Original Contribution

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Surgical Treatment of Vertically Unstable Sacral Fractures Using a New Plate

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Summary: Eighteen patients with vertically unstable sacral fractures in type C of AO classification, who underwent open reduction and internal fixation, were investigated. Vertically unstable sacral fractures were fixed using a M-Shaped Pelvic Plate prepared by the author with posterior longitudinal incision. The postoperative results were determined by Majeed's functional evaluation and radiography. Excellent in 12 and good in 3. Poor cases were infection and sciatic nerve paralysis. M transiliac plate fixation was achieved by rigid fixation with less invasion for vertically unstable sacral fractures.

Key words unstable pelvic ring fractures, sacral fractures, transiliac plate, iliosacral screw

INTRODUCTION

In pelvic ring fractures caused by high energy trauma, initial pelvic stabilization and subsequent rapid mobilization of the patient, lead to recovery of function and improved prognosis. In addition, vertically unstable pelvic ring fractures, in which the instability is associated with disruption of the posterior osseous ligamentous structure essential to pelvis stability, require posterior anatomic reduction and rigid fixation. Although iliac fractures or sacroiliac joint fractures and dislocations have been successfully fixed via an anterior-approach plate fixation or a percutaneous iliosacral screw fixation, methods for consistently successful fixation of sacral fractures remain unavailable. We have devised a method for fixation of vertically unstable sacral fractures, which involves a posterior longitudinal incision using a newly developed plate. This paper describes a retrospective review of the plate in terms of dynamic analysis, surgical approach and clinical experience.

MATERIALS AND METHODS

Sacral fractures

The posterior osseous ligamentous structures consisting of the sacrum and the posterior ligament groups are important structures of the pelvic ring, and can be compared to a suspension or stone bridge, in which the sacrum plays a particularly pivotal role as a keystone. The lumbar sacral venous plexus and nerve plexus lie anterior to the sacrum, while the paravertebral muscle lies posterior. Sacral fractures have been conventionally fixed using iliosacral screws or sacral bars. However, adequate fixation is impossible for cases involving residual deformity, crushed sacral foramina or lateral iliac fractures, because of the danger of nerve compression due to over-tight fixation. Hence, plate fixation is not feasible in such cases. In addition, the difficulty associated with exposing and fixing through the anterior pelvic cavity requires that posterior exposure and fixation are performed, but the foramina and the thin and narrow cortex present on the posterior sacral surface make it difficult to

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secure an adequate site for fixation.

Internal fixation material

We have devised the so-called M-transiliac plate fixation method, using a new plate developed by combining a transiliac plate and an iliosacral screw. This allows fixation such that the sacrum is sandwiched between the bilateral ilium without requiring direct exposure of the sacral fracture. The initial attempt to use this technique involved bending a 4.5-mm thick reconstruction plate to adjust it to the pelvic shape during surgery. Bending of the plate, however, required time and reduced its strength. Hence, by measuring the widths, lengths and angles of the axial sections of the posterior superior iliac spine, obtained from pelvic CT in control cases, a standard M-shaped titanium plate, the M-Shaped Pelvic Plate (BEST MEDICAL, Tokyo, Japan) was created. Plates were analyzed for strength with a computer-assisted finite element method. A Von Mises stress presentation, in which light colors represent weak regions, showed the greater strength of the M-Shaped Pelvic Plate compared with 4.5 mm thick reconstruction plate (Fig. 1).

Surgical methods

It is desirable that surgery should be preceded by traction to ensure adequate reduction. In a prone position, an approximately 5-cm longitudinal incision is made on the skin just above the bilateral posterior superior iliac spine to expose the iliac spines. If the incision reveals inadequate reduction, a Shanz screw is inserted into the same site for manipulation of reduction. The bilateral part of the iliac spine is periosteally avulsed to create a 1.5 cm×1.5 cm bone groove. The paravertebral muscle is avulsed from the posterior surface of the first sacral vertebra, and the spinal process is osteotomized to create a tunnel connecting the bilateral posterior superior iliac spines. The plate is inserted through under the paravertebral muscle and rotated 180° to fit in the bone groove on the posterior superior iliac spines. A cancellous bone screw 40 to 50 mm in length and 6.5 mm in diameter is inserted through a screw hole on the bone groove plate toward the greater sciatic notch (parallel to the lateral bone cortex, cephalically tilted by approx. 20°). The lateral ilium of the unaffected side is fixed by inserting two 20 to 30 mm long cortical bone screws through screw holes on the plate, and the affected side is fixed by inserting 20 mm long and 30 to 60 mm long cortical bone screws until they reach the lateral part of sacrum, under fluoroscopic control. Thus, the M-Shaped Pelvic Plate, which is anatomically designed, allows reduction and fixation of

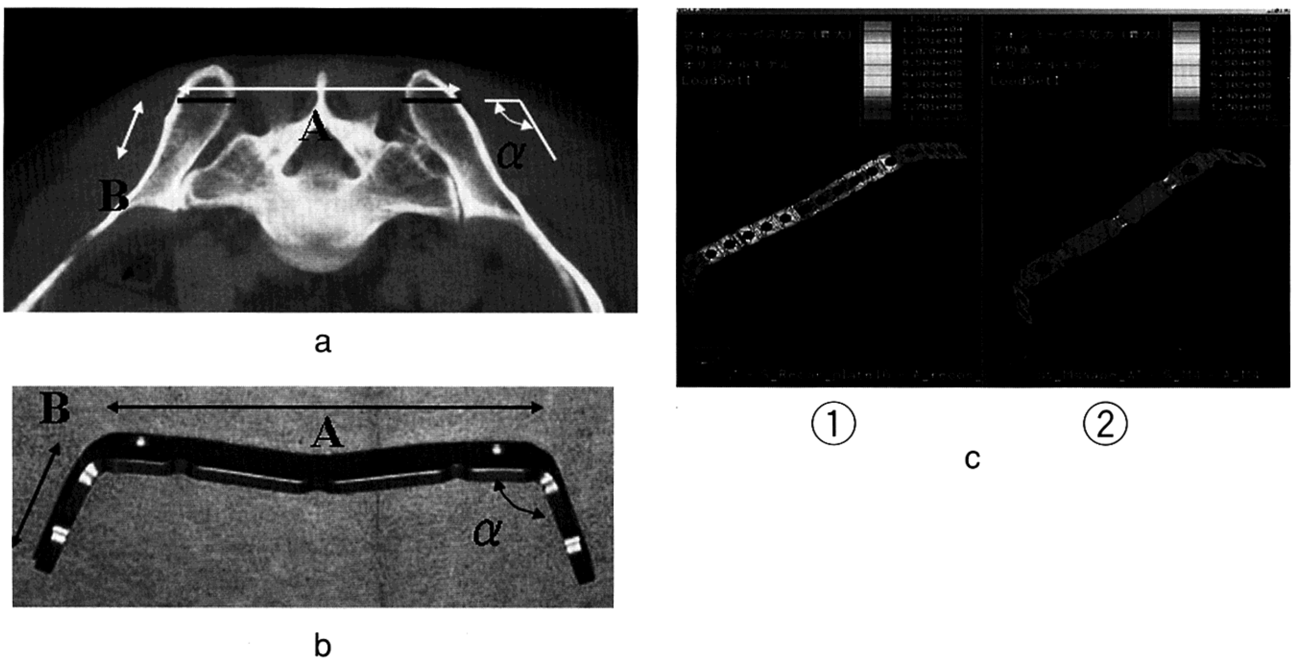


Fig. 1. a. Measured for axial section of S 1 level of normal pelvic CT. b. M-Shaped Pelvic Plate is produced from titanium. c. Comparison of both plate. ① 4.5 mm reconstruction plate ② M-Shaped Pelvic Plate (Von Mises method)

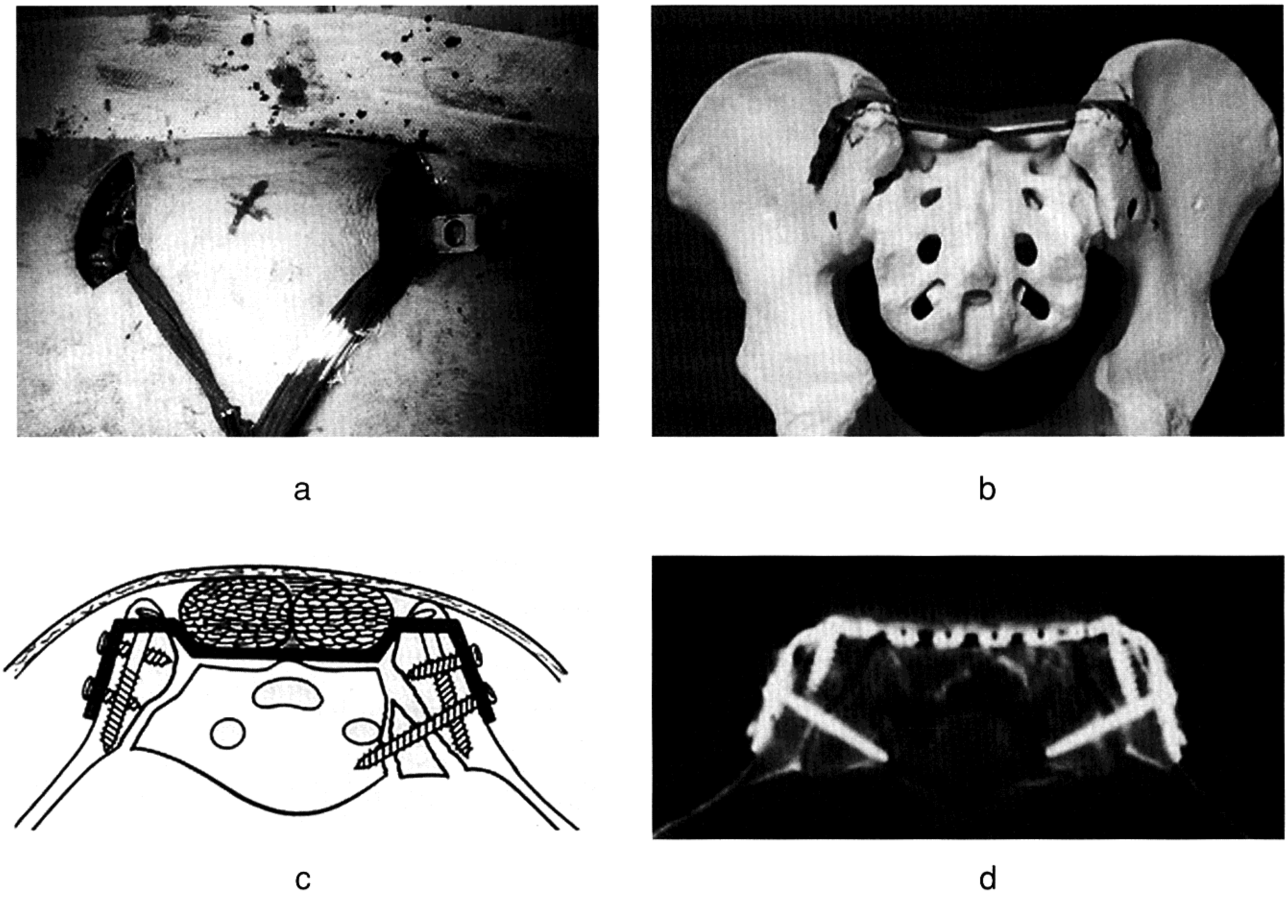


Fig. 2. a. Bilateral longitudinal skin incision were made just above posterior superior iliac spines (PSIS), and plate was through under the paravertebral muscles. b. M-Shaped Pelvic Plate on plastic bone. c. Fixation schema d. Postoperative CT of after fixation.

dislocation when fitted in the bilateral iliac spine grooves and fixed with screws inserted through the lateral ilium (Fig. 2).

Clinical materials

Of 35 patients with vertically unstable pelvic ring fractures, designated Type C under the AO classification [1] (Fig. 3), who were treated at our institution between October 1998 and June 2003, 18 patients with sacral fractures were included in the study. The study population consisted of 5 males and 13 females, with an age range of 23 to 75 years and a mean age of 49.8 years. The cause of injury was a traffic accident for 10 patients, a pincer attack for 4 patients and a fall for 4 patients. The patients were followed up for periods ranging from 10 months to 4 years, and the mean follow-up period was 20 months. Vertically unstable sacral fractures caused by high energy injury were complicated by additional injuries: 9 cases of lower extremity fractures, 5 cases of upper extremity fractures, 6 cases of thoracic and abdominal injuries, 3 cases of urinary tract injuries, 3 cases of sciatic nerve palsy and 3 cases of Morel-Lavallee lesion [2], a degloving injury in the subcutaneous tissue of the greater trochanter or sacral region. Unstable fractures were most commonly Type C1-3 unilateral complete type fractures, which were observed in 12 cases. There were also 4 cases of Type C2-3 contralateral incomplete type fractures, and 2 cases of Type C3-3 bilateral complete type fractures. Sacral fractures were classified under the Denis et al. [3] classification into Zone I, Zone II and Zone III in 6 cases, 13 cases and 1 case, respectively, with 3 of the Zone II cases complicated with sciatic nerve palsy (Fig. 4). The scoring system of Majeed [4] functional evaluation (Table 1) was used to clinical outcome at the time of the final follow-up. The mean clinical and radiographic evaluations were ana-

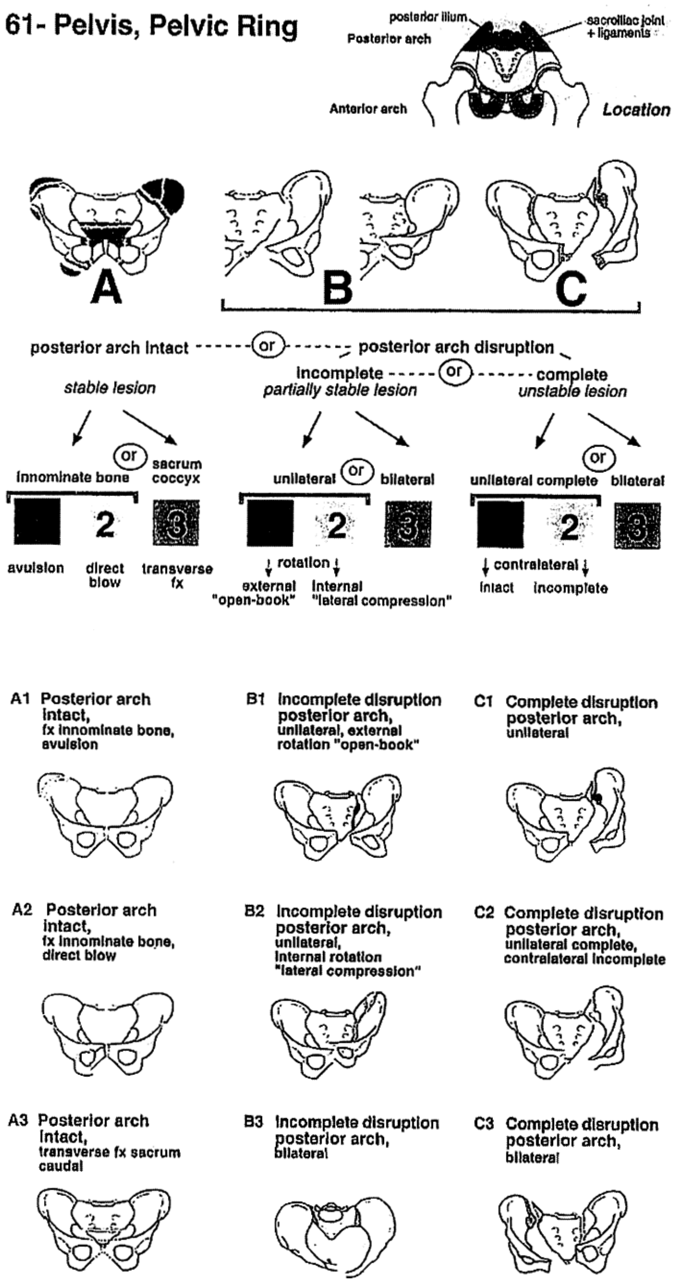
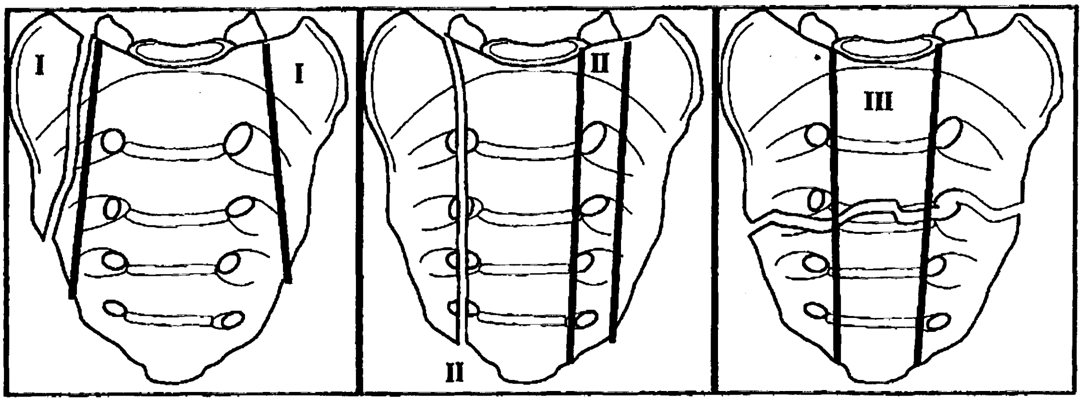


Fig. 3. Comprehensive classification of Fractures according to the AO/ASIF classification Guideline by Muller M.E.

lyzed with use of the two-tailed Student t test. The level of significance was $p<0.05$.

RESULTS

Surgery was performed from 4 to 24 days after injury (mean: 10 days), and surgical times ranged from 55 to 135 min (mean: 92.7 min), with intraoperative blood loss of 120 to 1120 g (mean: 428.3g). The postoperative protocol was designed on the assumption that the patients could change their posture and assume a sitting position from the day after the operation, use a wheel chair and walk without weight bearing 1 week after the operation, and walk with weight bearing 3 to 4 weeks after the operation. However, the reality was that even patients with only pelvic fractures could not rise and walk until a mean of 16 days postoperatively, which



Zone I transalar fractures | **Zone II** transforaminal fractures | **Zone III** central fractures

Fig. 4. Classification of sacrum fractures according to Denis et al. The sacrum is divided into three anatomic regions. The most medial zone crossed by a fracture line defines the classification.

TABLE 1.
Functional evaluation by S. A. Majeed

Pain - 30 points		Standing - 36 points	
Intense, continuous at rest	0-5	*A Walking aids (12)*	
Intense with activity	10		
Tolerable but limits activity	15	Bedridden or almost	0-2
With moderate activity, abolished by rest	20	Wheelchair	4
Mild, intermittent, normal activity	25	Two crutches	6
Slight, occasional or no pain	30	Two sticks	8
		One stick	10
Work - 20 points		No sticks	12
No regular work	0-4	*B Gait unaided (12)*	
Light work	8		
Change of job	12	Cannot walk or almost	0-2
Same job, reduced performance	16	Shuffling small steps	4
Same job, same performance	20	Gross limp	6
		Moderate limp	8
Sitting - 10 points		Slight limp	10
		Normal	12
Painful	0-4		
Painful if prolonged or awkward	6	*C Walking distance (12)*	
Uncomfortable	8		
Free	10	Bedridden or few metres	0-2
		Very limited time and distance	4
Sexual intercourse - 4 points			
		Limited with sticks, difficult without	6
Painful	0-1	prolonged standing possible	8
Painful if prolonged or awkward	2	One hour with a stick limited without	10
Uncomfortable	3	One hour without sticks slight pain or limp	12
Free	4	Normal for age and general condition	

Grade	Excellent	Good	Fair	Poor
Working before Injury	>85	84-70	69-55	<55
Non working before injury	>70	69-55	54-45	<45

was further delayed to 20 to 24 days, far behind the anticipated schedule, in patients with complications of the upper or lower extremity or with abdominal/thoracic injuries.

Clinical outcome was favorable in 15 of the 18 patients (83.3%), being rated "excellent" in 12 patients and "good" in 3 patients, according to the Majeed [4] functional evaluation. The three other patients had complications of sciatic nerve palsy and/or infection, and were rated "fair" or "poor". Postoperative complications were delayed wound-healing in 3 patients, infection in 2 patients and mistaken screw insertion in 1 patient. When assessed based on preoperative complications, the most successful outcome (mean score 95.5 points) was obtained for pelvic fracture without associated injuries cases, whilst the least successful (mean score 69 points) occurred for sciatic nerve palsy-complicated cases. A significant difference was observed between these two patient populations (Fig. 5). Radiography revealed 6 cases of residual deformity of 1 cm or more, but no significant difference in outcome was observed between patients with and without dislocation, which was attributable to rigid fixation that was not susceptible to residual deformity (Fig. 6).

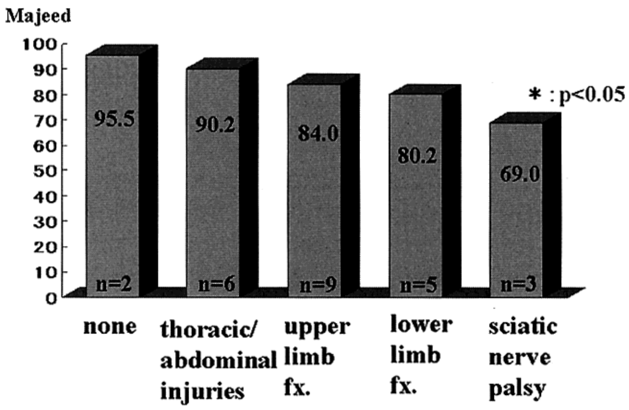


Fig. 5. Outcome was best for pelvic fracture without associated injuries cases, and worst for sciatic nerve palsy-complicated cases, significant difference being observed only between these cases.

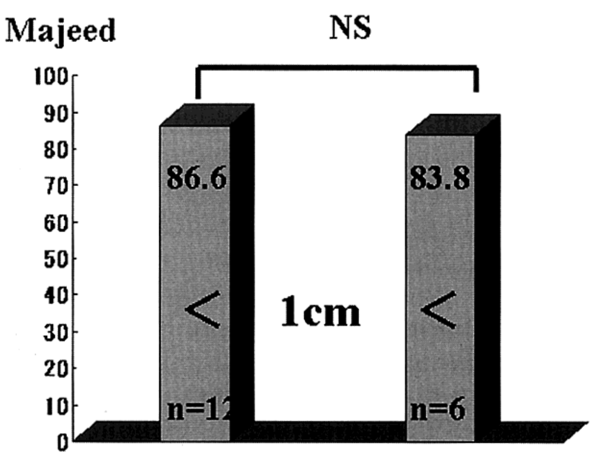


Fig. 6. There was no significant difference in outcome between presence and absence of dislocation according to radiographic evaluation.

CASE EXAMPLES

Case 1

A 66-year-old female was involved in a motor vehicle accident. The patient had a bilateral sacral Zone II fracture Type C3-3, complicated with radius and ulna fracture but not with sciatic nerve palsy. Six days after occurrence, the fracture was subjected to reduction/fixation using a 4.5-mm reconstruction plate via a posterior longitudinal incision. The operation was completed after 90 min, with intraoperative blood loss of 400 g. The patient started gait training 4 weeks postoperatively and returned to housework 6 months postoperatively. This case was rated with a Majeed score of 100 point (Fig. 7).

Case 2

A 42-year-old female was involved in a motor vehicle accident. The patient had a sacral Zone II fracture Type C1-3, complicated with a left humerus fracture and a left tibia fracture but not with sciatic nerve palsy. Seven days after occurrence, the fracture was subjected to reduction/fixation using an M-Shaped Pelvic Plate via the posterior approach. The operation was completed after 90 min, with intra-operative blood loss of 120 g. Following the operation, however, left sciatic nerve palsy occurred, which was attributed by CT to the screw penetrating a foramen. The screw was immediately re-inserted, and the symptoms were improved. The patient returned to office work 4 months postoperatively. As of 1 year postoperatively, this case was rated with a Majeed score of 100 point (Fig. 8).

Case 3

A 25-year-old female was injured during a jump from the 4th floor of a building. The patient had a sacral Zone II fracture Type C1-3, complicated with

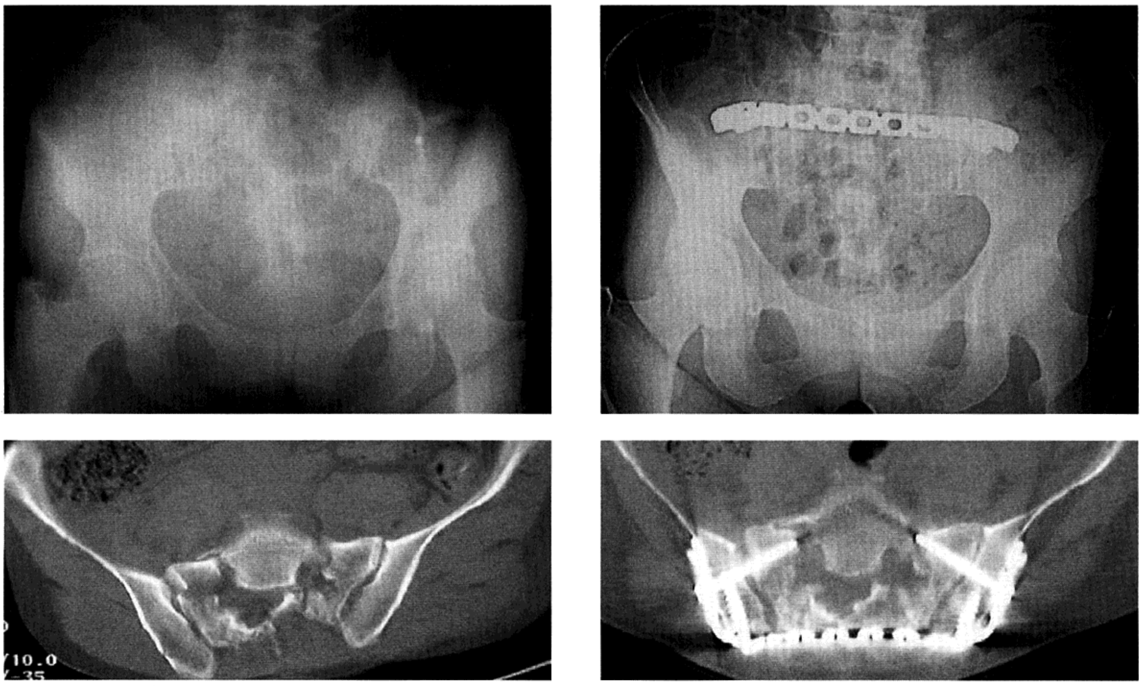


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Fig. 7. a. Preoperative AP radiography and CT, sustained bilateral Zone II sacral fractures. b. Postoperative AP radiography and CT, demonstrates use of the 4.5 mm reconstruction trasiliac plate.

clavicular fracture, ankle fracture-dislocation and calcaneal fracture but not with sciatic nerve palsy. Seven days after occurrence, the fracture was subjected to reduction/fixation using an M-Shaped Pelvic Plate via a posterior longitudinal incision. Due to fractures of both lower extremities, she started gait training with weight bearing 6 weeks postoperatively, and was discharged with independent gait at 12 weeks. As of 10 months postoperatively, this case was rated with a Majeed score of 93 point (Fig. 9).

DISCUSSION

There is wide agreement that in conventional treatment for vertically unstable pelvic ring fractures, external fixation fails to provide the posterior substructure with stability. The clinical outcome of cases treated by traction and external fixation, was rated "good" in 4 patients (57.1%), and "fair" or "poor" in 3 patients (42.9%), according to the Majeed [4] functional evaluation, and pain remained in 75% of patients, as reported by Dujardin et al [5]. After open reduction of a vertically unstable sacral fracture using iliosacral screws, sacral bars or plate-assisted tension band fixation, pain persisted in 55% of patients, as reported by Tornetta et al [6], and in 70% of patients with residual deformity of 1 cm or more, according to Mclaren et al. [7], suggesting a problem with conventional methods for reduction and fixation of sacral fractures. Plate fixation from the posterior sacrum, as attempted by Mears et al. [8] using a double Cobra plate, has not come into widespread use due to its extensively invasive nature. Regarding the strength of various methods for fixation of sacral fractures, Simonian et al. [9] have reported that the combination of a reconstruction plate and an iliosacral screw can provide the most rigid fixation, although there is no substantial difference among fixation methods. This, however, applies only to cases where reduction has been anatomically performed with optimal screw insertion. In performing iliosacral screw insertion, it is extremely difficult to reach the optimal site of the sacrum, and Routt et al [10] have reported that, despite the transdermal and minimally invasive nature of the procedure, the likelihood of erroneous insertion is around 10%, and caution should be taken due to this difficulty. Recent reports have presented accurate insertion methods

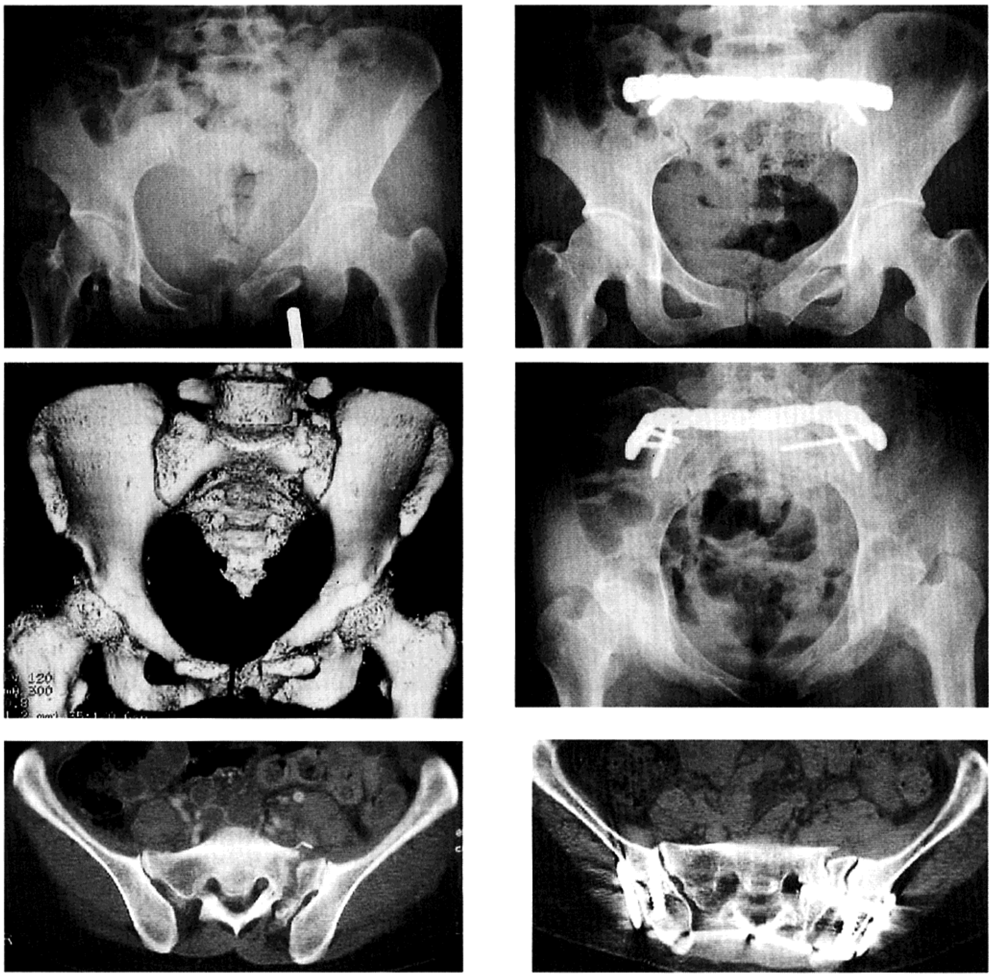

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Fig. 8. a. Preoperative AP radiography and 3D-CT, CT, sustained a Zone I sacral fracture. b. Postoperative AP and inlet radiographs and CT, fixed by M-Shaped Pelvic Plate.

using CT or a navigation system [11,12]. Nevertheless, in cases of Zone II fractures, in which it is difficult to obtain rigid fixation, anterior fixation may be additionally required, or overtight fixation may compress foramina, causing the complication of nerve palsy. Posterior fixation is associated with such problems as infection or delayed wound-healing, as we experienced, consistent with the cases reported by Kellam et al. [13], 25% of which were complicated with infections. This warrants special caution regarding complications of soft tissue injuries, such as a Morel-Lavallee lesion [2]. In addition, neurological complications were associated with poor outcome in our cases, as also pointed out by Pohlemann et al. [14] and Tornetta et al. [6].

The M-Shaped Pelvic Plate that we have developed is inserted under the paravertebral muscle via a 5-cm long posterior longitudinal incision, causing only minor invasion. The plate, which is anatomically designed, allows accurate reduction and rigid fixation by simple tightening of a 6.5-mm cancellous bone screw inserted toward the greater sciatic notch, the thickest and most solid pelvic region, and cortical bone screws are laterally inserted toward the body of the first sacral vertebra. This study suggests that the M-transiliac plate fixation method using the M-Shaped Pelvic Plate may offer an extremely effective treatment modality for vertically unstable sacral fractures.

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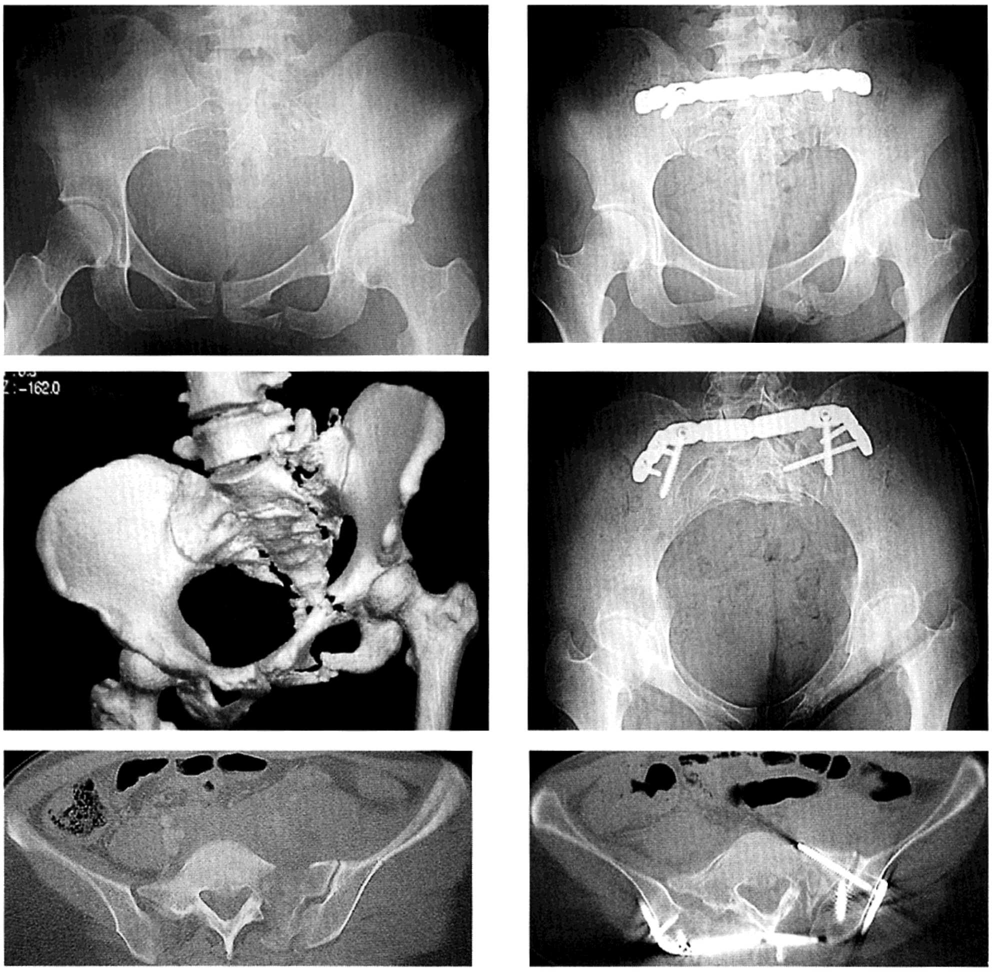

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Fig. 9. a. Preoperative AP radiography and 3D-CT, CT, sustained a Zone II sacral fracture. b. Postoperative AP and inlet radiographs and CT, fixed by M-Shaped Pelvic Plate.

of Tech.) for his analysis of the plates.

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