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ORIGINAL ARTICLE

Standalone percutaneous transiliac plating of vertically unstable sacral fractures: outcomes, complications, and recommendations

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Abstract

Purpose The aim of this study is to evaluate results of a standalone percutaneous posterior plating of the vertically unstable sacral fractures, to analyze the influencing factors, to discuss encountered complications, and to express the related recommendations.

Methods Forty two cases were included; all of them had type C vertical sacral fractures; and 16 cases had associated nerve roots injury. Subcutaneous 3.5-mm reconstruction plate was used in all cases, through vertical incisions in 28 cases and transverse incisions in 14 cases. Hannover pelvic outcome scoring system was implemented for results evaluation.

Results The mean follow-up period was 22.1 ± 7.5 months; the mean operative time was 43.3 ± 7 min; the mean surgical incision length was 4.6 ± 1.1 cm. 14 cases had excellent scores, 16 cases had good scores, 6 cases had fair scores, and 6 cases had poor scores. Younger age groups had significantly better outcome ($P = 0.015$), whereas the comminuted sacrum had significantly worse score ($P = 0.041$). Final residual posterior displacements significantly improved ($P = 0.001$) in comparison to the initial displacement. The nerve roots injury had final significant recovery ($P = 0.012$). Transverse skin incisions had subjectively significant satisfaction ($P = 0.017$).

Conclusions Percutaneous 3.5-mm reconstruction plate is a good alternative to percutaneous iliosacral screws in vertically unstable sacral fractures; especially in the presence of contraindication to the latter. It is simple procedure with minimal incisions; short operative time; less radiological exposure; good mechanical stability; and less iatrogenic injuries.

Introduction

The surgical treatment method of injuries to the posterior pelvic ring is still a subject of controversy. The reasons lie in the difficult anatomic relationships, jeopardized local soft tissue, lack of knowledge of the pathomechanisms and the biomechanics of these injuries, reports of intra- and postoperative complications, and poor outcomes [1].

Vertically unstable sacral injuries are the most challenging in their surgical management, as they have mechanical instability in addition to the usually associated lumbosacral roots injuries. The more common methods for their stabilization are transiliac rods [2], transiliac plates [3], posterior plating of the sacrum [4] with small plates, percutaneous iliosacral screws [5, 6], and spinopelvic instrumentation [7, 8].

Currently, percutaneous iliosacral screws (PISS) seem to be the most promising method [5, 6, 9]. However, the technique is demanding, and concerns have been raised regarding iatrogenic injuries to neurovascular structures [10]. Minimally invasive transiliac plate osteosynthesis may be an alternative to PISS as evident in a few recent publications [1, 11–14].

The aim of this prospective study is to evaluate results of a standalone 3.5-mm percutaneous posterior

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reconstruction plating (PPRP) of the vertically unstable sacral fractures, to analyze factors influencing these results, to discuss encountered complications, and to express related recommendations.

Patients and methods

Forty two cases were included in that series between February 2009 and December 2013. The studied cases were all adult patients with vertically unstable sacral fractures; type C according to Tile's classification [15]. All had nondisplaced anterior pubic arch fractures. The exclusion criteria included cases with associated other posterior pelvic instabilities; associated displaced acetabular fractures; anterior instabilities in need for surgical stabilization; direct posterior Morel-Lavallee lesions (MLL); cauda equina or separate roots insult that in need for direct decompression; spinopelvic dissociation injuries; and pediatric cases. 27 cases were males and 25 cases were related to fall from height injuries (Table 1). Nine cases had posterolateral and anterolateral MLL. 16 cases had associated type III neurological injury according to Gibbons [16]. 28 cases had zone II sacral fractures according to Denis et al. [17].

All cases had full history and clinical examination followed by pelvic plain radiographs evaluation and mandatory computed tomography (CT) scanning. All cases had initially mechanical prophylaxis for deep vein thrombosis (DVT) then chemical prophylaxis in the form of low molecular weight heparin. Timing of surgery varied according to management of associated injuries; however, ten cases were operated primarily; 21 cases were operated secondarily; and 11 cases were tertiary fixed according to Tscherne et al. [18] schedule. Perioperative antibiotics were given for 48 h unless their extended use was needed for an associated injury.

The operation was carried out on a radiolucent table; in prone position; under C-arm fluoroscopy if needed. The surgical procedure was that described by Dolati et al. [1] and Krappinger et al. [13] with slight modifications. In their original technique, the skin incisions were bilateral vertical surgical incisions; a transverse submuscular tunnel under the erector spinae muscles was developed; they did bilateral posterior iliac osteotomy grooves to adapt the large profile 4.5-mm reconstruction plate and to allow the plate to be at the same level of its submuscular tunnel; a median crest osteotomy was created to facilitate submuscular sliding of the plate; they bent one end of the plate prior to slide insertion to provide for a proper fit; the other was bent in situ using an impactor; finally, they refixed the previously osteotomized bone fragments on top of the plate using small fragment screws. They did not mention any repair to the subperiosteally elevated gluteal muscles from

the outer iliac tables. As our technique depended on subcutaneous 3.5-mm reconstruction plate insertion, the following innovations were applied to the original technique during the study. First, bilateral transverse skin incisions were used in the last 14 cases. Second, no osteotomy grooves were needed in the posterior iliac spines as the used plate was the low profile 3.5-mm reconstruction plate that was applied subcutaneously just below the posterior superior iliac spines prominence. Third, the posterior tunnel was typically subcutaneous, and therefore, there was no need for the median crest osteotomy which was needed for their submuscular tunnel preparation. Fourth, a template was used to help in typical obtuse "U-shaped" plate contouring. Fifth, the contoured plate was applied subcutaneously on its side with its limbs directed upwards and when it emerged from the contralateral approach, it was flipped either 270° clockwise or 90° anticlockwise to be seated in its final position on the outer table of the posterior ilium bilaterally. Sixth, the subperiosteally elevated gluteal muscles were reattached to the posterior ilium through a Kirschner wire created drill holes and via polydioxanone suture (PDS) materials. Cases with MLL were drained through a separate small lateral incision; debrided with a curette; and finally closed over a suction drain.

Depending on the severity of concomitant injuries, patients were initially allowed to sit up and turn on his/her side in the first postoperative week, and subsequently, partial weight bearing with crutches was allowed with the beginning of the 4th week. Full weightbearing was permitted after the 10th postoperative week after the radiological evidence of good bone healing.

Conventional pelvic radiographs and clinical evaluation were conducted immediately postoperative and then after 3, 6, 10, and 12 weeks as well as after 6 months, 1 year, and at every full year thereafter. The minimal follow-up used to gauge outcome was 6 months.

Results were evaluated according to Hannover pelvic outcome scoring system [19]. In this system, the ratings of the radiologic result and the clinical result are assessed as one score on a 7-point scale, where the maximum of 7 points represents an excellent result, 6 points is a good result, 5 and 4 points is a fair result, and 3 and 2 points is a bad or poor result. Excellent and good scores were categorized as a satisfactory result; fair and poor scores as an unsatisfactory result.

Statistical analysis was done using SPSS version 11.0.1 for windows (SPSS Inc., Chicago, Illinois), one-way analysis of variance (ANOVA) test, and its non-parametric equivalent, the Kruskal–Wallis test, were used for variables that were small and not normally distributed. One-sample t test was applied for means comparison. Chi-square and Fisher exact tests were also applied. A P value 0.05 or less was considered to be statistically significant.

Table 1 Demographic data of the patients

Groups	Subgroups	Number	%
Age in years	21–30	18	42.9
	31–40	14	33.3
	41–50	10	23.8
Gender	Males	27	64.3
	Females	15	35.7
Injured side	Right	19	45.2
	Left	23	54.8
Associated injuries	Non-displaced pubic rami fractures	42	100
	Non-displaced acetabular fractures	7	16.7
	Spine fractures	11	26.2
	Calcaneal fractures	10	23.8
	Long bones fractures	8	19
	Tibial plateau fracture	1	2.4
	Morel-Lavallee lesions	9	21.4
	Urogenital injuries	17	40.5
	Abdominal injuries	12	28.6
	Chest injuries	18	42.9
	Head injuries	4	9.5
Mechanism of injury	Fall from height	25	59.5
	Road traffic accidents	17	40.5
Injured sacral zones	Zone I (transalar)	14	33.3
	Zone II (transforaminal)	18	42.9
	Both zones (comminuted)	10	23.8
Neurological insult	Gibbons type I	26	61.9
	Gibbons type III	16	38.1
Affected roots	5th lumber and 1st sacral roots	5	11.9
	1st sacral root	6	14.3
	1st and 2nd sacral roots	5	11.9
Initial posterior displacement	0–5 mm	11	26.2
	6–10 mm	24	57.1
	11–15 mm	7	16.7
Time of fixation	Primary	10	23.8
	Secondary	21	50
	Tertiary	11	26.2

Results

The mean age of the studied groups was 33.3 ± 8.7 years (range 21–50). The mean follow-up period was 22.1 ± 7.5 months (range 6–36). The mean preoperative posterior displacement was 7.8 ± 3.3 mm (range 2–15), and the mean final residual posterior displacement was 2.0 ± 2.3 mm (range 0–8), and the difference was found to be significant ($P = 0.001$). In all cases, there was no re-displacement in comparing immediate postoperative radiographs to those of the final follow-up periods.

Intraoperatively, the mean operative time was 43.3 ± 7 min (range 35–60); the mean number of fluoroscopy exposure was 2.5 ± 1.2 times (range 0–4); the mean blood loss volume was 181.4 ± 72.2 ml (range 100–300); and the mean surgical incision length was 4.6 ± 1.1 cm (range 4–8).

The final pelvic outcome was satisfactory in 30 cases (71.4 %) and unsatisfactory in the other 12 cases (28.6 %) due to persistent posterior pelvic pain in all of them with residual neurological deficits among five cases. 14 cases had excellent scores (Fig. 1), 16 cases had good scores, 6 cases had fair scores, and 6 cases had poor scores.

Younger age groups had a significantly better pelvic outcomes, whereas comminuted sacral zones injuries had a significantly worse pelvic scores (Table 2).

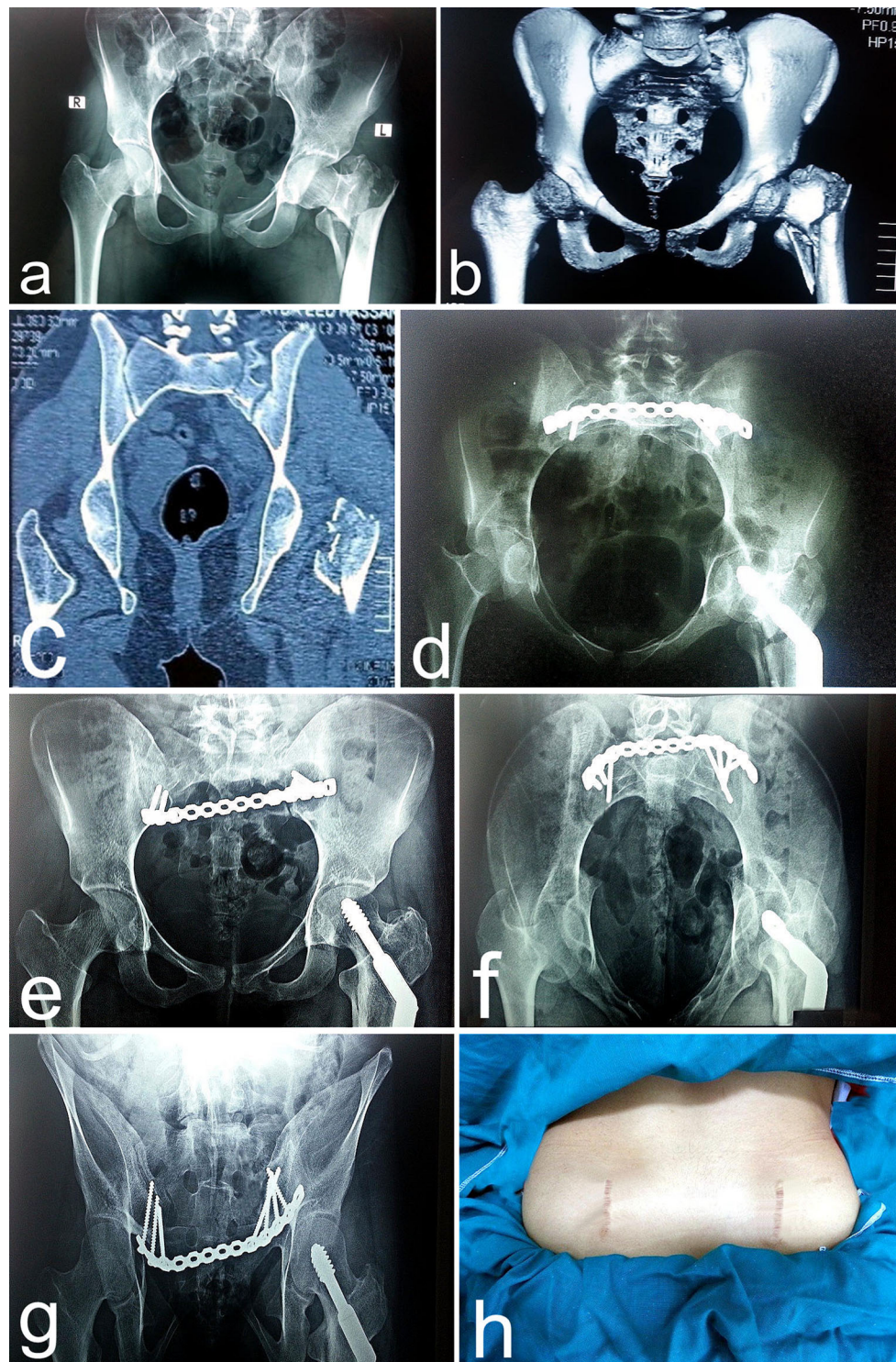Preoperative posterior displacements more than 1 cm had less favorable pelvic scores, but their effect was

Fig. 1 A 22-year-old female sustained type C pelvic fracture following fall from height. She had associated left intertrochanteric fracture femur and abdominal injury (internal hemorrhage). She was neurologically intact. Her pelvic internal fixation was carried out in the 4th posttraumatic day. **a–c** Plain anteroposterior radiograph and CT scan with its 3D reconstruction show the transalar left sacral instability, left pubic rami fractures, and the comminuted left intertrochanteric fracture. **d** The immediate postoperative inlet plain radiograph shows anatomical pelvic reduction. **e–g** Anteroposterior, inlet, and outlet radiographs show anatomical pelvic fractures healing after 1 year follow-up. The patient had excellent pelvic outcome in spite of the subjective unsatisfactory surgical scars (**h**)

insignificant. Also, the tertiary operated cases had insignificantly worse outcomes (Table 2).

The presence of anterolateral and posterolateral MLL in 9 cases had insignificant effect on the final pelvic outcome in spite of the high incidence of delayed wound healing and superficial infection among them (Table 2).

The associated neurological injuries among 16 cases had insignificant influence on the final pelvic outcome (Table 2), as 11 cases had complete neurological recovery (Gibbons type I) at their final follow-up periods (Fig. 2). The neurological improvement was found to be statistically significant (Table 3). It was noticed that the five cases that had no neurological improvements had initially fall from height injuries.

During surgery of the 28th case, there was an ipsilateral superficial skin ulcer at the site of the proposed vertical incision, and therefore, a transverse elliptical incision was achieved to excise the ulcerated area. The wound healing was even with excellent cosmetic appearance in contrast to the vertical contralateral wound scar (Fig. 3). Therefore, the last 14 cases were operated using bilateral transverse skin incisions just below the posterior superior iliac spines. In comparing the subjective cosmetic satisfaction among all patients, there was a significant difference in favor of the transverse incision scars ($P = 0.017$).

Complications were encountered in 8 cases (19 %); two cases had superficial infection that responded well to repeated dressing and parenteral antibiotics; two cases had delayed wound healing more than 3 weeks (both of them had ipsilateral MLL); one case had deep infection after 1 month and was managed with surgical debridement and parenteral antibiotics (Fig. 4); three cases had implant

Table 2 Factors affecting Hannover pelvic outcome

Factor		Hannover pelvic outcome scores					Statistical analysis	
Groups	Subgroups	Excellent cases	Good cases	Fair cases	Poor cases	Total no.	Test value	P value
Age	21–30 years	6	7	3	2	18	6.510*	0.015***
	31–40 years	5	5	2	2	14		
	41–50 years	3	4	1	2	10		
Gender	Males	7	11	4	5	27	4.823**	0.171
	Females	7	5	2	1	15		
Injury mechanism	Fall from height	5	11	5	4	25	4.375**	0.324
	Road traffic accidents	9	5	1	2	17		
Injured sacral zones	Zone I	6	4	2	2	14	8.230**	0.041***
	Zone II	5	8	2	3	18		
	Combined zones	3	4	2	1	10		
Neurological insult	Gibbons type I	9	10	4	3	26	5.566**	0.114
	Gibbons type III	5	6	2	3	16		
Nerve roots injury	Absent	9	10	4	3	26	2.969**	0.396
	5th lumber + 1st sacral roots	1	2	0	2	5		
	1st sacral root	2	2	1	1	6		
	1st + 2nd sacral roots	2	2	1	0	5		
Initial posterior displacement	0–5 mm	5	4	1	1	11	1.165*	0.381
	6–10 mm	8	10	3	3	24		
	11–15 mm	1	2	2	2	7		
Time of surgery	Primary	5	4	0	1	10	4.649**	0.199
	Secondary	9	6	3	3	21		
	Tertiary	0	6	3	2	11		
Morel-Lavallee lesion	Absent	11	13	4	5	33	1.392**	0.771
	Present	3	3	2	1	9		

* The F value of one-way analysis of variance test

** The H value of the Kruskal–Wallis test
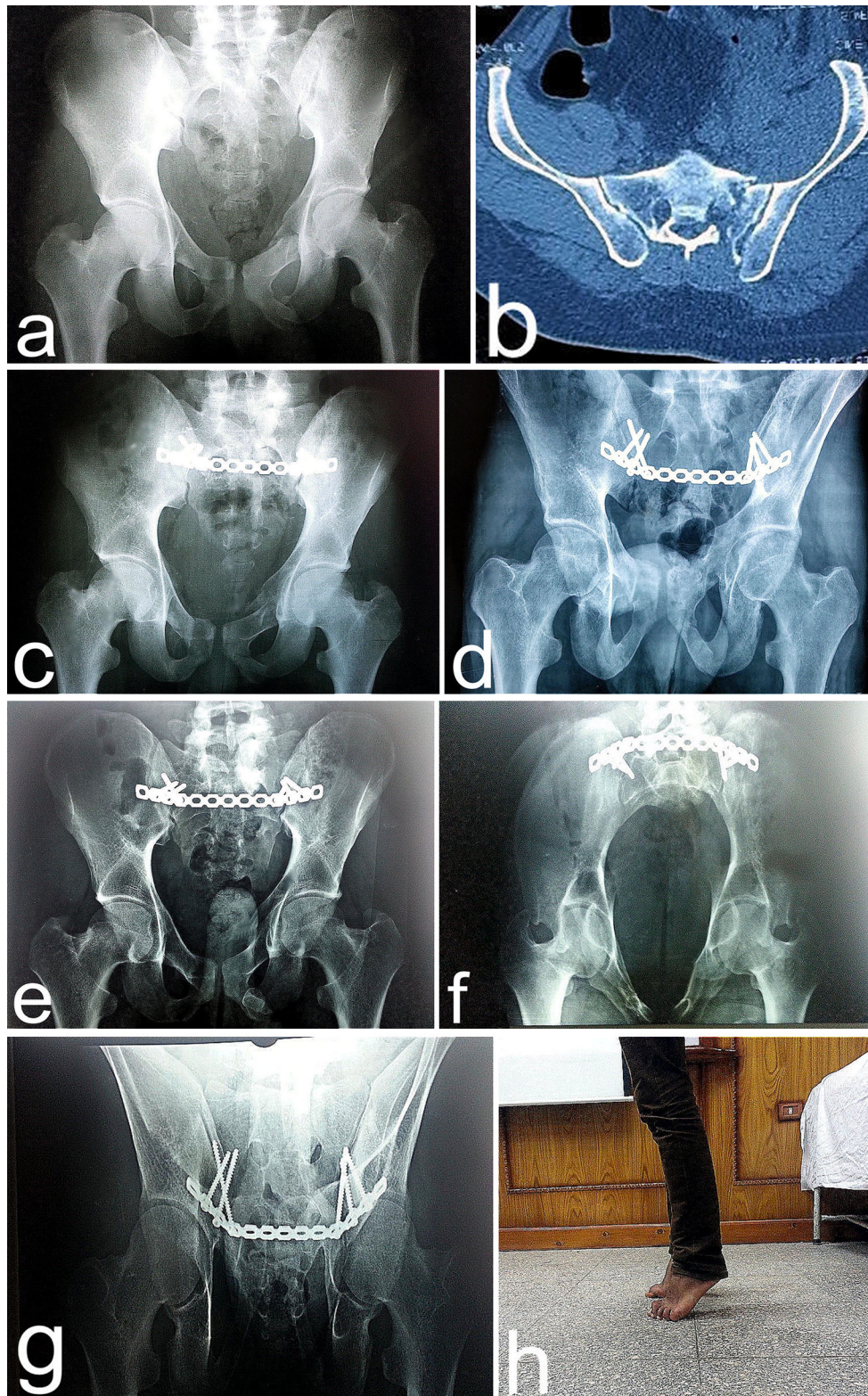
*** Statistically significant difference

Fig. 2 A 31-year-old male sustained type C pelvic fracture following a road traffic accident. He had associated abdominal injury (internal hemorrhage). His full neurological assessment documented left 1st sacral root insult (Gibbons grade III). The pelvic injury was addressed in the 3rd day after trauma. **a, b** The initial anteroposterior radiograph and axial CT scan show the left transforaminal sacral instability and the anterior pubic rami fractures. **c, d** The immediate postoperative anteroposterior and outlet plain radiographs. **e–g** The anteroposterior, inlet, and outlet plain radiographs show good anatomical healing without re-displacement after 18 months follow-up. The patient had excellent pelvic outcome as the insulted sacral root had complete recovery (Gibbons type I) after 10 months follow-up (**h**)

Table 3 Improvement of the associated nerve roots injuries according to Gibbons classification [16]

Evaluation time	Neurological injury			Chi-square test	
	Gibbons type I cases (no deficits)	Gibbons type III cases (motor and sensory deficits)	Total cases	Test value	P value
Preoperative period	26	16	42	6.349	0.012*
Final follow-up periods	37	5	42		

* Statistically significant
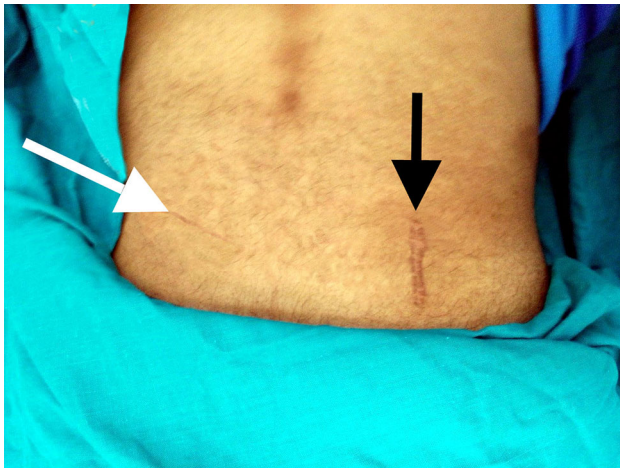
Fig. 3 An 11 month follow-up photo shows the cosmetic difference between the vertically oriented *right side* surgical incision healing (*black arrow*) and the transversely oriented *left side* surgical incision healing (*white arrow*) in spite of the subcuticular skin closure of both wounds

removal in a mean of 11.7 ± 1.5 months (range 10–13). Implant removal was indicated for bilateral sacroiliac pain on sport activities in two young cases, and posterior pelvic discomfort in supine posture of the last case who had asthenic body physique.

Discussion

Management of vertically unstable sacral fractures is still challenging; they have not only mechanical instability but also often neurological and hemodynamic instabilities. The frequently associated MLL is another obstacle for decision making.

Percutaneous iliosacral screws (PISS) became the first choice in most of these cases during last decades; they can be applied in the supine position especially among polytrauma patients, have very small incision with minimal blood loss, have very low rate of deep infection, and have a good mechanical stability [5, 6, 9, 10, 14]. However, they need good experience, good quality fluoroscopic machine,

radiolucent table, and good preoperative bowel preparation otherwise the incidence of screws malposition will be high. Also, they give high radiological exposure rate during their insertion and their removal, cannot be applied in the presence of sacral anomalies, and have weak mechanical stability in the presence of comminuted sacral fractures or if they intruded through the lateral iliac cortex with their washers. However, Matityahu et al. [20] recommended recently the use of 3D navigation to improve intraoperative imaging for accurate insertion of PISS especially among the patients with dysmorphic proximal sacral segment. Also, Zwingmann et al. [21] found that CT navigation has the lowest rate of screw malposition. They reported that 2D and 3D image-based navigation and reconstruction techniques provide encouraging results with slightly lower rate of complications compared to the conventional technique. Moreover, Kraus et al. [22] found that the 3D navigated sacroiliac screw insertion had 1/5 the effective radiation dose of the conventional technique. On the other hand, Oberst et al. [23] described a novel endoscopic technique to reduce the radiation hazards during sacroiliac screws removal. Most recently, Firoozabadi et al. [24] advised the use of combined obturator and inlet views during final tightening of PISS to avoid their intrusion within the lateral iliac cortex and loss of their mechanical efficacy.

In this series, we tried to the study the standalone 3.5-mm percutaneous posterior reconstruction plating (PPRP) as an alternative option for management of vertically unstable sacral fractures. All cases in the study had stable anterior pubic rami fractures i.e., with less than 20-mm initial displacement according to Matta [25]; and therefore, they were not in need for either internal or external fixation. Accordingly, our clinical results were directly related to the standalone 3.5-mm PPRP.

In spite of type C sacral injuries of that study, the standalone 3.5-mm PPRP has clinically proved its efficient mechanical stability as there was significant postoperative improvement of the initial posterior displacements without any re-displacement at the final radiological follow-up. Similarly, the two studies of Chen et al. confirmed biomechanically and clinically the effectiveness of the 3.5-
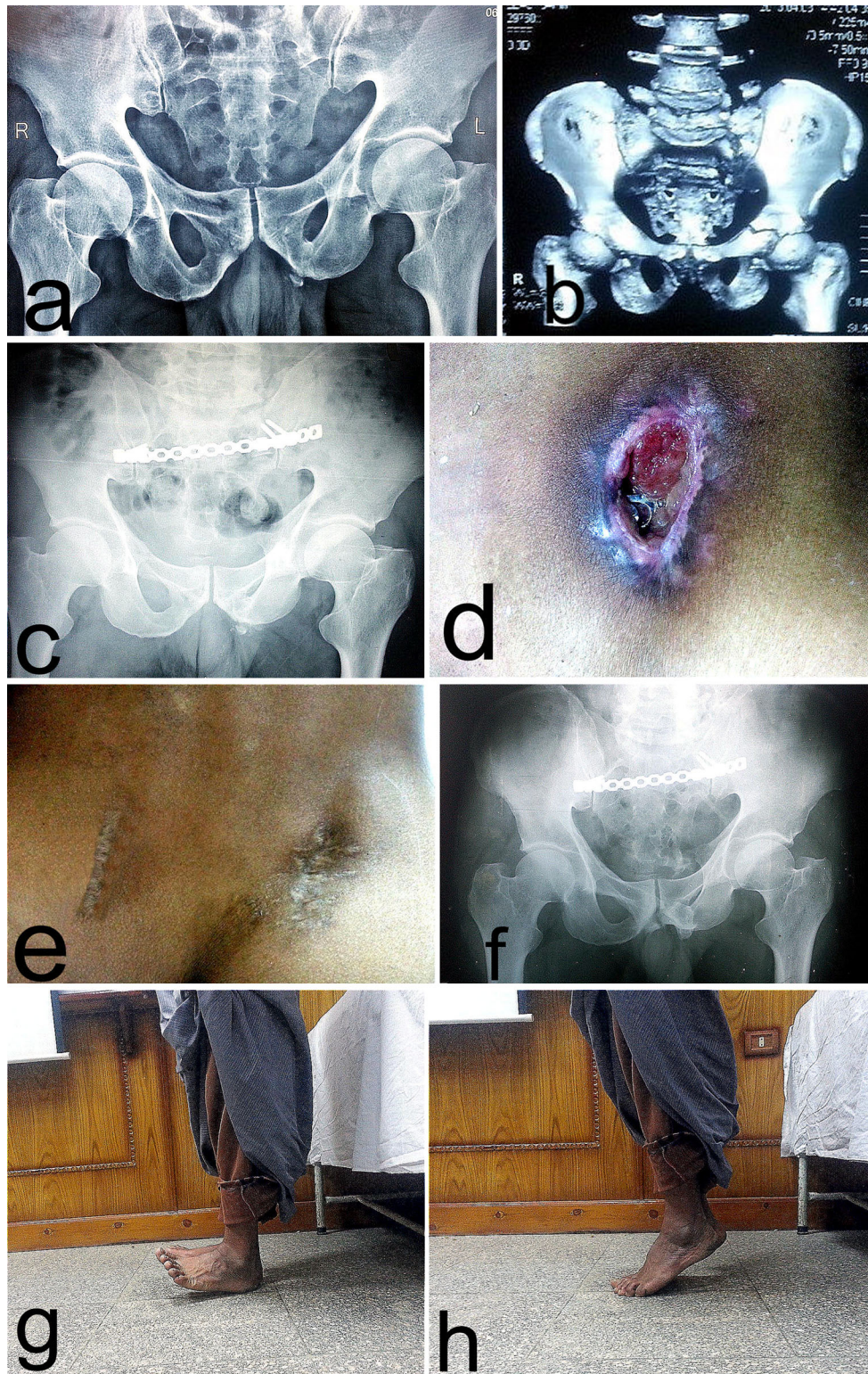
◄ **Fig. 4** A 44-year-old male sustained type C pelvic fracture following fall from height. He had associated left olecranon fracture and abdominal injury (internal hemorrhage). His full neurological assessment documented affection of left 5th lumber and 1st sacral roots (Gibbons grade III). His pelvic injury was internally fixed 10 days after trauma. **a**, **b** The initial anteroposterior plain radiograph and 3D-CT scan reconstruction show the left transforaminal sacral instability, avulsion of the left 5th lumber transverse process, and anterior left pubic arch injuries. **c** The immediate postoperative anteroposterior plain radiograph shows residual vertical displacement 6 mm. **d** A photo shows the right surgical site deep infection and wound dehiscence after 4 weeks from surgery. After wound culturing, the suitable parenteral antibiotic was initiated, and the wound was aggressively debrided with primary closure. **e** A photo 6 months postoperatively shows the surgical wounds final healing. **f** The follow-up plain anteroposterior radiograph after 24 months shows good bony healing with the same residual 6-mm vertical displacement. The patient had good pelvic outcome as the insulted lumber and sacral roots had a complete recovery (Gibbons type I) after 20 months follow-up (**g**, **h**)

mm PPRP in maintaining reductions of Denis I and II sacral fractures. They found that load stress distribution with the 3.5-mm reconstruction plate was similar to that of the normal pelvis, being sufficient for clinical stabilization [14, 26]. They stated also that 3.5-mm PPRP appears to be superior to PISS for Denis III type vertical sacral fracture.

In that study, it was evident that intraoperative risks to the patient and the operating team were reduced in spite of the major initial trauma. The subcutaneous mini-invasive approach reduced greatly: operative time (averaged 43.3 min); blood loss (averaged 181.4 ml); and radiological exposure rate (averaged 2.5 times). Therefore, the risks of prolonged prone position in anesthesia, blood loss and transfusion hazards, great fluoroscopy exposure for patients, and the operating room staff were markedly eliminated. However, Chen et al. [14] had significant results favoring the percutaneous plate regarding the operative time and the fluoroscopy exposure rate, whereas they had significant results favoring the percutaneous screws regarding the blood loss and the surgical incision length. In Dolati et al. [1] series, the operating time for posterior plate fixation was longer (averaged 82 min) as they utilized bilateral iliac notch osteotomy, median sacral crest osteotomy, and submuscular tunneling to adopt the higher profile 4.5-mm reconstruction plate application.

In our study, the final pelvic outcome was satisfactory in 30 cases (71.4 %) and unsatisfactory in the other 12 cases (28.6 %) due to persistent posterior pelvic pain in all of them with residual neurological deficits among five cases. Similarly, Krappinger et al. [13] had satisfactory pelvic outcome in 73.9 % of their cases. Contrarily, Chen et al. [14] in their posterior plating group had satisfactory results in 86.1 % of cases as none of them had associated neurological injuries and they fixed the associated anterior instabilities.

Younger age groups had significantly better outcome in our series. This may be related to their good bone quality, less fracture comminution, and their good healing potentials. Also, the tertiary operated cases had insignificantly worse results due to the difficult and suboptimal closed reduction especially with initial displacement more than 1 cm. Therefore, we agree with Chen et al. [14] that distal femur skeletal traction with 1/6 to 1/4 of the body weight is essential preoperative procedure for posterior percutaneous fixation especially if it will be inevitably postponed for more than 1 week after injury.

The presence of anterolateral and posterolateral MLL had insignificant effect on the final pelvic outcome in our study as all lesions were debrided through a separate lateral incision with prolonged closed suction drain and antibiotic therapy. This finding confirmed the suggestion of Steiner et al. [27] that surgical access for osteosynthesis and for debridement of MLL can be used without increased infection rate.

There was significant improvement of the associated neurological injuries in that study. This improvement abolished the significant effect of these neurological injuries on the final pelvic outcome, confirmed the suggestion that most of these injuries had a neurapraxia pattern except those related to fall from height injuries, supported the decision of closed reduction in the presence of these injuries provided that there was no clinical or radiological indication for open reduction and direct decompression, and gave an upper hand for the percutaneous plating over the percutaneous iliosacral screws in providing good circumstances for neurological recovery and in avoiding the iatrogenic nerve injuries either directly or indirectly via over-compression of the fracture lines.

Transverse skin incisions had significantly better subjective satisfaction among our cases as they are going with Langer's lines of the skin in that area. Although they were parallel to the applied plate, no case developed any wound healing problem as the straight part of the plate was hidden under intact skin and the bent ends were hidden under the repaired gluteal muscles.

The implant-related complications, that necessitated plate removal, were recorded only in three cases (7.1 %) of this series. The plate restricted the sacroiliac motions in two sportsmen with strenuous exercises. The third case had asthenic body with plate-related discomfort on supine position. Dolati et al. [1] recommended plate removal after 6–9 months in younger and slimmer patients in order to facilitate recovery of pelvic elasticity and overcome the plate-related discomfort in lying position.

According to our study, we found that the 3.5-mm PPRP was a good alternative to the PISS in vertically unstable sacral fractures especially in the presence of contraindications to screws application. The 3.5-mm PPRP has the

advantages of a mini-invasive approach; short operative time; less radiological hazards; lack of iatrogenic neurovascular injuries; providing good circumstances for recovery of the associated nerve neurapraxia; good standalone posterior mechanical stability even in comminuted fractures; minimal blood loss; short learning curve; easy application in hospitals with low facilities; good clinical and radiological outcomes especially when applied during the first week after injury; and good cosmetic scars when slided through transverse surgical incisions.

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