic ring and unstable pelvic fractures and presented with a high ISS and associated injuries. Eight patients underwent anterior plate fixation and posterior percutaneous sacroiliac screw fixation upon recovery of their general condition after temporary fixation using an external fixator due to hemodynamic instability or active bleeding in the pelvic cavity. Four patients underwent posterior fixation without anterior plate fixation after external fixator removal because of concerns about infection during pelvic packing due to active bleeding in the pelvic cavity or during abdominal surgery due to injury to the abdominal organs. Fifteen patients underwent anterior plate and posterior fixation upon the recovery of their general condition, without an external fixator (Fig. 2). In these patients, the posterior fixation method comprised percutaneous iliosacral screw fixation in 20 cases and sacroiliac plate fixation via the conventional method in 7 cases of bilateral posterior injury or sacral dysmorphism (Table 2).[24]

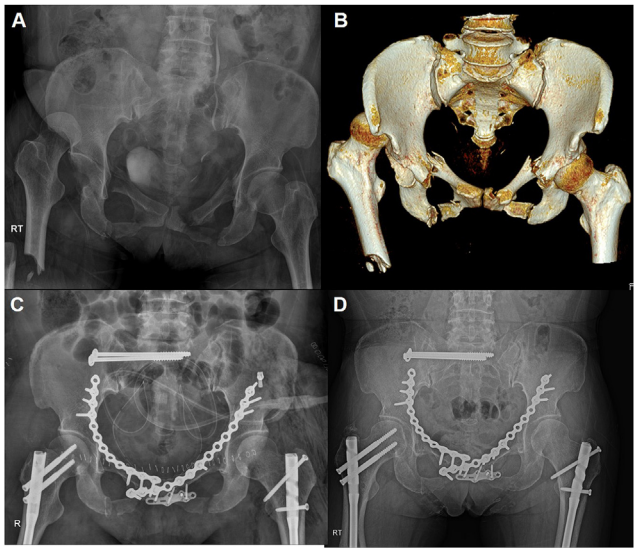

Fig. 2. (A, B) X-ray and computed tomography images of a 50-year-old woman who sustained a direct hit by a heavy object and presented with a lateral compression, type III pelvic fracture combined with dislocation of the right sacroiliac joint and straddle fracture. Associated injuries included posterior dislocation of the right hip joint and bilateral fracture of the femoral shaft. (C) To treat the injury, temporal fixation of the symphysis pubic region was performed using a 2.7-mm miniplate, and a 3.5-mm pelvic recon plate fixation was then bilaterally performed using the modified Stoppa approach. The posterior pelvic ring was stabilized by percutaneous insertion of a 7.0-mm cannulated screw. (D) After 1 year, anatomic bony union was achieved and the functional score was "good.

Table 1
Fracture classification of pelvic ring injuries associated with a straddle fracture (N = 73).

Young and Burgess classification, n		Tile classification, n		Denis classification, n	
Lateral compression	39	Type A	17	Zone 1	10
Anteroposterior compression	19	Type B	41	Zone II	25
Vertical shearing	15	Type C	15	Zone III	3
Combined mechanical injury	0			Sacroiliac joint dislocation	18

Table 2
Outcomes of treatment algorithm for straddle fractures.

Fracture type	Treatment methods	Number of patients (N = 66)	Functional outcome	Radiological outcomes
Straddle fracture and ≥1 cm posterior displacement	① Anterior fixation + posterior TBP	7	E: 2, G: 1, F: 2, P: 2	A: 2, NA: 3, M: 1, P: 1
	② Anterior fixation + posterior SIS	20	E: 13, G: 3, F: 2, P: 2	A: 10, NA: 6, M: 3, P: 1
Straddle fracture and <1 cm posterior displacement	③ Conservative treatment	7	E: 2, G: 2, F: 2, P: 1:	A: 0, NA: 3, M: 3, P: 1
	④ Anterior plating + posterior TBP	3	E: 0, G: 2, F: 1, P: 0	A: 2, NA: 1, M: 0, P: 0
	⑤ Anterior plating + posterior SIS	13	E: 6, G: 3, F: 2, P: 2	A: 6, NA: 4, M: 1, P: 2
Isolated straddle fracture	⑥ Conservative treatment	16	E: 8, G: 6, F: 2, P: 0	A: 9, NA: 2, M: 5, P: 0

Treatment methods –TBP: tension band plate; SIS: sacroiliac screw; Functional outcomes – E: excellent, G: good, F: Fair; P: poor.
Radiological outcomes – A: anatomic, NA: nearly anatomic, M: moderate, P: poor.

3.3.2. (2) Straddle fracture with posterior displacement <1 cm (23/66 cases; 34.8%)

A further displacement of >2 cm was caused by the stress test in 16 of the 23 cases tested, whereas the remaining 7 presented no significant change. Further displacement was more common in patients with anteroposterior compression (APC) than in those with lateral compression (LC). Cases showing further displacement were considered to have unstable pelvic injuries and treated with both anterior and posterior fixation (Fig. 3). In most cases, sacroiliac screws were used for posterior fixation, whereas a sacroiliac plate was used in three cases due to the presence of a bilateral posterior injury or sacral dysmorphism. A single cannulated screw was used in most cases, whereas two screws were inserted in cases of severe instability.

3.3.3. (3) Isolated straddle fracture (16/66 cases; 24.2%)

Sixteen patients underwent conservative treatment as they presented with anterior straddle fracture only. They underwent periodic radiography and a 3-week bed rest period and subsequently permitted to begin partial weight-bearing exercises after callus formation. Non-union of the pubis was observed in two cases on the final follow-up radiographs.

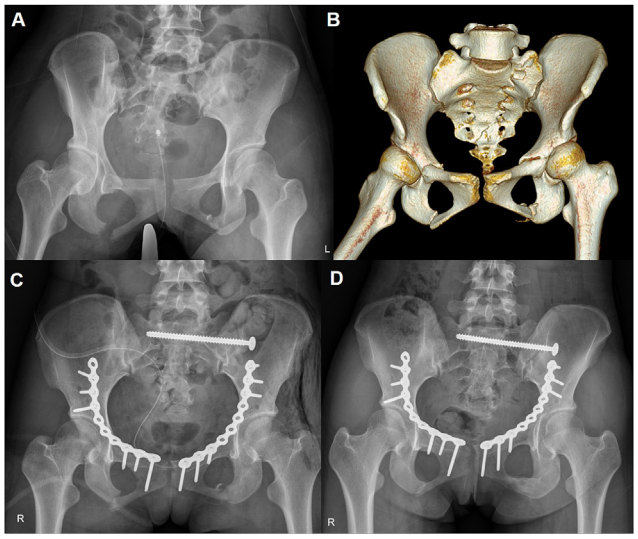

Fig. 3. (A, B) X-ray and computed tomography scan images of a 21-year-old woman who jumped from the third floor, with suicidal intent. She presented with a straddle fracture and Denis Type II sacral fracture. (C) The anterior pelvic ring was stabilized using bilateral 3.5-mm pelvic recon plates via the modified Stoppa approach. The posterior pelvic ring was stabilized by percutaneous insertion of a 7.0-mm cannulated screw. (D) After 1 year, anatomic bony union was achieved and the functional score was "excellent."

4. Complications

Among 66 of the 73 surviving patients, 5 had non-union and 2 displayed sacroiliac joint separation. Three cases of non-union occurred in the anterior pubis; these patients received conservative treatment as the non-union caused no discomfort or gait disturbances. However, two cases of non-union occurred at the site of the crescent fracture; both comprised an iliac wing fracture with extension into the sacroiliac joint and sacroiliac joint separation. In patients whose condition was poor after external fixator removal, only screw fixation was performed, and sacroiliac joint separation occurred when the screws loosened. When pain in the pelvic region was accompanied by separation, a bone graft and sacroiliac plate fixation were performed (Figs. 4 and 5). Screw loosening occurred in seven cases (five involving sacroiliac screws and two, anterior plating), plate breakage occurred in two, superficial wound infection in four, and deep wound infection in two. In five of the seven cases of screw loosening, no clinical symptoms occurred, and patients required no surgical treatment, whereas in the remaining two cases, instability of the sacroiliac joint and consequent pain were observed; therefore, the fixation method was changed to posterior sacroiliac plating. Both cases of plate breakage occurred in the anterior pelvic ring, and no further management was required as both were asymptomatic. Massive debridement and irrigation, without plate removal, healed the deep wound infection observed in two cases. However, patients presented with gait disturbances due to pain in the pelvic region after surgery for infection.

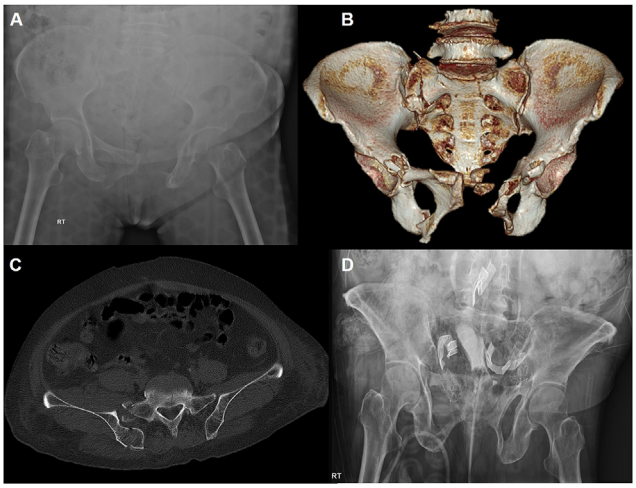

Fig. 4. (A) X-ray image of a 73-year-old woman who was crushed between a reversing car and a wall. (B, C) She presented with anteroposterior compression, type III pelvic fracture, a Denis type I sacral fracture and sacroiliac joint dislocation, and a crescent fracture at the CT scan. (D) Pelvic packing was performed to treat active bleeding within the pelvic cavity.

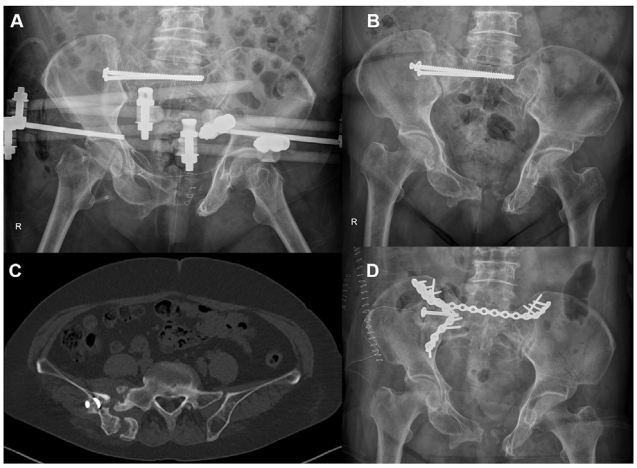

Fig. 5. (A) A supra-acetabular external fixator was inserted to stabilize the woman's anterior pelvic ring, and two 7.0-mm cannulated screws were inserted percutaneously to stabilize the right sacroiliac joint. (B, C) The external fixator was removed after 6 weeks. Six months later, screw loosening and non-union of the sacral and crescent fractures are shown on radiography. (D) Bone graft and plate fixation of the sacroiliac joint were performed. Bony union was achieved, but the functional score was merely "fair."

5. Factors influencing functional score

Statistical tests were performed to analyze five factors that can affect the Majeed scores measured a year after injury, namely, ISS, fracture type, fixation method, radiological outcomes, and complications (Tables 2–4).

Preoperative ISS and fracture type had no significant influence on the postoperative functional score; however, functional scores of fair and poor were achieved more frequently in APC than in LC ($P = 0.094$ and 0.091, respectively, Table 3). In addition, the fixation method did not significantly influence the postoperative functional score ($P = 0.081$, Table 2). However, patients who underwent sacroiliac plate fixation complained more about pain in the pelvic bone than those who underwent sacroiliac screw fixation. This pain was probably due to bilateral sacral injury, irritation because the plate was located in the posterior side of the sacrum, or bilateral SI joint fixation. Analysis of the level of fracture reduction revealed that patients evaluated as "anatomic" or "nearly anatomic" on radiological assessment achieved "excellent" or "good" clinical outcomes, whereas those classified as "poor" on the radiological assessment achieved unsatisfactory clinical outcomes ($p < 0.001$, Table 4). In addition, functional scores of patients with more complications, especially those with infection, were "fair" or lower ($p = 0.029$).

6. Discussion

A straddle fracture is not a simple bilateral fracture of the anterior pubis. In this study, the incidence of associated injuries to the head, thorax, and abdomen in addition to pelvic fracture was 75.3%, while that of consequent mortality was 9.6%. Bilateral anterior pubic bone fractures that occur due to high-energy injury are frequently associated with genitourinary injuries, including rupture of the urethra and bladder, which are intrapelvic organs, whereas single and ipsilateral ramus fractures are not associated with such complications.[25] In addition, energy transferred to the surrounding organs caused unstable pelvic fractures and associated injuries in the thoracic and abdominal regions; therefore, hospitalization duration was extended in such cases, and complications occurred more frequently.[26] In this study, the posterior pelvic ring injury associated with sacral fracture and sacroiliac joint dislocation was 76.7%, with 76.8% of those requiring surgery.

Dunn and Morris first used the term "straddle fracture" in 1968,[27] describing a comminuted fracture of the "tie arch." They reported that this was the most common type of unstable fracture pattern. They classified all investigated unstable fractures as straddle, vertical shear, pelvic dislocation, lateral compression, bucket-handle, and total disruption, thereby using descriptions that would not be considered systematic today. In a cadaveric study by Bucholz, straddle fractures were frequently found in patients with multiple injuries who sustained relevant accompanying injuries.[28] Upon dissection, the vast majority of cadavers with straddle fractures in that study had posterior involvement of the pelvic ring. Kanakaris et al. reported that the mortality rate of patients with straddle fractures was 6.5%; multiple concurrent injuries to the head, thorax, and abdomen commonly occurred, so prompt referrals and comprehensive multidisciplinary treatment involving both neurosurgeons and general surgeons were required.[29]

Straddle fractures occurred more often in APC than in LC. In APC, direct impact on the anterior side causes diastasis rather than ramus fracture by transferring energy to the symphysis pubis; this causes injury to the sacrum or sacroiliac joint. In LC, the impact from the lateral side causes direct injury to the ramus and sacroiliac joint, and energy transferred to the ramus in the opposite side is believed to cause the fracture. However, mortality and morbidity rates are higher and more stable fixation is required for APC-type straddle fractures than for the LC-type; moreover, extremely unstable pelvic fractures and associated genitourinary injuries are common in patients with APC-type straddle fractures. Unstable fractures are caused by intense energy delivery to the symphysis pubis and ramus or by a blunt object applying direct impact on both regions.[30]

Pelvic instability following fracture onset is assessed based on displacement degree. When the displacement is < 1 cm, the posterior skeleton-ligament complex is generally considered intact; most such cases do not create deformation or disability in follow-up observations.[31,32] However, cases with greater displacement due to fractures in the sacroiliac joint, sacrum, or ilium have a high crucial disability potential. Therefore, surgical treatment should be considered when a displacement of >1 cm presents on the anteroposterior or longitudinal plane of the pelvis, a clinically obvious

Table 3
Functional outcome (N = 66) according to patients' Injury Severity Score and fracture type.

		Injury Severity Score (ISS)		Tile classification			Young and Burgess classification		
		ISS <15	ISS≥15	Type A	Type B	Type C	LC	APC	VS
Functional outcome	Excellent (31)	17	14	8	22	1	25	5	1
	Good (17)	10	7	5	8	4	7	5	5
	Fair (11)	5	6	2	5	4	5	3	3
	Poor (7)	3	4	1	3	3	1	2	4

LC: Lateral compression, APC: anteroposterior compression, VS: Vertical shearing.

Table 4
Functional outcome (N = 66) according to postoperative radiological outcomes and presence of complications.

		Radiologic outcome				Complication	
		Anatomic	Nearly anatomic	Moderate	Poor	No	Yes
Functional outcome	Excellent (31)	23	8	0	0	28	3
	Good (17)	6	10	1	0	10	7
	Fair (11)	0	1	8	2	6	5
	Poor (7)	0	0	4	3	2	5

rotational deformation is observed, or a shearing force leaves a large gap in the cancellous bone.

Both plate fixation of the sacroiliac joint through a posterior approach and percutaneous iliosacral screw fixation are used to fix the posterior pelvic ring. Percutaneous iliosacral screw fixation is minimally invasive and causes less bleeding and infection than plate fixation, but both methods yield comparable biomechanical outcomes.[33–35] Therefore, percutaneous iliosacral screw fixation was chosen in this study, and plate fixation of the sacroiliac joint was only conducted in cases presenting with pelvic anomaly or bilateral injury of the posterior pelvic ring. The sacroiliac joint can also be accessed through the anterior approach; however, this was not attempted due to the narrow field of vision and proximity of the lumbar 5th nerve root to the surgical field.[36,37]

In unstable pelvic ring injuries, the anterior pelvic ring can be fixed using an external fixator or an anterior plate. In this study, we used the external fixator only in cases of hemodynamic instability or when there was infection risk in the pelvic cavity due to pelvic packing or abdominal surgery. This was because anterior plates are functionally and radiologically superior to external fixators and present higher patient compliance.[25,38] In addition, the minimally invasive method using intramedullary screws to fix the superior ramus is also often considered; however, this approach was not used because such screws cause frequent reduction loss in elderly women and yield poorer biodynamic outcomes than anterior plates.[39,40]

Good radiological and functional outcomes can be achieved by treating posterior pelvic ring injury associated with straddle fracture according to the classification method proposed in this study. This method is based on both patient's general condition and type of pelvic bone fracture. Such good outcomes were likely achieved because we did not consider the straddle fracture as a simple fracture of the anterior arch but rather as a fracture that can easily cause injuries to the posterior pelvic ring, as energy delivered to the ilium can affect the bones and ligaments of the posterior pelvic ring.

Our study had several limitations. First, a relatively small number of patients were enrolled because only those with straddle fractures were evaluated; there was no control group, and patient compliance was not considered. Second, the relatively short follow-up period may have limited our evaluation of clinical outcomes, including late complications of pelvic fracture such as traumatic arthritis that can occur due to unstable fractures. Nonetheless, we believe that our findings provide sufficient evidence to support the effectiveness of the fixation method considering that severe complications occur during the early stages of a general pelvic fracture. This retrospective study investigated the effectiveness of the fixation method for straddle fractures based on clinical and radiological outcomes. Future prospective and biomechanical studies should be performed to verify our results.

7. Conclusions

Straddle fractures are not simple fractures limited to the anterior pelvic ring but are associated with posterior pelvic ring injuries in 77% of all cases. Due to unstable pelvic fractures caused by posterior pelvic ring injuries, many patients require surgical treatment and experience associated injuries. For surgical fixation, plate fixation of the anterior pelvic ring and percutaneous sacroiliac screw fixation of the posterior pelvic ring were performed and clinically and radiologically satisfying outcomes were achieved. As such, straddle fractures provide important clues about unstable pelvic bone fractures; therefore, careful examination and treatment are needed.

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Declaration of competing interest

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