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Radiographic and clinical evaluation of external pedicle screw fixation as a definitive solution for selective acetabular fractures: a retrospective analysis

Zhen Xia[1†], Yazhong Zhang[1†], Xu Zhang[1,2], Wenbo Li[1], Yongxiang Lv[1], Xiangyu Qi[1,2], Yunqing Wang[1] and Ziqiang Zhu[1*]

Abstract

Background Acetabular fractures typically require open surgery to restore hip joint function. Openness may lead to serious tissue damage, increased bleeding, and the risk of nerve and vascular damage. Minimally invasive closed reduction or percutaneous fixation aims to minimize additional harm to patients and provide reliable fixation to promote fracture recovery and functional rehabilitation. This study aimed to assess the radiographic and clinical effectiveness of pedicle screw external fixation as a definitive treatment approach for selective acetabular fractures.

Methods The present study enrolled 43 patients with acetabular fractures who were categorized into three groups based on their definitive treatment plans: pedicle screw external fixation group, traditional external fixation stent fixation group, and open reduction internal fixation group, comparing the operative duration and the time required for fracture healing. Fracture reduction was evaluated using the Tornetta and Matta grading system, and postoperative clinical outcomes were analyzed using the Majeed score. Analyze three surgical methods by comparing clinical indicators and prognostic references.

Results Among the 43 patients, there were 12 cases in the pedicle screw external fixation group, 14 cases in the traditional external fixation stent fixation group, and 17 cases in the open reduction internal fixation group. There were no significant differences in age, gender, injury mechanism, Injury Severity Score (ISS), or other demographic factors among the three groups. The reduction of fractures with internal fixation was significantly better than that with external fixation($p=0.032$). Operative duration and quality of reduction did not significantly differ between the pedicle screw external fixation group and the traditional external fixation stent fixation group. However, the pedicle screw external fixation group exhibited distinct advantages in postoperative quality of life ($p=0.041$) and a lower incidence of loose fixing screws compared to the traditional external fixation stent fixation group.

†Zhen Xia and Yazhong Zhang contributed equally to this work and share first authorship.

*Correspondence:
Ziqiang Zhu
zhuziiq@163.com

Full list of author information is available at the end of the article

Conclusion Compared to traditional external fixation stent fixation, pedicle screw external fixation represents a superior definitive treatment option for acetabular fractures due to its stability and improved patient quality of life.

Keywords Acetabular fractures, Pelvic fractures, Minimally invasive external fixation, Pedicle screw external fixation, Operation, Outcome

Introduction

Acetabular fractures have been associated with high mortality rates and severe complications. These fractures typically occur in high-energy accidents, such as traffic collisions and falls from significant heights [1]. They are categorized as intra-articular fractures, and open surgery is often necessary for cases with substantial displacement to restore hip joint function [2]. Open reduction and internal fixation can result in substantial tissue damage, increased bleeding, and risks of nerve and vascular injuries. Patients with acetabular fractures frequently sustain multiple-system composite injuries, complex and severe trauma can cause hemodynamic instability in patients, and some may not meet the surgical prerequisites for open procedures [3]. Minimally invasive closed reduction or percutaneous fixation aims to minimize additional harm to patients, maintain hemodynamic stability, and provide reliable fixation to promote fracture recovery and functional rehabilitation [4].

For individuals who do not meet the indications for open surgery following trauma, timely and stable fixation can be advantageous for maintaining hemodynamic stability and reducing the incidence of severe complications [5]. Minimally invasive surgical techniques for pelvic injuries include traditional external fixation with stent fixation, percutaneous nail rod system pelvic internal fixator (INFIX), closed reduction with percutaneous anterior column screw fixation, and percutaneous minimally invasive steel plate internal fixation. Traditional external fixation with stent fixation, as the most prevalent minimally invasive pelvic treatment, has drawbacks, including poor fixation needle holding power, inconvenient nursing, and a diminished quality of life for patients [1, 6]. However, although INFIX fixation is considered to be in line with the concept of minimally invasive surgery to some extent and can provide stronger stability compared to external fixation nails, there is often a risk of damaging the lateral femoral cutaneous nerve and soft tissue during complex surgical procedures [7]. To enhance screw stability, pedicle screws and connecting rods are typically employed for external fixation to simplify the surgical process, thereby offering a stable environment for fracture healing and significantly improving the postoperative quality of life for patients with pelvic fractures [8].

This study involves data collection and follow-up of patients with acetabular fractures who use external fixators as the final treatment strategy. We assume that external fixation as the ultimate treatment strategy is a reliable choice under complex trauma conditions. We validate this by comparing the clinical efficacy and imaging results of patients with novel pedicle screw external fixation, traditional external fixation stent fixation, and open surgery.

Methods

Patients

This study retrospectively analyzed 43 patients diagnosed with acetabular fractures who underwent surgical treatment at our hospital from January 2019 to January 2022. All patients were categorized into three groups for comparative research, depending on their surgical plans: patients who underwent pedicle screw external fixation (Group A, $n=12$), traditional external fixation stent fixation (Group B, $n=14$), and open reduction and internal fixation (Group C, $n=17$) for their acetabular fractures. All patients participated in postoperative follow-up for a minimum of 12 months. The summary process of this study is shown in Figure 1.

Ethical approval

for this study was obtained from the Medical Human Experimental Ethics Committee of Xuzhou Medical University (ethical approval number: [2019]080701), and all patients signed a written informed consent before recruitment, all experiments were performed in accordance with relevant guidelines and regulations. All procedures in this study were conducted in accordance with the Declaration of Helsinki.

Fracture types

Our cases include the following fracture types: (i) Closed acetabular fractures; (ii) Absence of hip joint dislocation; (iii) Significant anterior ring displacement that can be effectively managed with closed reduction; and (iv) A stable posterior pelvic ring, with or without fractures.

Inclusion criteria

Open reduction and internal fixation: i. The patient has a simple acetabular fracture and the fracture type has surgical indications for open reduction and internal fixation. Acetabular fracture is the main diagnosis of the patient (surgical indications: (1) Hip joint fracture accompanied by femoral head dislocation. (2) Although there is no femoral head dislocation, when the displacement of the fracture fragment in the acetabular fracture exceeds 2 mm, (3) The defect in the posterior wall or column of

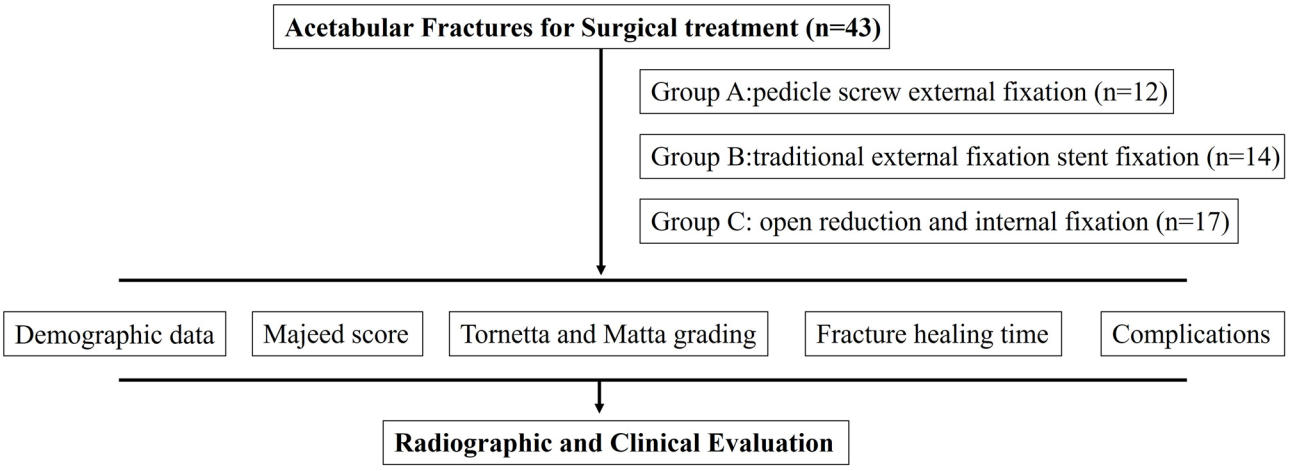

Fig. 1 The flowchart of the study

the acetabular fracture is greater than 40%. (4) The displaced fracture fragment affects the acetabular top.); ii. The patient has multiple system injuries, but all other system injuries have been treated and meet the general conditions for open reduction and internal fixation.

Closed reduction and external fixation: (i) The patient's acetabular fracture displacement is not significant; (ii) The patient's acetabular fracture displacement is significant, but the patient has multiple system injuries and does not have the conditions for open reduction and internal fixation under emergency conditions. Therefore, a temporary closed reduction and external fixation surgery is performed, and the patient does not have the basic conditions for open reduction and internal fixation during subsequent recovery.

Exclusion criteria

Injury to surgery time exceeding 3 weeks; Open pelvic fracture or combined acetabular fracture; Combined with severe osteoporosis; Combined cognitive impairment, unable to cooperate with treatment.

Preoperative examination

All patients underwent X-ray and CT examinations, and 3D bone models were generated by reconstructing 2D CT images in axial, sagittal, and coronal planes. The imaging digital system was used to assess and measure the presence and degree of pelvic fracture displacement.

Surgical procedures

Pedicle screw external fixation group (Group A)

General anesthesia or local anesthesia combined with analgesia was administered with the patient in a supine position. Two incisions, approximately 2 cm in length and spaced about 2 cm apart, were made 1 to 2 cm behind the bilateral anterior superior iliac spine. The skin and subcutaneous tissue were incised, and they were meticulously separated to expose the anterior superior iliac spine. A universal pedicle screw, 60–85 mm in length, 6.5 mm in diameters, was inserted along the direction of the iliac bone. C-arm fluoroscopy was used during surgery to confirm screw position and prevent penetration of the bone. The titanium rod was pre-bent and connected according to the patient's abdominal shape, maintaining a distance of approximately 2–3 cm between the connecting rod and the abdomen. Based on the injury mechanism, the affected side was appropriately braced or compressed to achieve fracture reduction and fixation, followed by tightening the tail cap. Two connecting rods were joined using connectors. Typical cases are shown in Figs. 2 and 3.

External fixation with stents group (Group B)

The anesthesia and fixation needle positions were identical to those in Group A, with traditional external fixation connecting rods for connection. Both Group A and Group B underwent femoral traction surgery, depending on the fracture displacement prior to surgery, with traction reduction or lateral compression reduction performed during the operation. Typical cases are shown in Figs. 4 and 5.

Open reduction and internal fixation group (Group C)

After induction of general anesthesia, open reduction, and internal fixation were carried out using steel plates/screws through a conventional surgical approach for acetabular fractures. The surgical approach employed in this study included the ilioinguinal approach and the Stoppa combined iliac fossa surgical approach. Typical cases are shown in Figs. 6 and 7.

Postoperative management

Thrombolytic agents were administered to prevent thrombosis following surgery. Passive hip joint

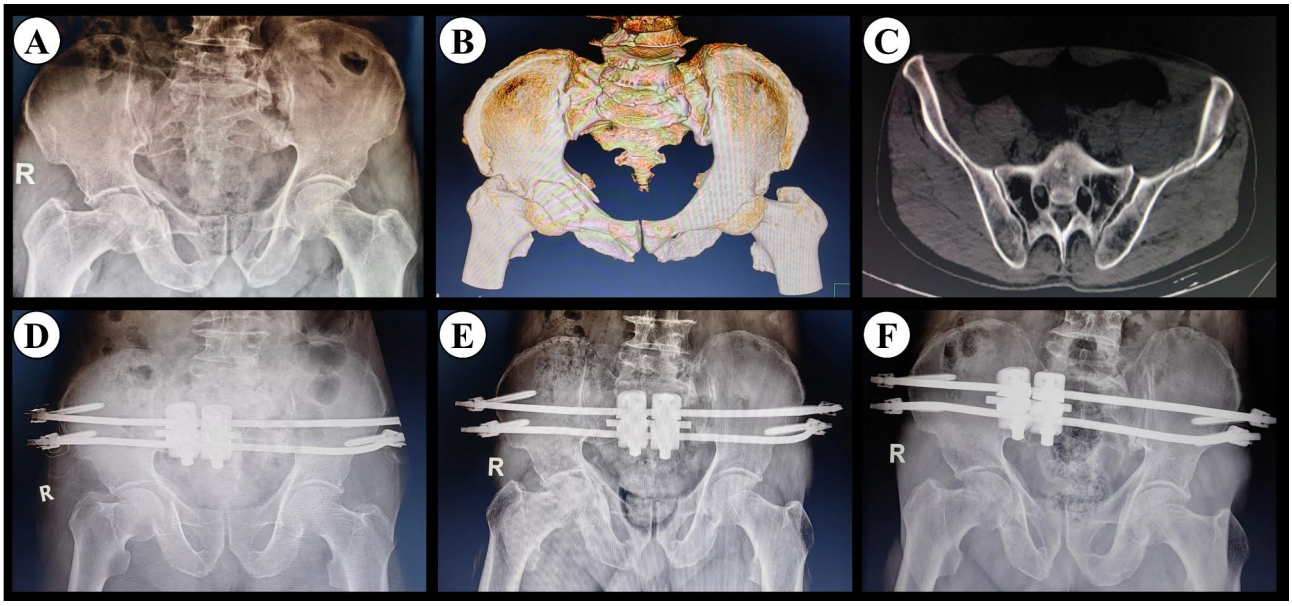

Fig. 2 **A** and **B**: Preoperative X-ray pelvic anteroposterior and CT three-dimensional reconstruction display, Letournel-Judet classification VIII, Matta score NA. **C**: Pre operative CT plain scan showed iliac bone fracture with no significant displacement. **D**: After external pedicle screw fixation, X-ray examination of the pelvis in the anteroposterior position. **E** and **F**: After 1 month and 3 months of external fixation with pedicle screws, X-ray examination showed obvious callus formation

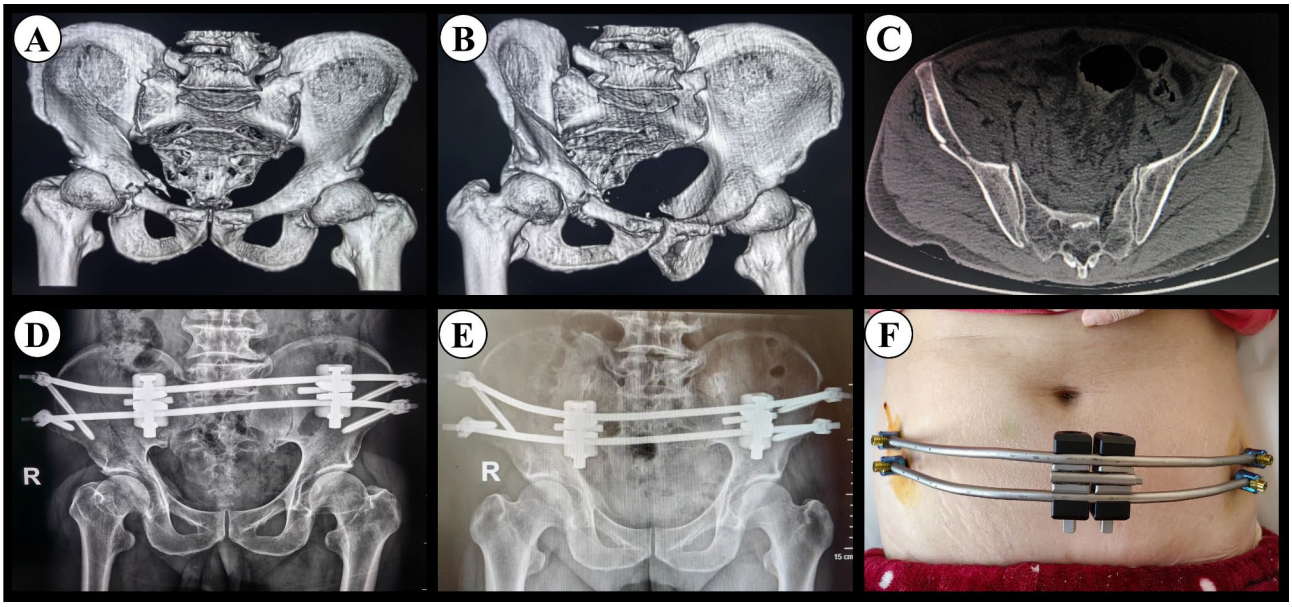

Fig. 3 **A** and **B**: Preoperative CT three-dimensional reconstruction examination showed Letournel-Judet classification VII, with a Matta score of M. **C**: Pre operative CT plain scan showed ipsilateral iliac bone fracture. **D**: After the pedicle screw external fixation surgery, X-ray examination of the pelvis showed free bone fragments in the posterior wall. **E**: Three months after the external pedicle screw fixation surgery, X-ray examination showed obvious callus formation, and free bone fragments were still visible on the posterior wall. **F**: Photos of pedicle screw external fixation

movement training began three days post-surgery, with active hip joint movement starting ten days after surgery. X-ray examination should be conducted every two weeks after surgery to verify the formation of callus and determine bone healing. Starting from 12 weeks after surgery, it is encouraged not to use crutches for complete weight-bearing.

Between 4 and 6 weeks post-surgery, patients began attempting to stand and walk with crutch support. Recommendations were made for the affected limb on the injured side not to bear full weight, with potential delayed weight-bearing due to post-fracture pelvic ring fractures. Patients with bilateral posterior pelvic injuries attempted to stand with bilateral assistance. Full

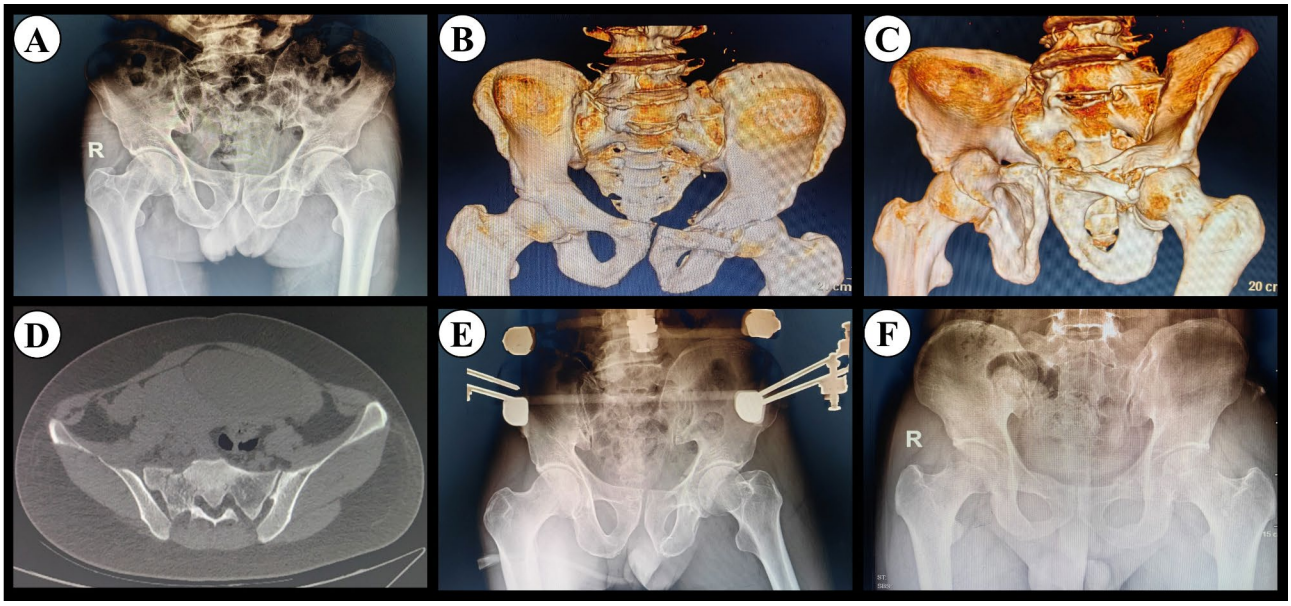

Fig. 4 **A-C**: Preoperative X-ray pelvic anteroposterior and CT three-dimensional reconstruction examination showed Letournel-Judet classification VIII, Matta score M, and significant displacement of acetabular anterior column fracture. **D**: CT plain scan showed a posterior pelvic ring sacral fracture with no significant displacement. **E**: Postoperative X-ray examination of the pelvis by external fixation with stents. **F**: After removing external fixation devices, recheck the X-ray pelvic anteroposterior position

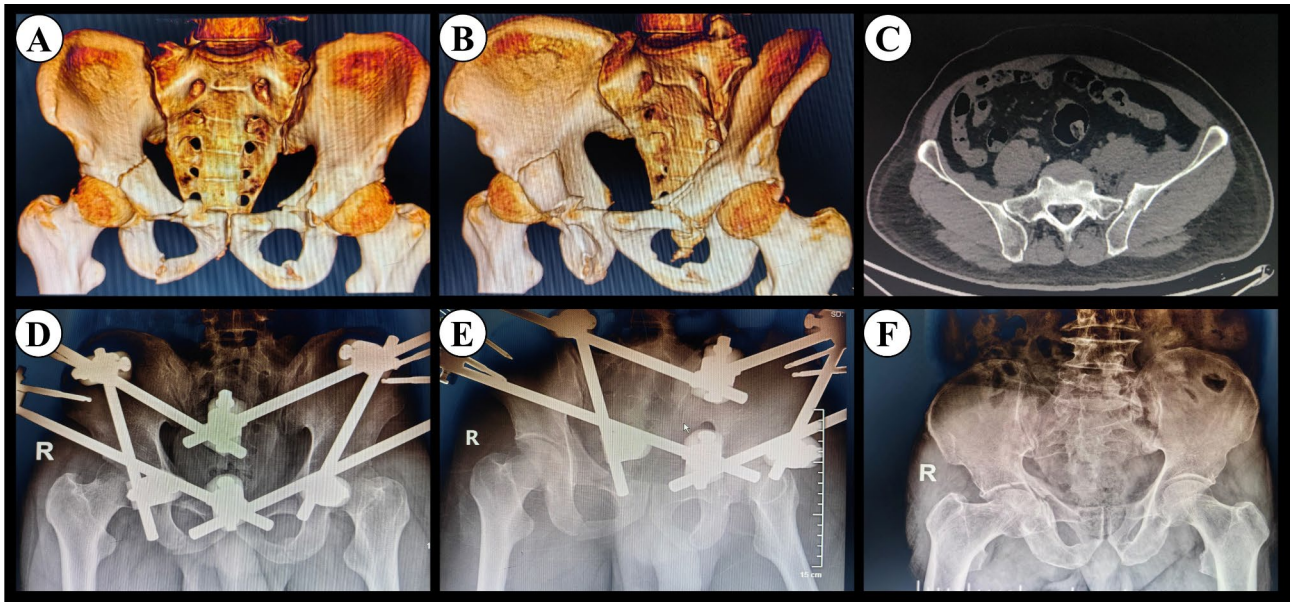

Fig. 5 **A** and **B**: Preoperative CT three-dimensional reconstruction examination showed bilateral acetabular fractures, Letournel-Judet classification III/IV, Matta score M/NA. **C**: CT plain scan showed a fracture of the posterior iliac bone in the pelvis, with no significant displacement of the fracture. **D** and **E**: X-ray examination of the pelvic anterior and posterior position after external fixation with stents and one month after surgery. **F**: Three months after surgery, remove the fixed instruments and recheck the X-ray pelvic anteroposterior position

weight-bearing standing or walking typically began 12 weeks after the injury, based on evidence of callus formation in X-ray examinations and patient pain tolerance. After confirming stable callus formation, all external fixation instruments were removed within 3 to 6 months postoperatively.

Postoperative follow-up and functional score

Following the surgical procedure, patients underwent a series of postoperative assessments and functional evaluations. These assessments were conducted at specific time points: immediately following the procedure, at 1 month, 3 months, 6 months, 1 year, and during recent follow-up intervals. During follow-up, X-ray images

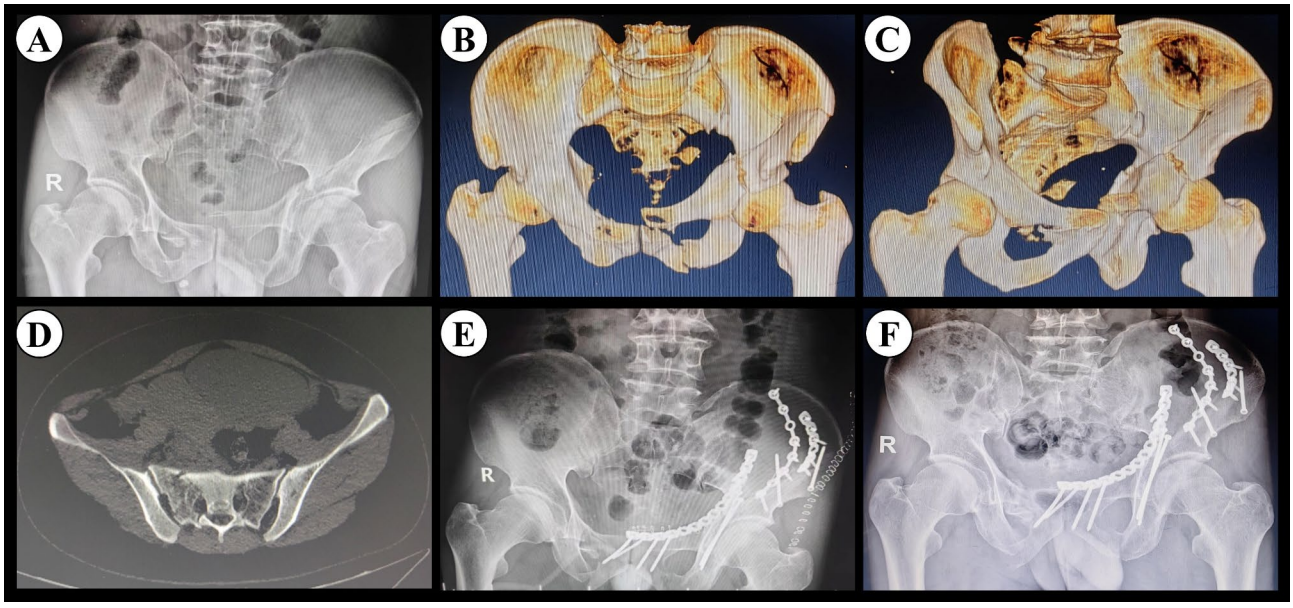

Fig. 6 **A-C**: Preoperative pelvic X-ray and CT three-dimensional reconstruction examination showed Letournel-Judet classification IX, with a Matta score of M. D: CT plain scan showed a posterior pelvic ring sacral fracture with no significant displacement. **E**: Open reduction and internal fixation for acetabular and iliac fractures through the ilioinguinal approach. Internal fixation of the anterior wall of the acetabulum with channel screws. **F**: Follow up X-ray examination 3 months after surgery

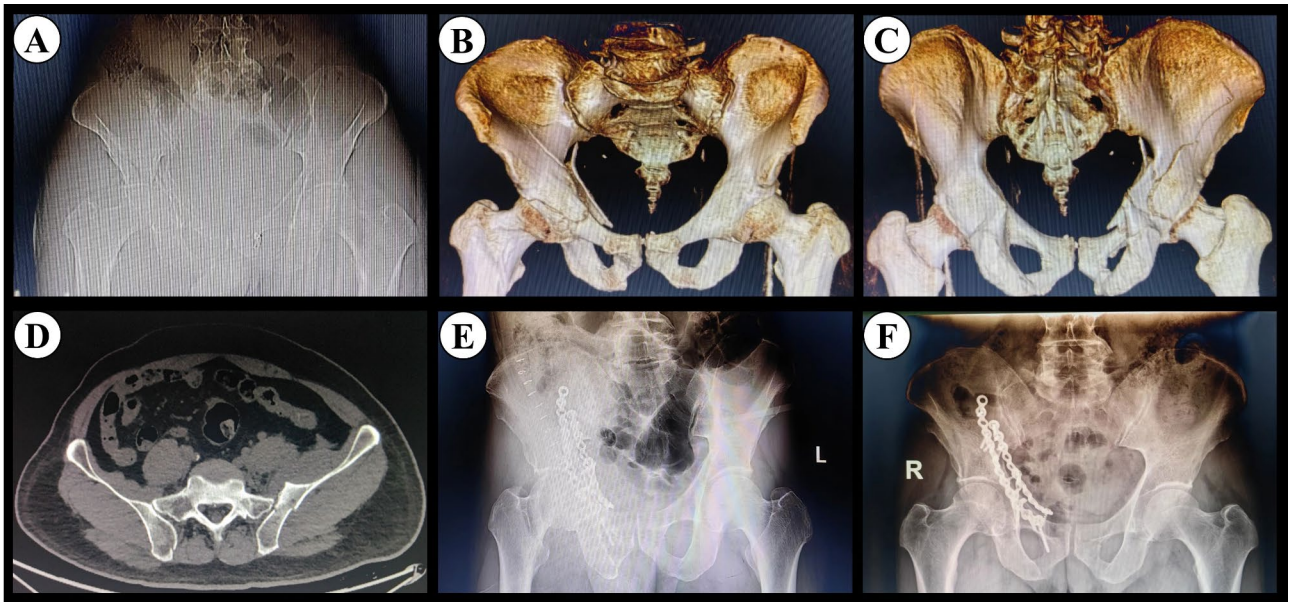

Fig. 7 **A-C**: Preoperative pelvic X-ray and CT three-dimensional reconstruction examination showed Letournel-Judet classification X, with a Matta score of M. D: CT plain scan showed a posterior pelvic ring iliac bone fracture with no significant displacement. **E**: Open reduction and internal fixation of acetabular fractures through the ilioinguinal approach. **F**: Follow up X-ray examination 3 months after surgery

were taken to monitor fracture recovery, and radiological scores were determined using the Matta and Saucedo methods. The postoperative quality of life and functional outcomes of patients in the external fixation group were assessed, focusing on sitting, walking, lying flat, and the lateral position, utilizing the Majeed pelvic score. Additionally, the follow-up assessment examined the impact of external fixation devices on soft tissue damage and pain. Evaluated complications encompassed external fixation device failure and loosening, screw-related infections, ectopic ossification, stimulation of the lateral femoral cutaneous nerve, and traumatic arthritis.

Radiological evaluation is based on Matta and Saucedo's method, defining fracture displacement ≤ 4 mm as

Table 1 Patient demographics

Parameter	Group A $n=12$	Group B $n=14$	Group C $n=17$	p
Age (years)	55.08 ± 11.20	53.50 ± 10.40	55.00 ± 9.94	0.903
Gender: male/female	8/4	10/4	11/6	0.921
Injury mechanism				0.563
Traffic accident	8	7	11	
Fall from height	3	5	6	
Other	1	2	0	
ISS	37.08 ± 11.29	40.93 ± 9.65	41.41 ± 8.86	0.471

anatomical (A), displacement 4–10 mm as near anatomical (NA), displacement 1–2 cm as moderate (M), and displacement ≥ 2 cm as poor (P). A and NA are considered satisfactory results.

Patient functional outcomes were assessed by the Majeed pelvic score. Patients were scored based on their pain level, work status, sitting posture, use of walking aids, independent gait, and walking distance. Patients were categorized into two groups: those who were working before the injury and those who were not. Functional outcome scores ranged from 100 points (best score) and were further classified 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). Patient satisfaction was defined by Excellent and Good scores.

Statistical methods

Statistical analyses were conducted using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used for assessing data normality. Group comparisons employed the two-sided Chi-square test. Perform statistical analysis on three sets of data using one-way ANOVA and Tukey HSD post hoc analysis. Differences were considered significant at $p < 0.05$.

Results

Demographic data

The workflow of this study is demonstrated in Fig. 1.

The mean age of patients that underwent pedicle screw external fixation surgery (Group A, $n=12$), traditional external fixation stent fixation (Group B, $n=14$), and open reduction and internal fixation surgery (Group C, $n=17$) was 55.08 ± 11.20, 53.50 ± 10.40, and 55.00 ± 9.94 years, respectively. There were no significant differences among the three groups ($p=0.903$). Additionally, the gender distribution and injury mechanisms were comparable among the three patient groups. The predominant injury mechanism was traffic accidents ($n=26$, 60.47%), followed by high-altitude fall injuries ($n=14$, 32.56%) and other causes ($n=3$, 6.98%). The Injury Severity Score (ISS) was comparable for the three patient groups (37.08 ± 11.29, 40.93 ± 9.65, and 41.41 ± 8.86, respectively, $p=0.471$). The dates are listed in Table 1.

Among the 48 patients analyzed in this study, 29 (61.7%) had concomitant multiple fractures in other body parts, including head ($n=22$), chest and lung ($n=19$), abdominal ($n=15$), and urinary system ($n=12$) injuries. None of the patients included in the study experienced any fatal events during their hospitalization. Over the follow-up period, a total of 5 patients passed away, comprising 1 patient from the pedicle screw external fixation group, 2 patients from the traditional external fixation stent fixation group, and 2 patients from the open reduction internal fixation group. The causes of death were attributed to multiple organ failure and abnormal cardiopulmonary function, with no direct link to the surgical procedures. These five patients are not included in the data statistics.

We have collected fracture related information for all patients, including gap displacement and fracture length. The dates are listed in Table 2.

Out of the 43 patients with acetabular fractures, 32 (74.42%) had posterior ring fractures (sacral and iliac fractures), and 29 (67.44%) had pubic ramus fractures. According to the Letournel-Judet classification, the distribution of acetabular fractures was as follows: type II ($n=3$), type IV ($n=34$), type V ($n=5$), type VI ($n=3$), type VII ($n=7$), type VIII ($n=8$), type IX ($n=6$), and type X ($n=8$).

Table 2 Fracture information

	Group A $n=12$	Group B $n=14$	Group C $n=17$
Gap displacement (mm)			
2–5	4	6	5
5–10	3	5	3
>10	5	4	9
Length (mm)			
0–10	2	4	6
10–30	3	2	4
30–50	5	4	4
>50	2	4	3

Trauma-related complications that occurred during the treatment period were as follows: pneumonia ($n=14$), urinary system infection ($n=10$), acute respiratory distress syndrome ($n=5$), deep vein thrombosis (managed with minimally invasive intervention, $n=5$), and pressure ulcer ($n=1$).

Surgical indicators

The average operative duration for the three patient groups was 27.08±8.38 min, 26.07±6.84, and 170.00±29.84, respectively, with a statistically significant difference ($p=0.000$). The pedicle screw external fixation group (Group A) and the traditional external fixation stent fixation group (Group B) exhibited comparable operative duration. We did not compare the surgical time between external fixation and internal fixation, which is meaningless. Fracture reduction status was assessed using the Tornetta and Matta grading system. In Group A, most patients achieved moderate ($n=5$) and near anatomic ($n=4$) reduction, followed by anatomic ($n=2$) and poor ($n=1$) reduction, resulting in a satisfaction rate of 50%. Consistently, in group B, most patients achieved moderate ($n=6$) reduction, followed by near anatomic ($n=3$) and poor ($n=3$) reduction, and anatomic ($n=2$) reduction, resulting in a satisfaction rate of 35.71%. In the open reduction and internal fixation group (Group C), most patients achieved near anatomic reduction ($n=9$), followed by anatomic ($n=6$) and moderate ($n=2$) reduction, resulting in a satisfaction rate of 88.23%. There was no significant statistical difference in postoperative anatomical scores among the three groups ($p=0.093$). However, it cannot be denied that the reset quality of the internal fixation group is significantly better than that of the external fixation group. The external fixed group can only complete a certain degree of reset.

Rehabilitation

The postoperative rehabilitation of all patients mainly includes two methods: on the one hand, rehabilitation is carried out in professional rehabilitation and health institutions; On the other hand, patients should follow the doctor's guidance and engage in rehabilitation exercises on their own upon discharge, and follow up with follow-up guidance at the hospital. The rehabilitation content mainly includes lower limb muscle strength exercise, joint function activity exercise, and sensory stimulation. The goal is to walk independently or use assistive devices to walk independently. The proportion of self rehabilitation/rehabilitation institutions in each group is Group A (8/4), Group B (10/4), and Group A (11/6).

Functional rating

The Majeed score was used to assess postoperative patient function, with patients divided into two groups based on their pre-injury working status: the pre-injury normal working group and the non-normal working group. The maximum score for the non-normal working group was 80 points, converted as a percentage of 100 points. The mean scores for the three groups were 75.67±7.40, 70.71±11.47, and 76.53±9.08, respectively, with no significant difference ($p=0.221$). In Group A, 3 patients scored Excellent (<85), 7 scored Good (69–85), and 2 scored Fair (55–69), resulting in a satisfaction rate of 10/12 (83.33%). Group B had 3 patients scoring Excellent (<85), 5 scoring Good (69–85), 5 scoring Fair (55–69), and 1 scoring Poor (<55), with a satisfaction rate of 8/14 (57.14%). In Group C, 6 patients scored Excellent (<85), 8 scored Good (69–85), 2 scored Fair (55–69), and 1 scored Poor (<55), resulting in a satisfaction rate of 14/17 (82.35%). There was no significant difference in satisfaction rate ($p=0.652$). The results indicate that satisfactory postoperative functional recovery can be achieved for our study population.

Fracture healing time

The fracture healing times for Groups A, B, and C were 14.08±3.68, 15.36±4.09, and 13.06±3.49 weeks, respectively. There was no significant difference in the healing time among the three fracture groups ($p=0.652$).

The dates of comparison of clinical outcomes are listed in Table 3.

Complications

Postoperative complications among the three surgical groups primarily included screw loosening, wound infection, soft tissue pain, and traumatic arthritis. Group B had 3 cases of screw loosening, demonstrating a significant difference compared to the other two groups ($p=0.041$). There were no significant differences in incidence of wound infection, soft tissue pain, and traumatic arthritis among the three groups. The dates of complications are listed in Table 4.

Discussion

In contrast to anterior ring fractures of the pelvis, acetabular fractures require higher standards for surgical reduction. In the external fixation surgery group, potential definitive treatment necessitates achieving the maximum possible reduction through traction or compression before and during surgery. While the pedicle screw external fixation group exhibited a lower satisfaction rate for surgical reduction quality (approximately 50%), which was significantly lower than the open reduction internal fixation group (88.23%), there was no significant difference ($p>0.05$), which may be attributed to the small sample size. In terms of postoperative complications, the pedicle screw external fixation is significantly superior in terms of quantity compared to the external fixation

Table 3 Comparison of clinical outcomes

	Group A $n=12$	Group B $n=14$	Group C $n=17$	p
Procedure time (mins)	27.08 ± 8.38	26.07 ± 6.84[a]	170.00 ± 29.84	0.000
Fracture healing time (weeks)	14.08 ± 3.68	15.36 ± 4.09	13.06 ± 3.49	0.652
Tornetta and Matta grading				
A	2	2	6	
NA	4	3	9	
M	5	6	2	
P	1	3	0	
Satisfactory rate	6/12(50%)	5/14(35.71%)[b]	15/17(88.23%)	0.093
Majeed score	75.67 ± 7.40	70.71 ± 11.47 [c]	76.53 ± 9.08	0.221
Excellent (>85)	3	3	6	
Good (69–85)	7	5	8	
Fair (55–69)	2	5	2	
Poor (≤55)	0	1	1	
Satisfactory rate	10/12(83.33%)	8/14(57.14%)	14/17(82.35%)	0.652

a: compared with Group A, $p=0.738$; b: compared with Group A, $p=0.782$; c: compared with Group A, $p=0.041$

Tornetta and Matta grading- A: anatomic, NA: nearly anatomic, M: moderate, P: poor

Table 4 Surgical complications

	Group A $n=12$	Group B $n=14$	Group C $n=17$	p
loose screws	0	3	0	0.041
wound infection	1	3	1	0.374
soft tissue pain	1	1	2	0.890
traumatic arthritis	1	1	1	0.963

group. However, at the final follow-up, there was no statistically significant difference in functional scores and fracture healing time among the three patient groups, but the traditional external fixation stent fixation had lower numerical values than the other two groups. Due to the limited quality of external fixation and reduction, long-term follow-up is needed to assess complications, including traumatic arthritis of the hip. Theoretically, compared with open reduction, traumatic arthritis has a higher incidence rate. However, we should also consider the cost performance ratio of surgical risk and prognosis. On the other hand, closed reduction reduces damage to the blood supply and the joint capsule, which requires longer follow-up for verification.

In terms of patient functional outcomes, at the last follow-up, the satisfaction rate of the pedicle screw external fixation group was similar to that of the open reduction group. Although there was no significant difference compared to the traditional external fixation stent fixation group, there was a significant advantage in the satisfaction rate value, which may be limited by the sample size. For emergency trauma patients, multiple system injuries, stable fixation, high-quality postoperative care, and high quality of life often have a significant impact on fracture healing. Compared with the traditional external fixation bracket fixation group, the pedicle screw external fixation group not only provides stronger stability, but also significantly improves the quality of life of patients, which is beneficial for wound healing and psychological rehabilitation. In this study, there were no serious postoperative complications in the pedicle screw external fixation group, and the fixation screws were removed 3–4 months after surgery [9]. A patient experienced inflammation around the incision, which healed after removing the screw. Some research groups have reported complications related to pelvic external fixation, needle bundle infection (2.5–50%), aseptic loosening (0–19%), an increase in fracture displacement (0–33%), skin and subcutaneous tissue compression (8%), and nerve damage (0–7%) [10]. The pitch and thread depth of the pedicle screw are significantly greater than those of the external fixation needle. During the follow-up process, no cases experienced screw loosening, making this external fixation method more advantageous for patients with osteoporosis. Lateral femoral cutaneous nerve (LFCN) stimulation is the most common postoperative iatrogenic complication. A multicenter study showed that 30% (21/91) of patients had LFCN stimulation, but in most cases, LFCN was self-limiting and improved after implant removal. In the present study, the anterior superior iliac spine was selected for minimally invasive surgery and no cases of nerve damage were observed [3, 11]. Meanwhile, based on predictive model algorithms, redefining fracture classification and treatment through new methods can help establish more mature judgment criteria for acetabular fractures under complex trauma conditions [12, 13].

During clinical practice, for patients with acetabular fractures and multiple system injuries who cannot undergo open reduction and fixation, anterior external fixation is usually used for initial stability to ensure the stability of the pelvic ring [14, 15]. It can also be used

for definitive treatment in cases where fracture patients exhibit partial stability and unclear displacement [6, 11]. Acetabular fractures, being intra-articular fractures, often necessitate open reduction and internal fixation surgery for displacement greater than 2 mm [16]. This surgical approach aims to restore hip joint function and prevent traumatic arthritis. However, prolonged surgery and anesthesia under severe traumatic conditions may make open surgery unsuitable for patients with poor overall condition [17]. Minimally invasive surgical treatments, in combination with appropriate external reduction, aim to restore pelvic mechanical stability, reduce blood loss-induced shock, and offer better functional outcomes compared to non-surgical treatments. These procedures also significantly reduce postoperative disability rates and the likelihood of fracture deformity healing [18, 19]. Percutaneous reduction and external fixation are widely employed for pelvic fracture treatment due to their lower requirements for local soft tissue conditions, shorter surgical durations, reduced soft tissue damage, decreased bleeding, and enhanced functional recovery compared to open surgery [20, 21].

INFIX fixation technology operates on a principle similar to external fixators. Kuttert et al. employed INFIX for anterior ring fixation of unstable pelvic fractures as a definitive treatment in 2009 [4, 20]. This method offers the advantages of reduced soft tissue damage, lower blood loss, and a low incidence of iatrogenic nerve damage during surgery. It minimally impacts patients' daily activities and is suitable for obese patients. However, when INFIX rods and screws are inserted into the subcutaneous soft tissue, patients often experience significant foreign body sensation and are at risk of damage to the lateral femoral cutaneous nerve and the femoral nerve during insertion and removal [2, 22].

In the present study, we combined the advantages of two external fixation methods to preserve the stability and bone-holding power of INFIX. The improved INFIX technology features the following characteristics: (1) The pedicle screws and connecting rods are placed outside the skin, with the nail tail and connecting rods 1–2 cm away from the skin, allowing the patient to dress normally, lie on their side, and engage in sexual activity without discomfort. This significantly improves patients' quality of life compared to traditional external fixation stents; (2) The diameter of pedicle screws is generally over 6.5 mm, with lengths exceeding 60 mm, minimal force applied, and greater pitch and thread depth compared to external fixation pins, resulting in higher biomechanical fixation strength and suitability for patients with osteoporosis; (3) During surgery, tightening the connecting rod achieves a certain reduction effect; (4) The guide needle is used to explore the bone structure in front of the center of the hollow universal screw to prevent the screw from entering the pelvic cavity, thereby reducing the surgical time and shortening the learning curve; (5) Selecting the anterior superior iliac spine as the insertion point reduces the risk of lateral femoral cutaneous nerve injury; (6) Outpatient follow-up for fracture healing and patient pain from 2 to 3 months is carried out to remove the nail and rod system, avoiding secondary hospitalization surgery and reducing patient pain and expenses.

Our research has several limitations that should be acknowledged. Firstly, it should be borne in mind that the patient cohort in this study was relatively limited in size. Secondly, no stratification was conducted according to the various subtypes of acetabular fractures, which hindered the ability to establish the optimal treatment approach for a specific subtype of acetabular fracture. Thirdly, the duration of the follow-up period was relatively short, which made it challenging to assess potential long-term complications, such as traumatic arthritis.

This study introduces the effectiveness of pedicle screw external fixation as a definitive treatment method for patients with selective acetabular fractures. "Selective" means that the patient does not have the surgical conditions for open reduction and internal fixation at the time. In emergency treatment, pedicle screw external fixation has a better therapeutic effect than traditional external pelvic fixation. Therefore, this method is only suitable for special cases, and although statistical rigor is not guaranteed, the advantages in terms of data are obvious. In future work, we will continue to collect and statistically analyze similar cases in order to obtain a relatively sufficient number to rigorously verify our hypothesis about the problem of case limit.

In this study, external fixation with pedicle screws was used as the final treatment option for the primary treatment of post-ring-stabilized acetabular fractures. For some special types of fractures, such as multiple fractures or patients undergoing posterior ring surgery, it was not included in the study. For displaced acetabular fractures, open reduction and internal fixation remain the primary option. The significance of this study lies in two aspects: 1. Prior to open reduction surgery, pedicle screw external fixation has a more significant advantage compared to traditional screw external fixation; For patients who do not have the conditions for open reduction surgery after external fixation, closed reduction with pedicle screw external fixation can achieve good clinical results and can be used as a definitive treatment plan.

Conclusions

For patients with acetabular fractures and severe trauma who cannot undergo open reduction and fixation surgery, pedicle screw external fixation can be used as a definitive treatment option. Compared to traditional external fixation stent fixation, pedicle screw external fixation has

significant advantages in terms of fixation strength and improving patient quality of life.

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Author contributions
Zhen Xia and Yazhong Zhang wrote the main manuscript text; Zhen Xia and Xu Zhang collected the data; Yazhong Zhang prepared figures; Wenbo Li and Yongxiang Lv checked the data; Xiangyu Qi and Yunqing Wang calculated the data; Yunqing Wang and Ziqiang Zhu checked the data and manuscript text.

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Data availability
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained from the Medical Human Experimental Ethics Committee of Xuzhou Medical University, and all patients signed a written informed consent before recruitment.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopaedics, The Second Affiliated Hospital of XuZhou Medical University, No 32 Meijian Road, Xuzhou, Jiangsu 221000, China
[2]Graduate school of Xuzhou Medical University, Xuzhou, Jiangsu 221000, China

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References

1. Vaidya R, Kubiak EN, Bergin PF, Dombroski DG, Critchlow RJ, Sethi A, et al. Complications of anterior subcutaneous internal fixation for unstable pelvis fractures: a multicenter study. Clin Orthop Relat Res. 2012;470(8):2124–31.
2. Chen H, Ding C, Liu Y, Kong Z, Chang S, Huang F, et al. A clinical and biomechanical comparison of INFIX plus single versus double sacroiliac screw fixation for unstable pelvic ring injury. J Orthop Surg Res. 2022;17(1):285.
3. Bozzio AE, Johnson CR, Mauffrey C. Short-term results of percutaneous treatment of acetabular fractures: functional outcomes, radiographic assessment and complications. Int Orthop. 2016;40(8):1703–8.
4. Hung CC, Wu JL, Li YT, Cheng YW, Wu CC, Shen HC, et al. Minimally invasive treatment for anterior pelvic ring injuries with modified pedicle screw-rod fixation: a retrospective study. J Orthop Surg Res. 2018;13(1):238.
5. Yoon Y-C, Ma DS, Lee SK, Oh J-K, Song HK. Posterior pelvic ring injury of straddle fractures: incidence, fixation methods, and clinical outcomes. Asian J Surg. 2021;44(1):59–65.
6. Vaidya R, Tonnos F, Nasr K, Kanneganti P, Curtis G. The Anterior Subcutaneous Pelvic Fixator (INFIX) in an anterior posterior Compression type 3 pelvic fracture. J Orthop Trauma. 2016;30(Suppl 2):S21–2.
7. Du W, Sun T, Ding Y, Jiang C, Qu W, Zhang S. Robot-assisted treatment of unstable pelvic fractures with a percutaneous iliac lumbar double rod fixation combined with a percutaneous pelvic anterior ring INFIX fixation. Int Orthop. 2020;44(6):1223–32.
8. Chen CH, Lien FC. Subcutaneous anterior pelvic bridge - an innovative technique for fixation of selective acetabular fracture: a case series and literature review. Int Orthop. 2022;46(8):1863–72.
9. Meesters AML, Ten Duis K, Kraeima J, Banierink H, Stirler VMA, Wouters PCR, et al. The accuracy of gap and step-off measurements in acetabular fracture treatment. Sci Rep. 2021;11(1):18294.
10. Kelly J, Ladurner A, Rickman M. Surgical management of acetabular fractures - a contemporary literature review. Injury. 2022;51(10):2267–77.
11. Tian S, Zhang R, Liang S, Yin Y, Ma L, Liu G et al. Is plating fixation through the Kocher-Langenbeck Approach for Associated posterior wall Fragment Indispensable in both-Column Acetabular fractures? Orthop Surg.2022; 14(3):513–21.
12. Kulakowski M, Reichert P, Elster K, Sleczka P, Oleksy L, Krolikowska A. Safety and efficacy of two ilioiliac tension band plates osteosynthesis of fragility fractures of the pelvis. Sci Rep. 2022;12(1):20436.
13. Petryla G, Uvarovas V, Bobina R, Kurtinaitis J, Puronaite R, Kvederas G et al. Comparison of one-year functional outcomes and quality of life between posterior pelvic Ring fixation and combined anterior-posterior pelvic Ring fixation after lateral Compression (B2 type) pelvic fracture. Med (Kaunas).57(3) (2021).
14. Wan Y, Yu K, Xu Y, Ma Y, Zeng L, Zhang Z, et al. Both-Column Acetabular fractures: should Pelvic Ring reduction or Acetabulum be performed first? Orthop Surg. 2022;14(11):2897–903.
15. Devaney GL, Bulman J, King KL, Balogh ZJ. Time to definitive fixation of pelvic and acetabular fractures. J Trauma Acute Care Surg. 2020;89(4):730–5.
16. Zhang BF, Wang J, Zhang YM, Cheng HG, Cheng QY, Cao WW. The morphological mapping of lateral compression type 1 pelvic fracture and pelvic ring stability classification: a finite element analysis. J Orthop Surg Res. 2021;16(1):675.
17. Butler BA, Lawton CD, Hashmi SZ, Stover MD. The Relevance of the Judet and Letournel Acetabular Fracture Classification System in the Modern Era: A Review. J Orthop Trauma. 2019;33 Suppl 2:S3-s7. Epub 2019/01/29.
18. Kuttner M, Klaiber A, Lorenz T, Füchtmeier B, Neugebauer R. The pelvic subcutaneous cross-over internal fixator. Der Unfallchirurg. 2009;112(7):661–9.
19. Qi H, Geng X, Yu X, Chen W, Jia J, Tian W. Posterior INFIX for treating unilateral unstable sacral fractures. Orthop Surg. 2022;14(4):750–7.
20. Patel S, Aggarwal S, Jindal K, Kumar V, Sharma S. Outcomes and complications of the INFIX technique for unstable pelvic ring injuries with high-velocity trauma: a systematic review and meta-analysis. Arch Orthop Trauma Surg. 2022;142(5):787–803.
21. Naguib SM, Kassem MA, Hamza HM, Fouda MM, Saleh MK, Hosny KM. Automated system for classifying uni-bicompartmental knee osteoarthritis by using redefined residual learning with convolutional neural network. Heliyon. 14;10(10):e31017(2024).
22. Naguib SM, Hamza HM, Hosny KM, Saleh MK, Kassem MA. Classification of Cervical Spine Fracture and Dislocation Using Refined Pre-Trained Deep Model and Saliency Map. Diagnostics (Basel). 28;13(7):1273(2023).

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