BMC Musculoskeletal Disorders

RESEARCH

Open Access

Treatment of unstable pelvic fractures with double INFIX

Xu-Song Li[1†], Jun-Le Wu[2†], Liben Huang[3], Lin Ye[4] and Jie-Feng Huang[5*]

Abstract

Background This study investigated the clinical efficacy of Double INFIX for the treatment of unstable pelvic fractures.

Methods We performed a retrospective analysis of 23 patients with unstable pelvic fractures treated using the Double INFIX minimally invasive technique. The cohort included five cases of Tile B1 type, eight cases of B2 type, six cases of B3 type, three cases of C1 type and one case of type C2. Pre- and postoperative evaluations included standardised pelvic serial films and three-dimensional CT scans. Key observational indicators were fracture reduction quality (assessed using Matta's criteria), fracture healing, functional recovery (evaluated with the Majeed function assessment criteria), and incidence of complications.

Results The mean follow-up duration was 24.48 ± 1.78 months. The average fracture healing time was 4.00 ± 1.41 months, and the average time for removal of fixation was 7.43 ± 1.75 months. Repeat imaging at 12 months postoperatively using Matta's criteria showed eight cases with excellent results (52.17%), 13 cases with good results (34.78%), three cases with fair results (13.04%), and no cases with poor results. The combined excellent and good rate was 86.96%, whereas the fair rate was 13.04%. The average Majeed hip joint function score at the final follow-up was 95.04 ± 1.72. Postoperative complications included meralgia paresthetica in two cases (8.7%) and sacrococcygeal discomfort in three patients when lying flat.

Conclusion Double INFIX is a minimally invasive treatment technique with adequate clinical efficacy for managing unstable pelvic fractures.

Keywords Internal fixator (INFIX), Minimally invasive technique, Pelvic fracture, Anterior and posterior ring fixation

†Xu-Song Li and Jun-Le Wu contributed equally to this work and are share first authors.

*Correspondence:
Jie-Feng Huang
40983285@qq.com
[1]Zhongshan Hospital of Traditional Chinese Medicine Affiliated to Guangzhou University of Traditional Chinese Medicine, Zhongshan, Guangdong 528400, China
[2]Department of Orthopaedics & Traumatology, Zhongshan Hospital of Traditional Chinese Medicine Affiliated to Guangzhou University of Traditional Chinese Medicine, Zhongshan, Guangdong 528400, China
[3]Guangzhou Hospital of Integrated Tradictional and West Medicine, Guangzhou, Guangdong 510000, China
[4]Heyuan Woman and Children's Hospital and Health Institute, Heyuan, Guangdong 517000, China
[5]Department of Orthopaedics & Traumatology, The First Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou, Zhejiang 310006, China

Introduction

A primary objective in the treatment of pelvic fractures comprising restoring the integrity and stability of the anterior and posterior ring bone-ligament anatomy, which are essential for functional rehabilitation. According to the Tile classification of pelvic fractures [1], both Type B and Type C fractures are considered unstable. Concurrent fixation of the anterior and posterior pelvic rings can ensure sufficient biomechanical stability, promote proper healing, and facilitate functional recovery.

The main surgical techniques currently used for treating pelvic ring injuries include open reduction and internal fixation (ORIF), posterior sacroiliac screws, iliosacral screw (ISS) fixation, and plate fixation of the sacroiliac joint [2]. ORIF involves the incision of a significant amount of soft tissue to achieve adequate exposure, which increases the risk of soft tissue and neurovascular damage. Posterior sacroiliac screws and ISS fixation require precise positioning, a high level of surgical expertise, and high-quality fluoroscopy to avoid iatrogenic neurovascular injury [3].

Kuttner et al. first reported the use of the subcutaneous ventral internal fixator for the fixation of pelvic fractures in 2009. It is consistent with the principles of pelvic external fixation, but placed entirely subcutaneously [4]. Vaidya then first reported INFIX in 2012, using supraacetabular spinal pedicle screws and a subcutaneous connecting rod, and demonstrated its stability in biomechanical research [5, 6]. INFIX has been used in pelvic fractures for more than ten years, and their indications have been expanding and showing good application prospects [7].

Therefore, we utilised a new technique characterised by simplicity, minimal trauma, safety, faster recovery, and a minimally invasive approach, while providing reasonable stability of the pelvic ring. We retrospectively analysed the clinical efficacy of the Double INFIX procedure in 23 patients with unstable pelvic fractures.

Patients and methods

In total, 23 patients with unstable pelvic fractures (15 men and 8 women) were enrolled in the study between January 2017 and December 2019. These included 10 patients with traffic accidents and 13 with falls from height. According to the Tile classification of pelvic fractures, there were 5 cases of type B1, 8 cases of type B2, 6 cases of type B3, 3 cases of type C1 and 1 case of type C2. Among the type C1 fractures, 2 were type C1.1 and 1 was type C1.3. Upon admission, all patients underwent pelvic stabilisation using either pelvic pocket fixation or an external fixator, along with supracondylar skeletal bone traction on the affected side with heavy weights. Preoperative assessment included pelvic plain radiographs, entrance and exit radiographs, and three-dimensional CT scans to determine the fracture type. The average time from injury to operation was 10.39 ± 3.19 days. Preoperative fracture displacement was quantified using CT scans.

The study included patients aged > 18 years with type B or C1 pelvic fracture. Patients with severe osteoporosis, soft tissue infection at the site of the surgical screw placement, haemodynamic instability, or need for emergency treatment of open pelvic fractures were excluded (Fig. 1).

Surgical technique

Body position and reduction

After receiving general anaesthesia, patients were placed in a supine position. The vertical displacement of the pelvic fracture was reduced using supracondylar skeletal bone traction manual traction on the traction bed. The outlet and entrance positions of the pelvis were examined to confirm that the vertical displacement of the fracture or dislocation had been successfully reduced.

Surgical procedure

Anterior ring INFIX internal fixation An incision approximately 3 cm in length was made 1 cm below the bilateral anterior inferior iliac spine, exposing the anterior inferior iliac spine. A guide wire was drilled along the anterior inferior iliac spine toward the posterior superior iliac spine. Fluoroscopy confirmed that the guide pin was in the "teardrop" shape formed by the inner and outer plates. One INFIX screw was inserted on each side, and a subcutaneous tunnel was established at the level of the pubic symphysis. After installation of the transverse symphysis, the anterior pelvic ring fracture was repaired. If necessary, cannulated screws were percutaneously implanted under fluoroscopy for suprapubic ramus fractures.

Posterior ring INFIX fixation With the patient in the prone position, an oblique incision approximately 3 cm in length was made along the iliac spine, starting at the highest point of the bilateral posterior superior iliac spine. The incision was made in layers, exposing the posterior superior iliac spine. Using a surgical implant holder pointed toward the anterior inferior iliac spine, the direction was set to approximately 25° head tilt and 45° inclination. The hand vertebrae were sequentially advanced, confirming their position within the iliac plate and ensuring they did not protrude past the inner and outer edges. A positioning guide pin was then inserted. The direction and position of the guide pin were verified under C-arm fluoroscopy, confirming it was within the iliac plate and not extending to the edges. Using a rongeur, a 1-cm^2 section of bone at the posterior superior iliac spine protrusion was removed. The insertion depth of the guide pin was measured, and carbide taps with a diameter of 5–6 mm were used to prepare for the INFIX screw insertion. A 7-mm-diameter

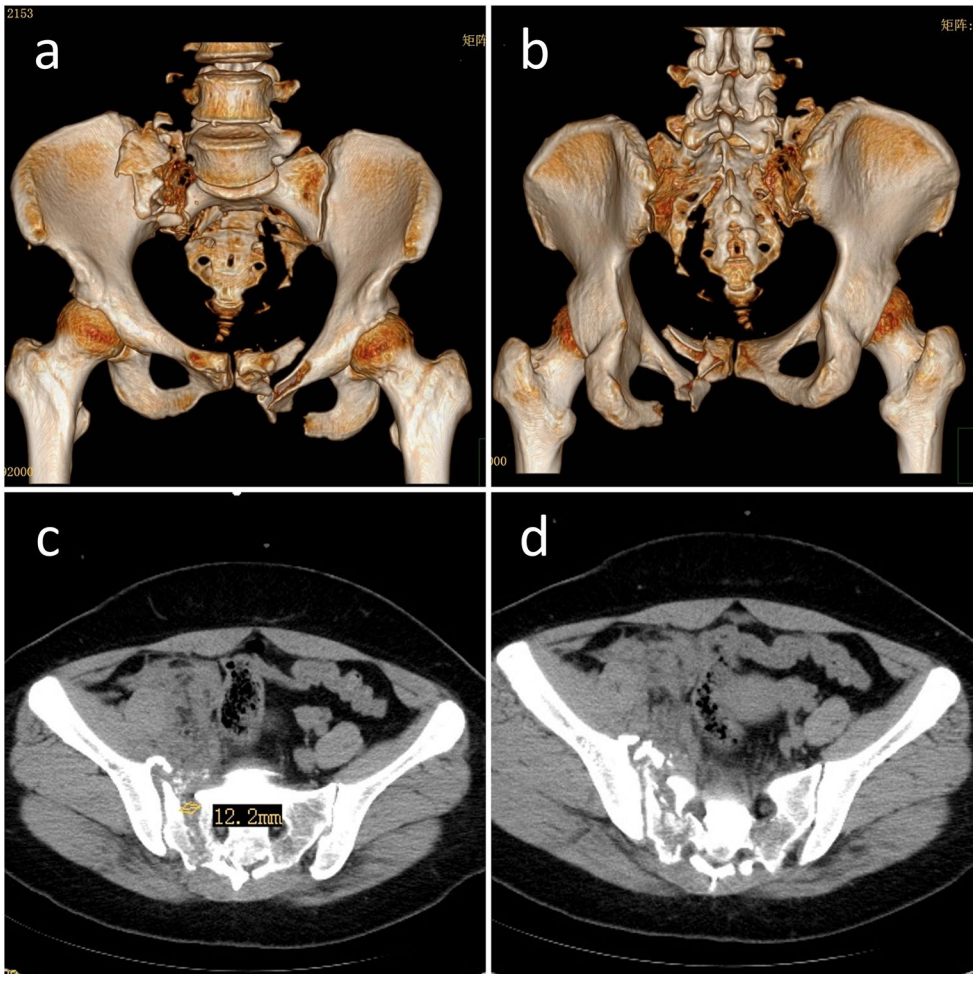

Fig. 1 Case 1: Preoperative three-dimensional CT of a 40-year-old female patient showing Tile type C2 pelvic fracture (**a**–**d**)

INFIX screw was then placed, and the screw tail cap was fully tightened into the previously created bone defect. The length and direction of the screw were verified again under fluoroscopy. The contralateral screw was inserted using the same procedure. The bilateral INFIX screws were connected by a transverse symphysis. Depending on the sacroiliac joint and sacral fracture, the posterior ring was either expanded or compressed, and the transverse symphysis screws were tightened. The incision was then sutured and bandaged after thorough flushing (Figs. 2 and 3).

Postoperative treatment

The patient was instructed to begin quadriceps exercises and hip and knee flexion exercises starting on the second day after the operation. Partial weight-bearing was recommended from 2 weeks onwards. After re-examination of X-rays to confirm fracture healing, the patient was advised to walk with full weight-bearing. X-ray and CT images were reviewed within 1 week postoperatively to evaluate fracture reduction and internal fixation. X-ray films were rechecked at 1, 2, 3, 6, and 12 months postoperatively. The internal fixation of the anterior and posterior rings was removed at an average of 7.43 ± 1.75 months postoperatively (Figs. 4, 5 and 6).

Outcomes

Postoperative outcomes included postoperative fracture displacement, fracture healing time, and incidence of complications. Tornetta and Matta's criteria [8] were used to evaluate fracture reduction. Displacement < 5 mm was categorised as excellent, 5–10 mm as good, 10–20 mm as fair, and > 20 mm as poor. The Majeed assessment [9] was used to evaluate postoperative functional recovery.

Results

All patients were followed up, and the mean follow-up duration was 24.48 ± 1.78 (range: 22–28) months. All patients achieved good fracture reduction postoperatively, and the internal fixation was reliable. The average bone union time after fracture was 4.00 ± 1.41 months.

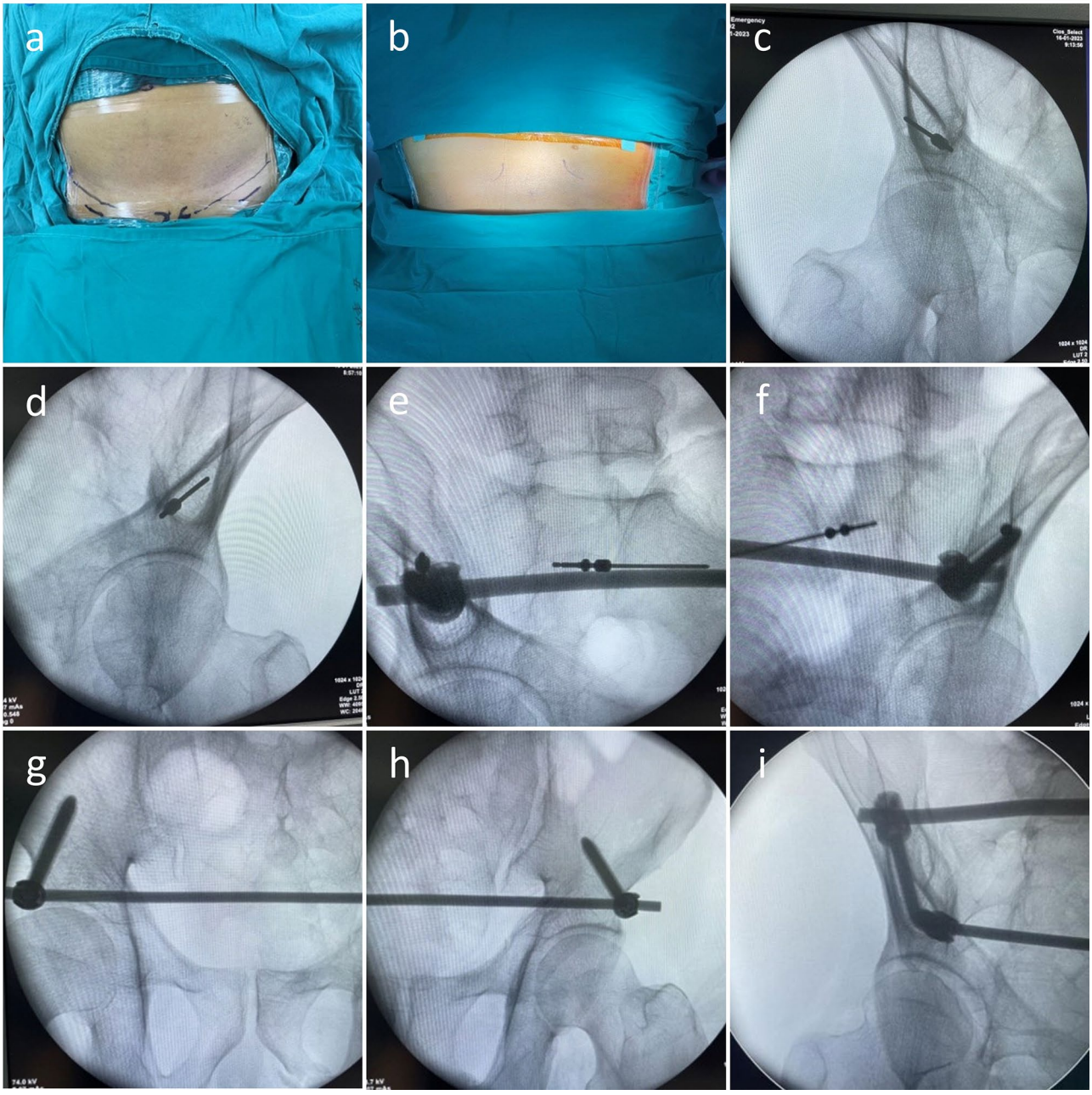

Fig. 2 Schematic diagrams of INFIX incisions on (**a**) anterior pelvic rings and (**b**) posterior pelvic rings. The position of the guide pin was in the "teardrop" shape of the inner and outer plates of the ilium (**c**,**d**). The position of the fixed INFIX was confirmed by fluoroscopy (**e**–**i**)

The average time for removal of fixation was 7.43 ± 1.75 months.

The mean preoperative fracture displacement was 8.66 ± 1.99 (range: 5–12.2) mm, whereas the mean postoperative fracture displacement was 3.88 ± 1.79 (range: 0–5.9) mm. Imaging was reassessed according to Matta's criteria 12 months postoperatively, showing 12 cases (52.17%) as excellent, 13 (34.78%) as good, 3 (13.04%) as fair, and 0 as poor. The combined rate of excellent and good outcomes was 86.89%. According to the Majeed assessment of hip joint function, the average score at the final follow-up was 95.04 ± 1.72.

In this group, meralgia paresthetica occurred in 2 cases (8.7%) postoperatively. Additionally, 3 patients experienced discomfort in the sacrococcygeal region when lying flat after the operation; however, none of these symptoms persisted after removal of the ring fixation.

Two patients in this group had experienced a Morel-Lavallée injury [10, 11] after the pelvic injury. In one case, the injury was located on the back of the thigh and

Fig. 3 Surgical implant holder, probe, and C-arm machine during the operation (**a**–**f**)

buttocks; in the other case, the injury was located on the anterolateral side of the thigh. Both patients underwent emergency minimally invasive irrigation and debridement surgery, followed by closure of the dead space. These patients completed the Double INFIX procedure on postoperative days 5 and 7, respectively. No skin necrosis or infection occurred during the postoperative follow-up (Table 1).

Discussion

In recent years, various screw channel technologies such as closed reduction pubic ramus screws, posterior ring sacroiliac screws, spinal pedicle screw-rod systems, plate screw internal fixation, and the anterior ring INFIX system [12–14] have been increasingly applied in the treatment of pelvic ring injuries, yielding adequate results. Despite the differing advantages and disadvantages of these internal fixation methods, debate continues regarding which approach is the most effective.

Indications and contraindications for double INFIX fixation

Vaidya et al. [5] initially suggested that the optimal indication for the INFIX technique was anterior pelvic ring injury in patients with obesity. Various methods have been used for the reduction and fixation of the posterior pelvic ring, including the anterior iliac fossa approach, posterior plate screws, sacroiliac screws, and iliac lumbar screws. However, double plate fixation of the sacroiliac joint has a high probability of causing vascular nerve injury [15, 16] due to its proximity to large vascular and nerve structures in the pelvis. Additionally, the long learning curve and high technical demands of the procedure, particularly with intraoperative fluoroscopy, increase the risk of iatrogenic neurovascular injury, which can lead to haemorrhage, shock, and even be life-threatening. Alternative methods such as the rear arched steel plate [17] and bilateral screws [18] have been used for fixation. However, these methods are "eccentric" in their application, providing limited tightening effect on the injury to the posterior pelvic ring and potentially causing complications such as skin irritation and infection due to the proximity of the internal fixation to the skin. Unilateral and bilateral unstable pelvic fractures are typically indicated for simultaneous fixation of the anterior and posterior pelvic rings. Conventional methods include open reduction and internal fixation with plate screws, anterior ring plate screws, posterior sacroiliac screws, and iliac lumbar screws. Recently, the combination of INFIX and sacroiliac screws has been reported for the management of unstable pelvic fractures with

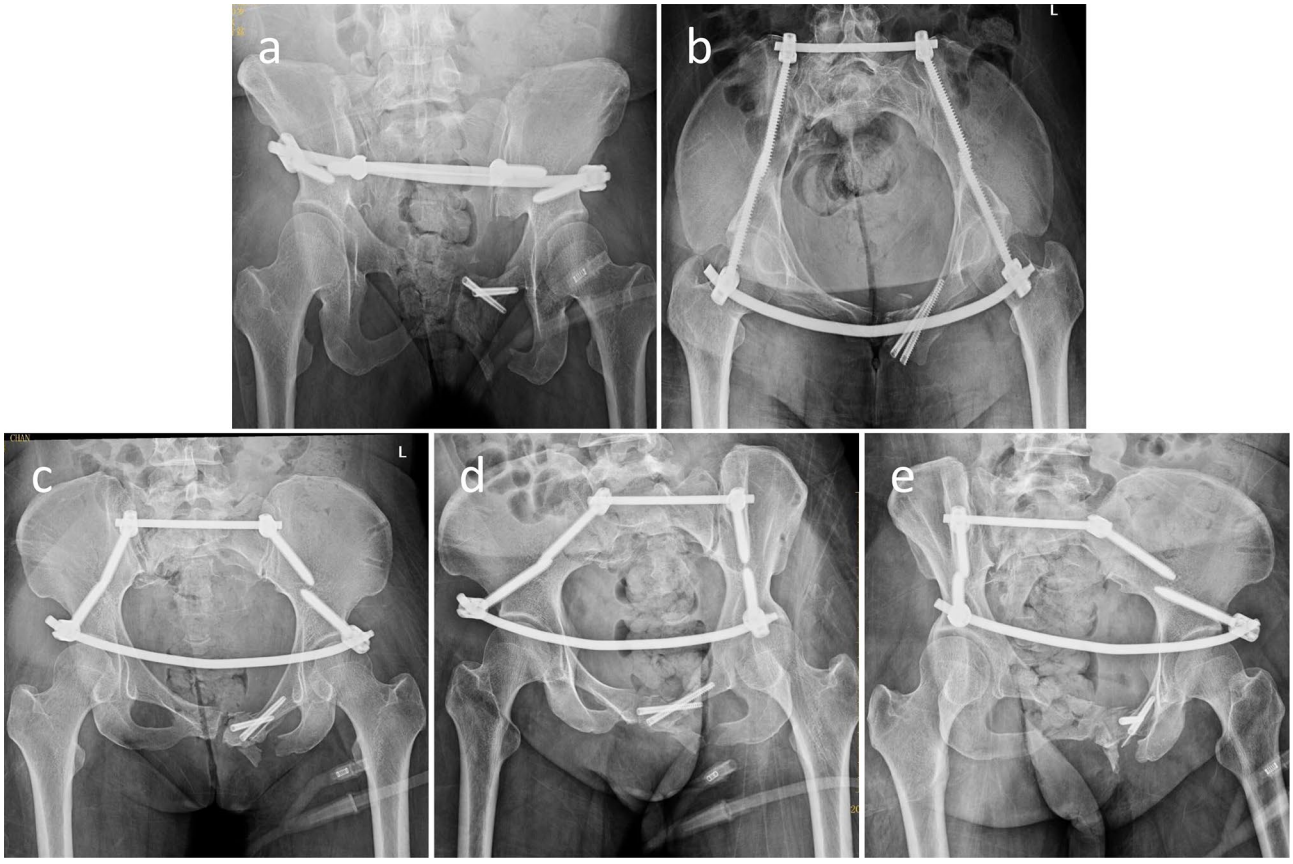

Fig. 4 Case 1: X-ray images at 2 days postoperatively showing that the anterior and posterior rings were adequately reset. Percutaneous impaction of two cannulated screws in left suprapubic ramus. The internal fixation was reliable (**a**–**e**)

damage to both the anterior and posterior rings [19]. In our clinical experience with Double INFIX for unilateral and bilateral unstable pelvic fractures without sacral plexus injury, the results have been satisfactory. The main advantages of Double INFIX are its minimally invasive nature, which reduces exposure of the fracture and dislocation and decreases surgical trauma. This approach also has a lower incidence of iatrogenic injury to presacral and pelvic blood vessels and nerves, results in less intraoperative bleeding, and supports quicker postoperative recovery.

For posterior ring injuries resulting from sacroiliac joint dislocation accompanied by a posterior iliac "crescent" fracture, posterior INFIX fixation has demonstrated significant promise. This technique allows for simultaneous reduction and fixation of both the "crescent" fracture of the posterior superior iliac spine and the sacroiliac joint dislocation.

The emergency treatment of open pelvic fractures was excluded from this study. This exclusion is due to the frequent occurrence of haemodynamic instability, polytrauma, and an increased risk of infection associated with open pelvic fractures. Immediate damage control operations typically involve the use of pelvic ring external fixation (EXFIX) or C-clamps. Once the patient's haemodynamic status is stabilised and the wound is free of infection, INFIX is a potentially viable option for definitive fixation [20].

There is ongoing debate regarding the optimal treatment plan for pelvic fractures with Morel-Lavallée injuries [21]. In this study, two patients with Morel-Lavallée injuries underwent irrigation and debridement surgery, followed by dead space closure, immediately after external fixation in the emergency department. Subsequently, double INFIX was performed in a second-stage procedure. Postoperative follow-up revealed no instances of skin necrosis or infection. Vaidya et al. [22] reported satisfactory outcomes using INFIX/EXFIX in four patients with severe open pelvic injuries. These findings suggest that Double INFIX is also effective for the management of unstable pelvic fractures associated with Morel-Lavallée injuries.

Surgical skills for double INFIX fixation

During INFIX anterior ring fixation, there are risks of lateral femoral cutaneous nerve injury and femoral nerve compression [23, 24]. In this study, the reported incidence of anterolateral femoral cutaneous nerve injury

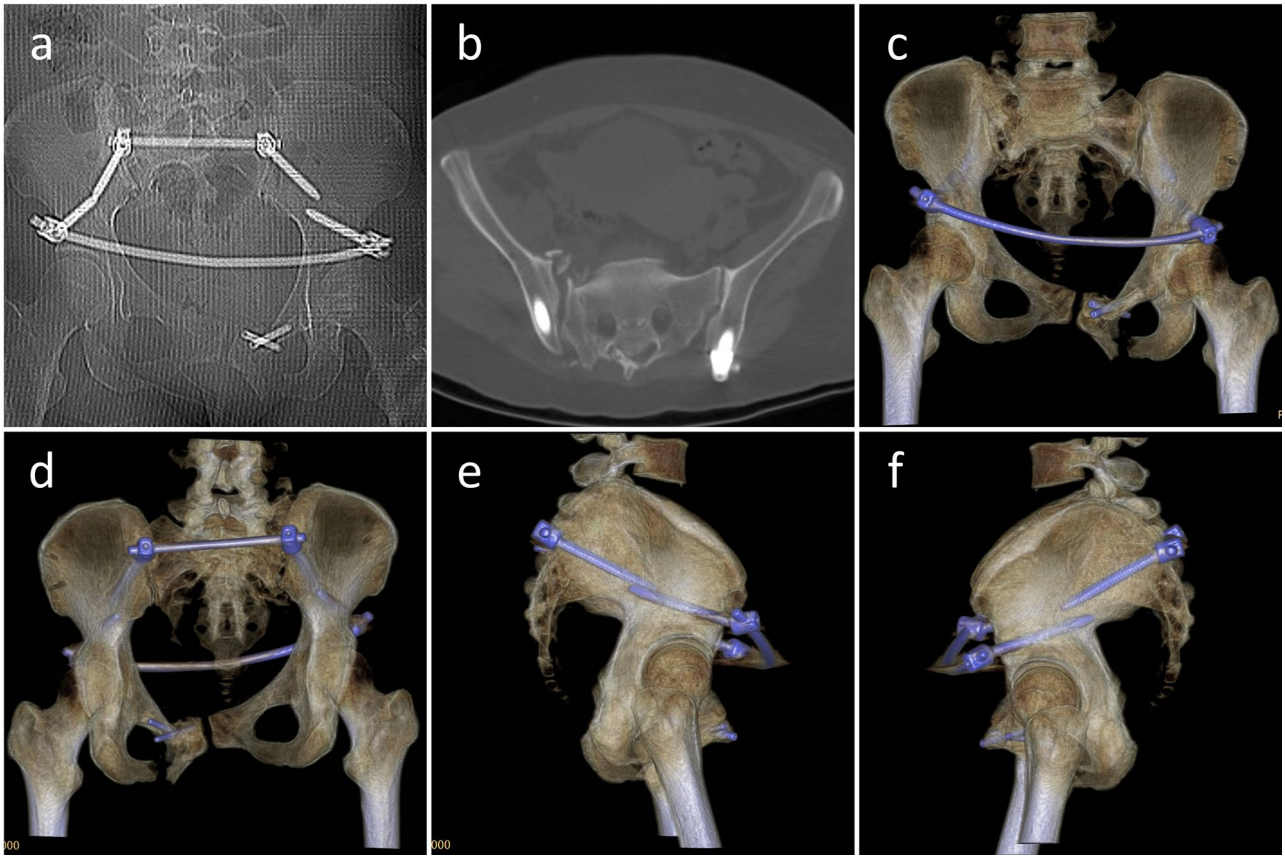

Fig. 5 Case 1: CT performed 2 weeks postoperatively showed that the anterior and posterior rings were adequately reset, and the internal fixation was reliable (**a**–**f**)

was 26.3%. This symptom can be either transient or persistent [25], but it typically resolves after removal of the internal fixation [26]. In this cohort, meralgia paresthetica occurred in 2 patients (8.7%) postoperatively, attributed to traction injury from the incision exposing the anterior inferior iliac spine. The symptoms resolved after 4 weeks of treatment with oral methylcobalamin. Li et al. [27] proposed improvements to the incision technique for anterior ring INFIX that involved shifting the inguinal incision downward and inward by 1–2 cm. This modification anatomically reduces the risk of iatrogenic injury to the lateral femoral cutaneous nerve and facilitates better screw placement.

When performing INFIX fixation, deviations in the insertion direction can lead to neurovascular damage. To minimise the risk of such injuries, our study revealed that the opener should be maintained at an angle of 20–25° tail tilt and 25–30° camber during placement in the anterior ring. This angle ensures that the opener remains between the inner and outer plates of the iliac bone. During the subsequent deepening process of the sharp cone, the probe should be used to measure the depth while tapping to ensure that the probe does not extend beyond the bone in any direction. Typically, the depth of the taper is 60–70 mm. After placing the cemented carbide taps, a screw 1–2 cm longer than the measured depth should be inserted. Additionally, maintenance of 1–1.5 cm of the screw thread outside the bone helps prevent compression of the femoral nerve and iliac vessels by the transverse symphysis when the screw is inserted too deeply [27, 28].

When placing nails in the posterior loop, the opener should be directed with a 25° head tilt and a 45° inclination. Maintenance of this angle ensures that the opener remains between the inner and outer plates of the ilium, similar to the approach used for the anterior ring. During the subsequent deepening process of the sharp cone, the probe should be used to measure the depth while tapping to ensure it does not extend beyond the bone in any direction—front, back, left, or right [23]. Before placing the fixation screws, approximately 1 cm of bone along the screw track should be removed to reduce implant prominence. This approach can enhance patient comfort [29]. Khaleel et al. [30] found that, in posterior plate treatment, two patients with a BMI of less than 19 kg/m² reported protruding implants. In this study, three patients reported discomfort in the sacrococcygeal region when lying flat after the operation, although it did not impact their normal activities. None of these

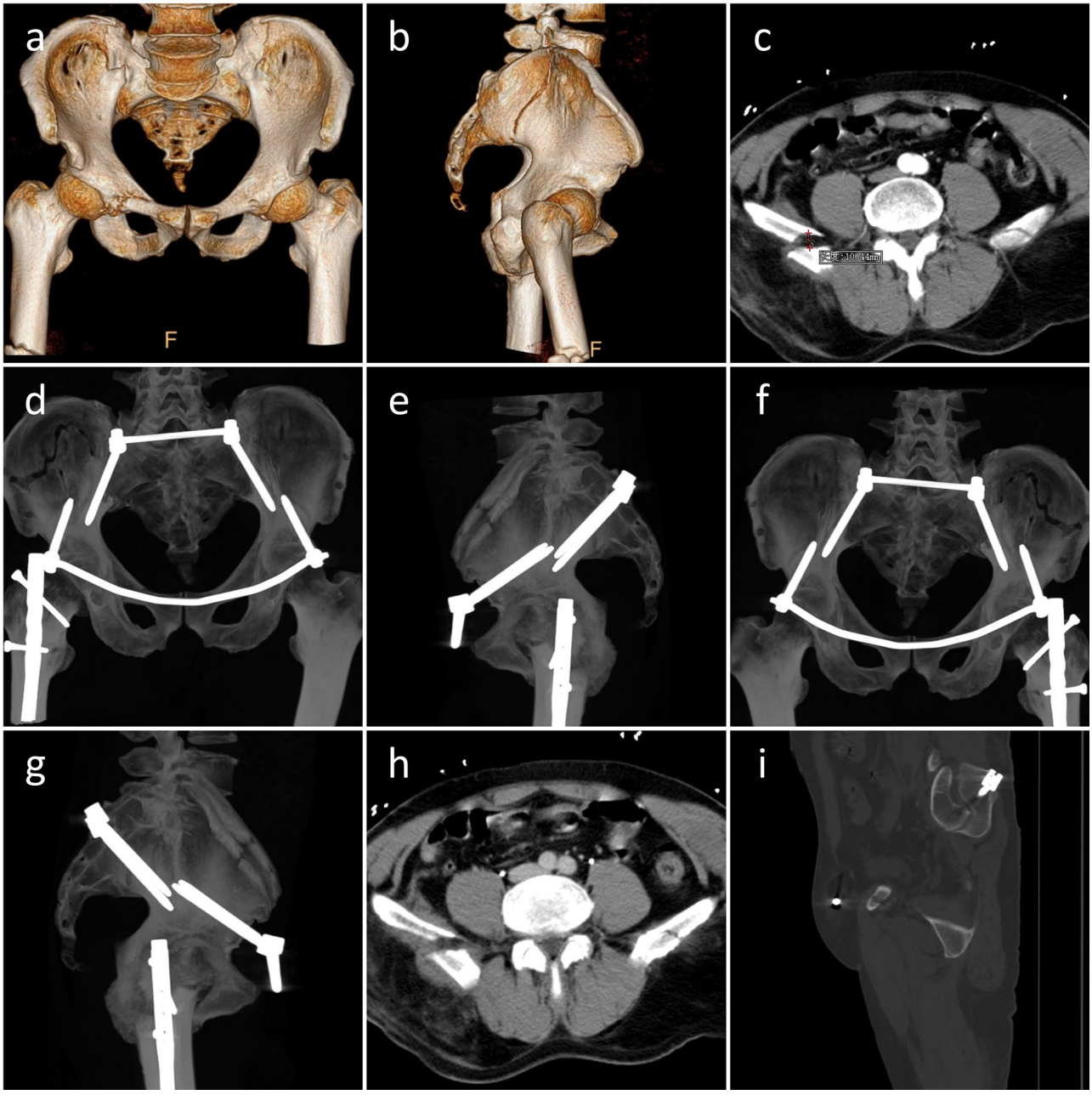

Fig. 6 Case 2: Preoperative CT of a 55-year-old male patient with pelvic fracture due to a fall revealed multiple pelvic fractures and a significantly displaced iliac fracture (**a**–**c**). CT performed at 2 weeks postoperatively showed adequately reduced anterior and posterior rings with firm and well-positioned internal fixation (**d**–**h**). Removal of sufficient bone to ensure complete burial of the screw cap (**i**)

symptoms persisted after removal of the posterior ring. Notably, the BMIs of two of these patients were less than 20 kg/m². It is likely that the reduced fat in the lower back compared with the lower abdominal region, especially in relatively thin patients, contributes to discomfort in the posterior iliac and coccygeal areas. Therefore, patient-specific factors should be considered when performing Double INFIX. Confirmation of sufficient bone removal to fully bury the screw cap can help mitigate this complication [23, 29, 31].

Advantages and disadvantages of double INFIX fixation

In contrast to ORIF, which often requires changing the patient's position during the operation, the need for repositioning and re-disinfection may increase procedure time. However, compared with traditional anterior and posterior ring open reduction with plate and screw internal fixation, this approach offers several advantages, including reduced trauma, less bleeding, fewer complications, and faster postoperative recovery. In this study, the average intraoperative blood loss was 60.87 ± 16.07

Table 1 Patient demographic characteristics

Case	Sex	Age	BMI	Fracture type	Mode of injury	Associated injuries	Interval from injury to surgery	Total procedure duration	Blood loss	Time to INFIX removal	Follow-up duration	Postoperative complications	Preoperative fracture displacement	Preoperative fracture displacement	Majeed Score	Matta Score
no.		range	(kg/m^2)	(Tile)			(days)	(min)	(ml)	(months)	(months)		(mm)	(mm)		
1	Female	40–49	29.4	C2	Fall	Distal femur and clavicle fractures	14	77	60	7	26	None	12.2	0.0	93	Excellent
2	Male	30–39	26.6	B3	Fall	Craniocerebral injury	10	70	90	6	22	None	10.4	4.2	94	Good
3	Female	50–59	20.7	B1	Traffic accident	Open fracture of tibia and fibula	18	65	50	6	25	None	9.0	4.7	96	Good
4	Male	50–59	22	B2	Traffic accident	Rib fracture	9	85	90	7	24	None	9.3	4.4	97	Good
5	Male	20–29	25.9	B2	Traffic accident	Pulmonary contusion and craniofacial and tibial fractures	10	72	70	4	24	Superficial wound infection	5.3	2.7	95	Excellent
6	Male	30–39	23.9	B1	Fall	Iliopsoas haematoma	12	60	50	8	23	None	9.5	3.7	98	Excellent
7	Male	50–59	17.6	C1.1	Traffic accident	Rib and craniofacial fractures and pneumothorax	16	80	60	10	26	Lumbar discomfort	7.0	2.9	93	Excellent
8	Male	30–39	17.8	B2	Traffic accident	Clavicle, rib, and craniofacial fractures	8	65	60	9	22	Lateral femoral cutaneous nerve numbness	8.0	2.2	92	Excellent
9	Female	10–19	20.7	C1.1	Traffic accident	Craniocerebral injury, Morel-Lavallee injury	8	75	90	10	24	Lumbar discomfort	7.0	4.7	96	Good
10	Female	40–49	27.9	B3	Fall	Rib fracture, lung contusion, and femur fracture	10	65	70	6	28	None	7.8	4.5	97	Good
11	Male	30–39	27.1	B1	Fall	Tibial fracture	7	60	50	6	22	None	11.9	5.7	95	Fair
12	Male	50–59	21.8	B1	Fall	Intertrochanteric fracture	13	60	60	6	24	None	9.5	2.1	93	Excellent
13	Male	30–39	20.8	B3	Traffic accident	Lumbar fracture	7	70	50	10	24	None	7.5	0.0	95	Excellent
14	Male	40–49	26.8	B3	Fall	Lumbar and tibial fractures	10	75	80	8	25	None	11.4	5.9	93	Fair

Table 1 (continued)

Case	Sex	Age	BMI	Fracture type	Mode of injury	Associated injuries	Interval from injury to surgery	Total procedure duration	Blood loss	Time to INFIX removal	Follow-up duration	Postoperative complications	Preoperative fracture displacement	Preoperative fracture displacement	Majeed Score	Matta Score
no.		range	(kg/m^2)	(Tile)			(days)	(min)	(ml)	(months)	(months)		(mm)	(mm)		
15	Male	30–39	19.3	B1	Fall	Pulmonary contusion and soft tissue abrasion	6	55	40	7	24	Lateral femoral cutaneous nerve numbness	9.8	4.1	97	Good
16	Female	60–69	22	B2	Fall	Rib fracture and lung contusion	7	77	45	6	27	None	6.7	2.5	97	Excellent
17	Male	30–39	25.5	B2	Traffic accident	Pulmonary contusion, lumbar fracture, and pelvic haemocoel	12	70	65	7	22	None	5.0	0.0	95	Excellent
18	Female	40–49	21.6	B3	Fall	Rib, wrist, tibial, and fibular fractures	14	70	80	10	26	None	8.1	2.8	93	Excellent
19	Male	40–49	19.4	C1.3	Fall	Rib fracture, lung contusion, and bladder injury	12	65	50	10	28	Wound infection	10.6	4.9	94	Good
20	Male	60–69	28.4	B2	Fall	Humeral fracture	7	58	40	6	23	None	11.3	2.2	97	Excellent
21	Female	20–29	19	B2	Fall	Femur fracture and Morel-Lavallee injury	7	60	40	6	25	None	8.4	5.0	96	Good
22	Female	40–49	25.7	B2	Traffic accident	Pelvic and buttock haematoma	12	70	55	7	25	None	7.7	2.8	94	Excellent
23	Male	30–39	18.1	B3	Traffic accident	Tibial fracture and bladder injury	10	80	55	9	24	Lumbar discomfort	10.4	5.8	96	Fair

(range: 40–90) mL, and the average operation time was 68.87 ± 8.02 (range: 55–85) min. Postoperatively, patients experienced rapid recovery without wound necrosis, pressure sores, or other adverse complications.

McDonald et al. [32] demonstrated that INFIX provides excellent resistance to axial displacement and separation. Additionally, Vaidya et al. [26, 33] revealed that INFIX can offer a fixation strength up to 23% greater than that of EXFIX. In this study, early partial weight-bearing exercises were initiated 2 weeks postoperatively. The use of minimally invasive INFIX to combine the anterior and posterior rings achieves 360° circular fixation of the pelvic ring.

In recent years, various techniques for posterior ring fixation have been explored, including posterior ring INFIX, pedicle screws connected to a transverse rod, pedicle screw-rod fixators, and transiliac internal fixators (TIFI) [3, 31, 34, 35]. Similar to our technique, subcutaneous screws and rods have been effectively used to treat anterior and posterior ring fractures, demonstrating consistent and reliable outcomes [34, 35]. Compared with sacroiliac screws, posterior ring INFIX offers several advantages: it is simpler, safer, and results in fewer iatrogenic injuries. It also involves a shorter operation time and lower radiation exposure. This technique avoids the surgical risks associated with sacroiliac screws, particularly in patients with abnormal sacral morphology or pneumatosis intestinalis [3, 36]. TIFI, similar to posterior ring INFIX, utilises a single rod and pedicle screws from the anterior inferior iliac spine to the posterior superior iliac spine. Biomechanical studies have shown that TIFI provides stability comparable to sacroiliac screws and plate osteosynthesis [37]. In a prospective cohort study, El-Hamalawy et al. found that TIFI resulted in reduced fluoroscopic exposure and operative time compared with sacroiliac screws, although it was associated with increased blood loss [31]. However, unlike sacroiliac screws, INFIX requires a second surgery to remove implants at approximately 6 months postoperatively, which can increase patient costs and the risk of complications.

Study strengths and limitations

To our knowledge, this is one of the first studies to introduce the Double INFIX concept for the treatment of pelvic fractures. We evaluated functional, surgical, and radiological outcomes, with clearly defined inclusion and exclusion criteria. The consistency of our findings across these various outcomes reinforces the validity of our conclusions.

This study had several limitations. It was a retrospective analysis without a control group, resulting in a relatively low level of evidence and a small sample size. Additionally, cases of Tile C3 were not included, and the postoperative follow-up period was relatively short, lacking mid- and long-term efficacy evaluations. The study's observational metrics were relatively limited. Future research should address these gaps by conducting multicentre, large-sample prospective randomised controlled trials focused on minimally invasive treatments for pelvic ring injuries. Such studies would provide more comprehensive insights. Further investigation into the biomechanical stability of Double INFIX, particularly regarding the maintenance of vertical stability in the pelvic ring through posterior ring fixation, is also warranted.

Conclusions

Double INFIX offers an effective and safe method for fixing unstable pelvic ring injuries. It is associated with advantages such as reduced trauma, less bleeding, faster recovery, and fewer complications.

Abbreviations

INFIX	Internal Fixation
EXFIX	External Fixation
TIFI	Transiliac Internal Fixator
ORIF	Open Reduction and Internal Fixation

Acknowledgements

None.

Author contributions

(1) All authors contributed to the study's conception and design. (2) LXS and WJL contributed equally to this study and are shared first authors.3. LXS: Designed the study, wrote the paper, and approved the final version for submission. WJL: Collected and analyzed the data and wrote the paper. YL and HLB: Collected and analyzed the data and approved the final version for submission. HJF: Designed the study, wrote the paper, prepared the figures, and approved the final manuscript for submission.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request. All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. All experimental protocols were approved by the Ethics Committee of Zhongshan Hospital of Traditional Chinese Medicine Affiliate to Guangzhou University of Traditional Chinese Medicine. Informed consent was obtained from all subjects and/or their legal guardian(s). Approval was granted by the Ethics Committee of Zhongshan Hospital of Traditional Chinese Medicine Affiliate to Guangzhou University of Traditional Chinese Medicine. (Date:2023-03-24/No:2023ZSZY-LLK-024).

Consent for publication

All patients consented to the publication of the case details.

Competing interests

The authors declare no competing interests.

Received: 17 September 2023 / Accepted: 14 December 2024

Published online: 10 January 2025

References

1. Tile M. Pelvic ring fractures: should they be fixed? J bone Joint Surg Br Volume. 1988;70(1):1–12.
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. Wang H, Fu YH, Ke C, Zhuang Y, Zhang K, Wei X, et al. Minimally invasive stabilisation of posterior pelvic ring instabilities with pedicle screws connected to a transverse rod. Int Orthop. 2018;42(3):681–6.
4. Kuttner M, Klaiber A, Lorenz T, Füchtmeier B, Neugebauer R. The pelvic subcutaneous cross-over internal fixator. Unfallchirurg. 2009;112(7):661–9.
5. Vaidya R, Colen R, Vigdorchik J, Tonnos F, Sethi A. Treatment of unstable pelvic ring injuries with an internal anterior fixator and posterior fixation: initial clinical series. J Orthop Trauma. 2012;26(1):1–8.
6. Vigdorchik JM, Esquivel AO, Jin X, Yang KH, Onwudiwe NA, Vaidya R. Biomechanical stability of a supra-acetabular pedicle screw internal fixation device (INFIX) vs external fixation and plates for vertically unstable pelvic fractures. J Orthop Surg Res. 2012;7:31.
7. Zhao P, Li R, Liu L, Wang X, Chen X, Guan J, et al. Clinical study of modified INFIX combined with sacroiliac joint screws for pelvic instable injuries. BMC Surg. 2023;23(1):350.
8. Tornetta P, Matta J. Outcome of operatively treated unstable posterior pelvic ring disruptions. Clin Orthop Relat Res. 1996;329:186–93.
9. Majeed S. Grading the outcome of pelvic fractures. J bone Joint Surg Br Volume. 1989;71(2):304–6.
10. Shen C, Peng J, Chen X. Efficacy of treatment in peri-pelvic Morel-Lavallee lesion: a systematic review of the literature. Arch Orthop Trauma Surg. 2013;133(5):635–40.
11. Tseng S, Tornetta P. Percutaneous management of Morel-Lavallee lesions. J bone Joint Surg Am Volume. 2006;88(1):92–6.
12. Cole P, Gauger E, Anavian J, Ly T, Morgan R, Heddings A. Anterior pelvic external fixator versus subcutaneous internal fixator in the treatment of anterior ring pelvic fractures. J Orthop Trauma. 2012;26(5):269–77.
13. Scheyerer M, Zimmermann S, Osterhoff G, Tiziani S, Simmen H, Wanner G, et al. Anterior subcutaneous internal fixation for treatment of unstable pelvic fractures. BMC Res Notes. 2014;7:133.
14. Hiesterman T, Hill B, Cole P. Surgical technique: a percutaneous method of subcutaneous fixation for the anterior pelvic ring: the pelvic bridge. Clin Orthop Relat Res. 2012;470(8):2116–23.
15. Frigon V, Dickson K. Open reduction internal fixation of a pelvic malunion through an anterior approach. J Orthop Trauma. 2001;15(7):519–24.
16. Yinger K, Scalise J, Olson S, Bay B, Finkemeier C. Biomechanical comparison of posterior pelvic ring fixation. J Orthop Trauma. 2003;17(7):481–7.
17. Krappinger D, Larndorfer R, Struve P, Rosenberger R, Arora R, Blauth M. Minimally invasive transiliac plate osteosynthesis for type C injuries of the pelvic ring: a clinical and radiological follow-up. J Orthop Trauma. 2007;21(9):595–602.
18. Giannoudis P, Tzioupis C, Pape H, Roberts C. Percutaneous fixation of the pelvic ring: an update. J bone Joint Surg Br Volume. 2007;89(2):145–54.
19. Füchtmeier B, Maghsudi M, Neumann C, Hente R, Roll C, Nerlich M. [The minimally invasive stabilization of the dorsal pelvic ring with the transiliacal internal fixator (TIFI)--surgical technique and first clinical findings]. Der Unfallchirurg. 2004;107(12):1142–51.
20. Mi M, Kanakaris NK, Wu X, Giannoudis PV. Management and outcomes of open pelvic fractures: an update. Injury. 2021;52(10):2738–45.
21. Becker C, Kammerlander C, Greiner A, Sommer F, Linhart C, Böcker W, et al. [Diagnostic and treatment strategies in Morel-Lavallee lesions in the spinal column and Pelvis]. Z fur Orthopadie Und Unfallchirurgie. 2018;156(5):541–6.
22. Vaidya R, Nasr K, Feria-Arias E, Fisher R, Kajy M, Diebel LN. INFIX/EXFIX: massive open pelvic injuries and review of the literature. Case Rep Orthop. 2016;2016:9468285.
23. Hesse D, Kandmir U, Solberg B, Stroh A, Osgood G, Sems S, et al. Femoral nerve palsy after pelvic fracture treated with INFIX: a case series. J Orthop Trauma. 2015;29(3):138–43.
24. Wu X, Liu Z, Fu W, Zhao S. Minimally invasive treatment of unstable pelvic ring injuries with modified pedicle screw-rod fixator. J Int Med Res. 2018;46(1):368–80.
25. Müller F, Stosiek W, Zellner M, Neugebauer R, Füchtmeier B. The anterior subcutaneous internal fixator (ASIF) for unstable pelvic ring fractures: clinical and radiological mid-term results. Int Orthop. 2013;37(11):2239–45.
26. Vaidya R, Kubiak E, Bergin P, Dombroski D, Critchlow R, 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.
27. Li X, Huang L, Kong Y, Fan M, Zheng Y, Huang J. Modified percutaneous iliosacral screw and anterior internal fixator technique for treating unstable pelvic fractures: a retrospective study. BMC Musculoskelet Disord. 2022;23(1):1068.
28. Reichel L, MacCormick L, Dugarte A, Rizkala A, Graves S, Cole P. Minimally invasive anterior pelvic internal fixation: an anatomic study comparing Pelvic Bridge to INFIX. Injury. 2018;49(2):309–14.
29. Müller F, Füchtmeier B. A systematic review of the transiliac internal fixator (TIFI) for posterior pelvic injuries. Sicot j. 2021;7:40.
30. Khaleel V, Pushpasekaran N, Prabhu N, Pandiyan A, Koshy G. Posterior tension band plate osteosynthesis for unstable sacral fractures: a preliminary study. J Clin Orthop Trauma. 2019;10:S106–11.
31. El-Hamalawy AG, Abdel Karim M, Khaled SA, Abdel-Kader KFM, Kassem E. Minimally invasive stabilization of posterior pelvic ring injuries through transiliac internal fixator versus iliosacral screw: a prospective comparative cohort study. Injury. 2023.
32. Mcdonald E, Theologis A, Horst P, Kandemir U, Pekmezci M. When do anterior external or internal fixators provide additional stability in an unstable (tile C) pelvic fracture? A biomechanical study. Eur J Trauma Emerg Surgery: Official Publication Eur Trauma Soc. 2015;41(6):665–71.
33. Vaidya R, Woodbury D, Nasr K. Anterior Subcutaneous Internal Pelvic Fixation/INFIX: a systemic review. J Orthop Trauma. 2018:S24–30.
34. Bi C, Wang Q, Nagelli C, Wu J, Wang Q, Wang J. Treatment of unstable posterior pelvic Ring fracture with pedicle screw-rod Fixator Versus Locking Compression plate: a comparative study. Med Sci Monit. 2016;22:3764–70.
35. Kassem E, Khaled SA, Karim MA, El-Hamalawy AG, Fahmy M. Does minimally invasive percutaneous transilial internal fixator became an effective option for sacral fractures? A prospective study with novel implantation technique. Eur J Trauma Emerg Surg. 2023;49(3):1535–44.
36. 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.
37. Dienstknecht T, Berner A, Lenich A, Zellner J, Mueller M, Nerlich M, et al. Biomechanical analysis of a transiliac internal fixator. Int Orthop. 2011;35(12):1863–8.

Publisher's note