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ORIGINAL ARTICLE

Type C pelvic ring injuries in polytrauma patients: can percutaneous iliosacral screws reduce morbidity and costs?

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Abstract Forty-two polytrauma patients with pelvic injuries were included in this retrospective study to evaluate the benefits of percutaneous iliosacral screwing. All patients were followed up for at least 1 year, and their mean age was 39 years. According to Tile's classification, all cases were type C pelvic injuries. After primary anterior fixation, the iliosacral screws were applied percutaneously. Twenty-two cases had excellent reduction, 15 cases had good reduction, 4 cases had fair reduction and one case had poor reduction. The unsatisfactory final displacements were common among dislocations of the sacroiliac joints and operated cases during the second week. The final clinical outcome was satisfactory in 31 cases and unsatisfactory in 11 cases. Unsatisfactory clinical results were due to persistent posterior pelvic pain and limited activities in 7 cases and residual neurological disability in four cases. No posterior infection or iatrogenic nerve injuries were encountered; however, two cases had loosening of the applied improper screws. There was significant direct reduction in the hospital stay, transfused blood amount, ventilator time and complications when the percutaneous iliosacral screwing was carried out early during the first week. Therefore, indirect reduction in the hospital cost and polytraumatized patient morbidity was achieved.

Keywords Unstable pelvic ring injuries · Percutaneous iliosacral screws · Polytrauma patients

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Introduction

High-energy fractures of the pelvis are a challenging problem in both the immediate post-injury phase and the later when definitive fixation is undertaken [1]. Although they are uncommon, but when they do occur they pose an extensive disruption of the pelvis, and can greatly contribute to significant patient morbidity and mortality [2], early operative stabilisation has been recommended to reduce mortality, to promote early rehabilitation and to diminish the complications [3, 4].

Anterior pelvic injuries can be stabilized by plating or external fixators; however, the selection of a fixation method for the posterior lesion, which is more important, is controversial. Although posterior approaches with plating, sacral bar and triangular fixation systems have been used until now, they need a wide exposure in the prone position, which can increase the rate of infection, wound sequelae and anaesthesia problems especially in the high-risk polytraumatized patients [5–7].

Although the benefits of acute stabilisation of long bone fractures are recognized, the role of early fixation of unstable pelvis and acetabular fractures is not well defined [4]. The purpose of this retrospective study was to evaluate the benefits and the functional outcome of two percutaneous iliosacral screws fixation, applied only under C-arm control as early as possible for polytraumatized patients with highly unstable posterior pelvic ring injuries.

Patients and methods

From March 2002 to January 2009, forty-two polytraumatized patients with unstable pelvic ring injuries were managed with two percutaneous iliosacral screws fixation after

primary anterior pelvic arch stabilization with plates in 31 cases (they had laparotomy for associated abdominal and/or genitourinary injuries) and supraacetabular external fixators in 11 cases (they had hypovolemic shock with large retroperitoneal haematoma). Cases with sacral dysmorphism were excluded due to the hazards of iatrogenic nerve injury with iliosacral screwing in the absence of navigation systems and electrodiagnostic monitoring. Also cases associated with grossly displaced acetabular fractures were excluded to avoid their influence on the clinical outcome. Three cases, with minimally displaced low anterior column fractures, were fixed by retrograde pubic screws during primary anterior plating. All patients had initial intensive care unit admission and were followed up for a mean of 18 months (range 12–36 months). There were 33 men and 9 women, with a mean age of 39 years (range 21–58 years). The mechanisms of the injuries were road traffic accidents (RTA) in 29 patients, a fall from a height in 8 patients, and a crushing work-related injury in 5 patients as shown in Table 1. All patients had associated injuries or fractures, and the mean Hannover polytrauma score (PTS) was 33.7 points (range 21–46). Initial mechanical and then chemical (low molecular weight heparin) prophylaxis against deep vein thrombosis (DVT) were used in all patients.

A pre-operative radiological evaluation, anteroposterior (AP), inlet and outlet views of the pelvis was carried out in addition to computed tomography (CT) scans to evaluate the exact characteristics of the fractures. All cases were type C injuries; 34 cases were type C1 and 8 cases were type C3 according to Tile's classification [8]. In the posterior pelvic ring injuries, there were 16 sacroiliac joint dislocations and 26 sacral fractures, 7 were type I and 19 were type II according to Denis et al.'s classification [9]. Eight patients had associated neurological deficits as shown in Table 1. There were no open fractures. On average, the operation took 5.2 days (range 2–12 days) from injury to a definitive posterior fixation. The haemodynamic parameters in the form of mean arterial pressure (MAP) and central venous pressure (CVP) were monitored and recorded during surgery.

All patients were placed in a supine position on a radiolucent table. The posterior ring was indirectly reduced and maintained after the primary procedure for the anterior arch in 30 cases, while 12 cases had residual vertical displacement that was reduced through a Schanz screw with T-handle applied percutaneously to the ipsilateral iliac crest. After obtaining an adequate lateral view under the fluoroscopic guide, the entry point for the iliosacral screw was determined. With the guidance of the pelvic AP, outlet and inlet views, two parallel guide pins, almost perpendicular to the midline, were inserted from the outer table of the iliac wing towards the body of sacral one vertebra. Care was taken to avoid intrusion into the sacral canal posteriorly or the sacral foramen inferiorly. Drilling was done, and then two was-

Table 1 Demographic data of the patients

Factors	Number	Percentage
Gender		
Males	33	78.6
Females	9	21.4
Age groups (years)		
21–30	16	38.1
31–40	12	28.6
41–50	10	23.8
51–60	4	9.5
Injury mechanism		
Car occupants[a]	10	23.8
Pedestrians[a]	11	26.2
Motorcycle[a]	8	19
Fall from height	8	19
Work-related injury	5	11.9
Associated injuries		
Head injuries	6	14.3
Chest injuries	9	21.4
Abdominal injuries	20	46.6
Urogenital injuries	17	40.5
Extremity injuries	22	52.4
Spinal fractures	4	9.4
Non-displaced acetabular fractures	5	11.9
Minimally displaced anterior column acetabular fractures	3	7.1
Morell-Lavallee lesions (MLL)	4	9.4
Anterior pelvic injuries		
Symphysis pubis diastasis	25	59.5
Pubic bone fractures	17	40.5
Posterior pelvic injuries		
Sacral fractures zone I	7	16.7
Sacral fractures zone II	19	45.2
Sacroiliac joint dislocations	16	38.1
Neurological injuries		
4th and 5th lumber roots	4	9.4
1st sacral root	2	4.8
1st and 2nd sacral roots	2	4.8
Posterior fixation onset		
1st 3 days	17	40.5
4–7 days	17	40.5
8–14 days	8	19
Hospital stay		
<2 weeks	9	21.4
2–4 weeks	30	71.4
>4 weeks	3	7.1
Initial displacement		
≤15 mm	19	45.2
>15 mm	23	54.8

[a] *RTA* road traffic accidents

Fig. 1 **a** The plain inlet view of 28-year-old male patient with 34-point PTS score after RTA shows the widely separated symphysis pubis anteriorly with involvement of the *right* sacrum posteriorly. **b** The axial CT scan cut shows type C zone II *right* sacral fracture. **c** The plain AP view after 10 months that shows excellent radiological results; the patient achieved good clinical result

hered cannulated screws (partially threaded, 7.0 mm in diameter) were inserted over the guide pins. The screws were tightened, alternatively, until the fractured surfaces were approximated without over-compression especially in comminuted sacral fractures. Postoperatively, active hip and knee joint motion was encouraged. Non-weight bearing with under arm crutches was encouraged as soon as possible after surgery according to the general condition and associated injuries of each patient. Partial weight bearing was allowed at 4–6 weeks, and full weight bearing usually began at 12–14 weeks postoperatively. Sequential follow-up radiographs of the anteroposterior, inlet and outlet views of the pelvis were observed at regular intervals of 4–8 weeks.

The radiological results relied on the maximal vertical or anterior–posterior displacement reached at the end of the follow-up periods of each patient. The results were classified according to Lindahl et al. [10] into the following groups: excellent (0–5 mm displacement), good (6–10 mm), fair (11–15 mm) and poor (more than 15 mm displacement).

The functional results were classified according to Lindahl et al.'s modification of Majeed score into the following groups: excellent (78–80 points), good (70–77 points), fair (60–69 points) and poor (<60 points) [10, 11]. We categorized excellent or good as a satisfactory result and fair or poor 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) and its non-parametric equivalent, the Kruskal–Wallis test, were used for variables that were small and not normally distributed. A P value ≤ 0.05 was considered to be statistically significant.

Results

The final clinical outcome in this study was satisfactory in 31 cases (73.8%) and unsatisfactory in 11 cases (26.2%), as 18 cases had excellent scores, 13 cases had good scores, 5 cases had fair scores and 6 cases had poor scores. Unsatisfactory results were due to persistent posterior pelvic pain and limited activities in 7 cases and residual neurological disability in four cases.

The final radiological results were satisfactory in 37 cases (88.1%) and unsatisfactory in 5 cases (11.9%), as 22 cases had excellent reduction (Fig. 1), 15 cases had good reduction, 4 cases had fair reduction and one case had poor reduction. The unsatisfactory final displacement were common among: the age groups more than 40 years old, dislocations of the sacroiliac joints, comminuted zone II sacral fractures, operated cases during the second week and cases with initial displacement more than 20 mm before surgery.

The clinical outcome was better significantly in the age groups below 40 years old and with 15 mm or less initial displacement. It was better insignificantly among sacral fractures cases and cases operated during the first week. The presence of MLL had insignificant effect on the final clinical and radiological results as shown in Table 2.

The radiological outcome was better significantly among the younger age groups, sacral zones I and II fractures, operated cases during the first week and cases with 15 mm or less initial fracture displacement as shown in Table 2.

Although the supraacetabular external fixator shared anterior plating in the satisfactory clinical and radiological results (Fig. 2), the plates augmented the iliosacral screws more significantly as shown in Table 2.

The few neurological injuries had insignificant effect on the final clinical results as the four cases of them with sacral root injury had complete recovery in a mean of 14 months (range 6–19). Other four cases with lumber root injury had partial recovery in a mean of 17 months (range 14–22). The satisfactory reductions in this study had also insignificant wallop on the functional results ($P = 0.963$) according to Kruskal–Wallis test.

Iliosacral screwing during the first week had strong impact on the hospital stay duration and on ventilator time; also, it has lowered significantly the needed total amount of transfused blood before and after its application as shown in Table 3.

Table 2 Variables related to the clinical and radiological results with their statistical significance

Variables	Clinical results				*P* value	Radiological results				*P* value
	Excellent cases	Good cases	Fair cases	Poor cases		Excellent cases	Good cases	Fair cases	Poor cases	
Age groups										
21–30	6	5	2	3	0.039*	9	6	1	0	0.016**
31–40	5	5	1	1		9	2	1	0	
41–50	5	3	1	1		3	6	1	0	
51–60	2	0	1	1		1	1	1	1	
Posterior injuries										
Sacral zone I	4	2	1	0	0.256***	4	3	0	0	0.024*
Sacral Zone II	11	5	2	1		12	5	2	0	
Sacroiliac joint	3	6	2	5		6	7	2	1	
Posterior fixation onset										
1st three days	9	7	1	0	0.278***	11	6	0	0	0.030*
4–7 days	8	5	2	2		8	7	2	0	
8–14 days	1	1	2	4		3	2	2	1	
Initial displacement										
≤15 mm	9	6	2	2	0.038**	12	6	1	0	0.010**
>15 mm	9	7	3	4		10	9	3	1	
Morell-Lavallee lesions										
Absent	16	12	4	6	0.781****	21	14	3	0	0.600****
Present	2	1	1	0		1	1	1	1	
Anterior implants										
Plate	9	7	2	2	0.038**	12	7	1	0	0.010**
External fixator	9	6	3	4		10	8	3	1	

* Statistically significant through one-way analysis of variance test

** Statistically significant through Kruskal–Wallis test

*** Statistically insignificant through one-way analysis of variance test

**** Statistically insignificant through Kruskal–Wallis test

The average posterior operating time was 52 min (35–90), and the average total screening time was 140 s (75–320). Blood loss was always less than 50 ml without any deterioration in the haemodynamic parameters, as the average MAP was 72.2 mmHg (65–90) and the average CVP was 3.8 cmH_2O (2–6). No mandatory blood transfusion was requested due to the percutaneous iliosacral screwing in any of our cases.

Regarding complications, no iatrogenic and/or worsened nerve injuries were encountered in this study, but slight loosening without loss of the posterior reduction (Fig. 3) happened in two cases. Those two cases were obese, had initially sacroiliac joint dislocation, and were operated after 10 days with very difficult closed reduction and C-arm monitoring. Their screws were short and about to penetrate the anterior alar cortex. Post-traumatic sacroilitis developed in 7 cases with sacroiliac joint injuries and gave rise to persistent posterior pain in all of them. DVT complicated 5 cases in spite of the mechanical and chemical prophylaxis. Adult respiratory distress syndrome (ARDS) was aroused in 6 cases, three cases had superficial pin tract infection of the supraacetabular external fixators and no case developed posterior infection. Significantly, it was clear that the earlier the iliosacral screwing, the least chance of development of both DVT and ARDS as shown in Table 3.

Discussion

Polytraumatized patients with major pelvic instabilities had many problems including the initial haemodynamic instability; associated pelvic soft-tissue and extra-pelvic injuries; intensive care unit need; mandatory supine positioning with difficult nursing care and high incidence of bed sores, ARDS, fat embolism, sepsis, DVT; in addition to the hazards of repeated blood transfusion, the open pelvic surgeries in compromised soft tissue and prolonged hospital stay. This study essayed facing all these problems through resus-

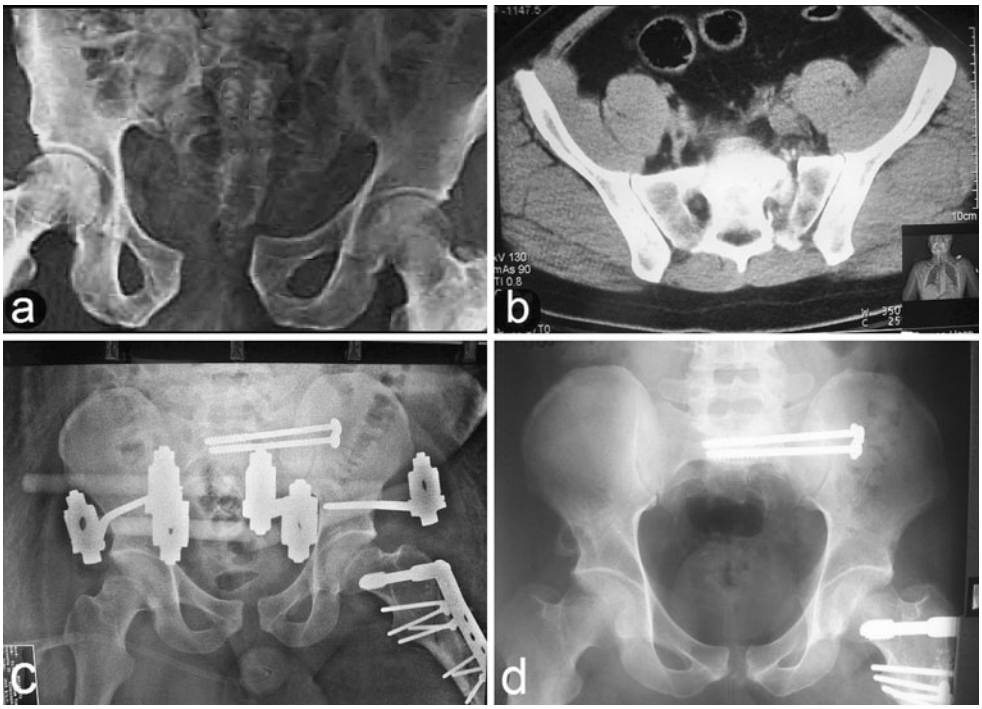

Fig. 2 **a** The plain AP view of 42-year-old male patient after motorcycle accident with 40-point PTS score shows type C injury of the *left* hemipelvis with symphysis pubis diastasis anteriorly and sacral fracture posteriorly. The patient had severe haemodynamic instability, *left* comminuted subtrochanteric fracture and first sacral root grade II motor weakness. **b** The axial CT cut shows zone II *left* sacral fracture. **c** The postoperative plain AP view after primary supraacetabular external fixator application, secondary dynamic condylar screw and two washered percutaneous iliosacral screws application. **d** The plain inlet view after 17 months with good radiological score; the patient had complete neurological recovery after 16 months with excellent clinical score

Table 3 The effect of timing of iliosacral screwing on hospital stay, transfused blood, ventilator time and general complications

Onset of iliosacral screwing	Hospital stay			Transfused blood before iliosacral screwing		Transfused blood after iliosacral screwing		Ventilator time		DVT		ARDS	
	<2 weeks	2–4 weeks	>4 weeks	Maximum amount	Minimum amount	Maximum amount	Minimum amount	Maximum days	Minimum days	Present	Absent	Present	Absent
1st 3 days	5 cases	12 cases	0 case	5,000 cc	2,000 cc	2,000 cc	500 cc	7	3	1 case	16 cases	0 case	17 cases
4–7 days	4 cases	12 cases	1 case	6,000 cc	2,500 cc	2,500 cc	1,000 cc	9	4	2 cases	15 cases	3 cases	14 cases
8–14 days	0 case	6 cases	2 cases	7,500 cc	4,000 cc	3,000 cc	1,500 cc	12	6	2 cases	6 cases	3 cases	5 cases
P value	0.012*			0.024*		0.021*		0.042*		0.029*		0.018*	

* Statistically significant through one-way analysis of variance test

DVT Deep vein thrombosis, *ARDS* Adult respiratory distress syndrome

citative anterior pelvic stabilization and as early as possible posterior percutaneous iliosacral screws application.

Early percutaneous iliosacral screws application during the first week, in this series, had significantly lowered the hospital stay, blood transfusion requirements, ventilator time, DVT and ARDS incidence; therefore, significant cost and morbidity reduction had been achieved without worsening of the initially impaired haemodynamic parameters. Similarly, Routt et al. [12] stated that early and accurate closed reduction in association with stable fixation utilizing percutaneous techniques may be an ideal treatment for specific disruptions of the pelvic ring, especially in polytrauma. In addition, blood loss is significantly decreased, which is particularly important when treating patients with an underlying haemodynamic instabilities. Recently, Enninghorst et al. [13] tried to evaluate the safety and efficiency of acute pelvic open reduction and internal fixation (during the first 24 h) by comparing its short-term outcomes with those who had staged surgery (after 24 h). They found that in spite of significant worsening of the initial shock parameters in the acute group, there was a trend to shorter intensive care unit and hospital stay, in addition to a

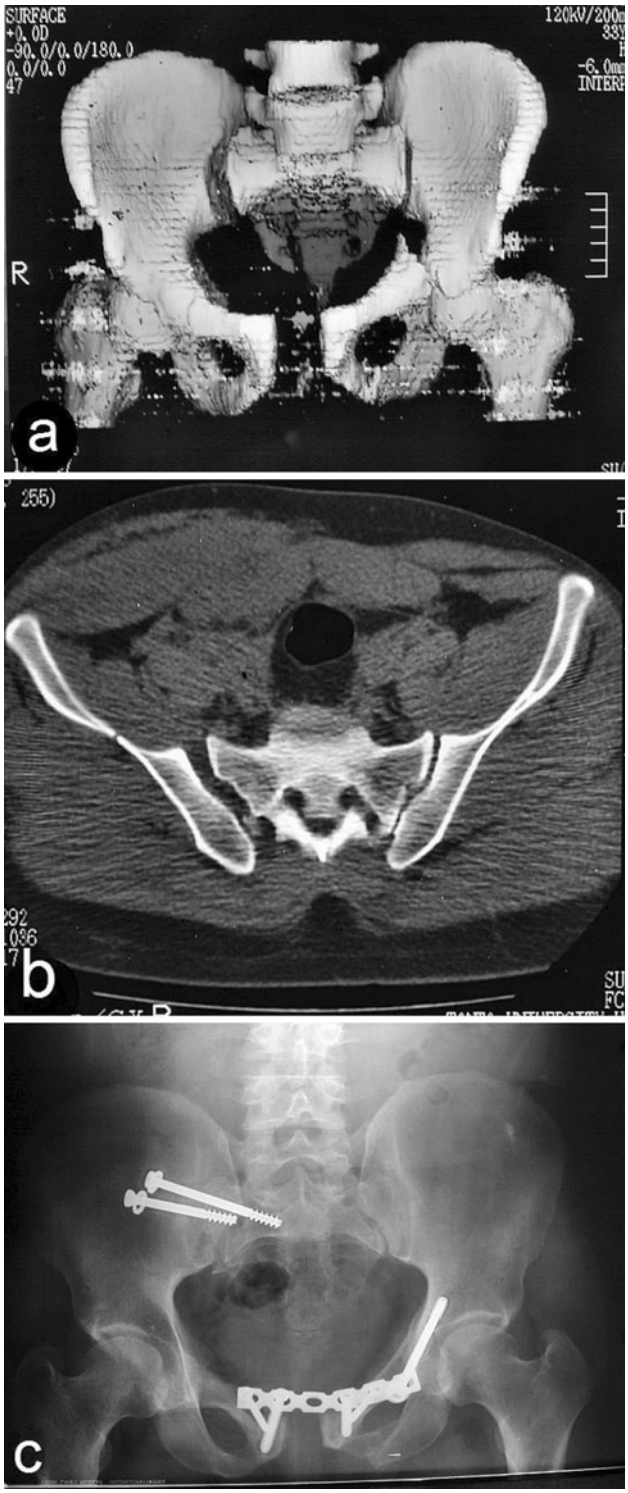

Fig. 3 **a** The AP 3D reconstruction CT image of 34–year-old pedestrian male patient with 38-point PTS score shows symphysis pubis disruption, *left* acetabulum low anterior column fracture and *right* sacroiliac joint injury. **b** The axial CT scan section that shows type C injury of the *right* sacroiliac joint. **c** The plain AP view after 13 months from internal fixation with symphyseal plate, retrograde anterior column screw and two washered percutaneous iliosacral screws shows the partially loose improper short iliosacral screws without loss of reduction, and the unsatisfactory anterior radiological result. The patient had fair clinical outcome

decreased blood transfusion rate among this group. More recently, Vallier et al. [4] confirmed our study findings and stated that early fixation of unstable pelvis and acetabular fractures in multiple-injured patients reduces morbidity and length of intensive care unit stay, which may decrease treatment costs. We agree with Flint and Cryer who stated that multidisciplinary protocols that control haemorrhage and manage other associated injuries as rapidly as possible have made it possible to prepare most patients for orthopaedic stabilization of their pelvic fracture within 24–72 h of injury [14].

Sacroiliac joint dislocations had the worst clinical and radiological findings among our cases especially those operated during the second week. This was partially due to the initial difficult closed anatomical reduction and partially due to the late development of post-traumatic sacroilitis. Similarly, Routt et al. [15] found particular difficulties when performing screw fixation of sacroiliac joint dislocations, due to the extreme difficulty of closed reduction. Also, Jacob et al. [16] had postoperative displacements of 2–22 mm in three out of four sacroiliac joint dislocations, which were reduced in closed technique, in spite of CT-guided iliosacral screw fixation.

Although primary anterior pelvic arch stabilization reduced the posterior lesions indirectly in this study, but closed anatomical reduction was very difficult to achieve during the second week after trauma, therefore, the radiological results were better significantly in the cases operated during the first week. Similarly, in the literature, it was found that closed reduction was very easy to achieve within the first 5 days after injury [17]. Patients treated after 7 days may require open reduction because of soft-tissue fibrosis that could prevent closed reduction [18, 19].

No posterior infection was recorded in this series in spite of the presence of MLL in four cases. This confirmed the golden role of the percutaneous technique in the presence of these massive soft-tissue injuries to avoid impaired posterior surgical wound healing and subsequent infection as evidenced in the literature [20, 21].

The satisfactory clinical and radiological results in 73.8 and 88.1% of this study cases, respectively, pay attention towards the effectiveness of percutaneous iliosacral screws in managing the highly unstable posterior pelvic ring instabilities especially in polytraumatized patients. Oh et al. [22] could also have a high rate of satisfactory outcomes (84%) in radiological reductions and function using the same principle.

Although neurological injuries had insignificant effect on the final clinical outcome in this series, they were responsible for 9.6% of the unsatisfactory results. Denis et al. [9] declared that the residual neurological deficit is critical factor affecting the functional outcome. Also, Lindahl and Hir-

vensalo documented the permanent neurological injury as a prognostic factor [23].

Although supraacetabular external fixators had a major role in controlling the initial haemodynamic instability and achieving good pelvic tamponade in 11 cases of this study, anterior plating had enhanced significantly the radiological and clinical results in conjunction with the percutaneous iliosacral screws. Similarly, anterior plate fixation, rather than an external fixation, is known to have the lowest rate of malunion and the highest rate of good functional outcome in Keating et al. series [18]. Also Sagi et al. [24] reported that anterior plating for the vertically unstable hemipelvis significantly increases the stability of the fixation construct.

Iliosacral screw position was divided into three categories postoperatively: completely within the bone; bordering on the neural foramina or the spinal canal; running through the neural foramina or the spinal canal [25]. Also, malposition was defined as any screw penetration of the bony cortices, regardless of the direction of the penetration (spinal canal, neuroforamen, intervertebral L5/S1, ventral penetration); on the other hand, correct screw placement was defined as a complete intercortical screw position [26]. In this study, no malpositioned screws, iatrogenic nerve injuries and/or worsened existing nerve injuries were encountered. The succeeded closed reduction, good C-arm machinery tracing of the safe bony landmarks, and the absence of sacral structures dysmorphism, or screws over-compression may be responsible for the absence of these complications in our cases. The risk of malpositioning of sacroiliac screws, with and without neurological injury, has been reported to be between 0.5% and 24% [16, 27]. However, with the use of high-quality image intensification and with due regard to the anatomy of the sacrum, the rates of complication have reached 0% as in Gardner et al. series [28]. Routt et al. [29] emphasized the use of the lateral image and the sacral alar slope and iliac cortical density to establish the 'safe zone' for screws application. Most recently, Grosterlinden et al. [26] had screw misplacement in 13 cases (8%), and three of them were applied under navigation control. They concluded that the accuracy of iliosacral screw placement depends significantly on the surgeon's experience, and in spite of the helpful effect of the navigation control to reduce the misplacement rate, its use leads to a potential increase of costs, and in the beginning, a relevant learning curve has to be overcome.

Insignificant loosened screws, without loss of posterior reduction, were faced in two cases of this study. The screws had correct intercortical positions but they were improperly short and about to penetrate the anterior alar cortex. The improper screwing was directly related to difficult closed reduction of the dislocated sacroiliac joints late at the end of the second week, and defective imaging in the presence of obesity. Likewise, Tosounidis et al. [30] had two cases of screw loosening and one case of screw bending, and they did not require further intervention.

According to findings of this series, early percutaneous iliosacral screwing can be advised for the polytraumatized patients with highly posterior pelvic ring instabilities especially in the presence of good experience, perfect closed reduction, high resolution fluoroscopy machine and massive soft-tissue injury including MLL. This technique can gain early rigid fixation without decompression of the huge pelvic haematoma and without disturbing the already impaired and just corrected haemodynamic parameters. It can help to reduce the expected long-term morbidity, devastating complications and hospital costs of those patients.

Conflict of interest No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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