

# Clinical research on minimally invasive internal fixation for the treatment of anterior ring injury in tile C pelvic fracture

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## Abstract

The aim of this study is to explore the clinical outcome and indications in treating anterior ring injury of Tile C pelvic fracture with minimally invasive internal fixation.

We retrospectively reviewed 18 patients (aged 25–62,  $34.2 \pm 7.4$ ) with 26 pelvic anterior ring injuries of Tile C pelvic fracture treated with minimally invasive internal fixation in our hospital were from January 2012 to August 2016. Two cases were pubic symphysis diastasis, 15 were anterior ring fracture (7 were bilateral), and 1 was vertical displacement of pubic symphysis associated with pubic ramus fracture. According to Tile classification, 8, 4, and 6 cases were types C1, C2, and C3, respectively. All patients accepted the operation of pelvic fractures on both rings, while the anterior ring injuries were treated with minimally invasive internal fixation. The period from injury to operation was 5 to 32 days ( $11.2 \pm 3.7$ ). Four patients had pubic symphysis diastasis or pelvic anterior ring fracture medial obturator foramen reduced with modified Pfannenstiel incision and fixed with cannulated screws, 14 patients (22 fractures) had a fractured lateral obturator foramen reduced with modified Pfannenstiel incision associated with small iliac crest incision and fixed with locking reconstruction plates. Clinical data, such as operation time, intraoperative bleeding, Matta standard to assess the reduction quality of fracture, and complications, were collected and analyzed.

The operation time ranged from 30 to 65 minutes ( $42.8 \pm 18.7$ ), and the intraoperative bleeding volume was 30 to 150 mL ( $66.5 \pm 22.8$ ). All cases were continuously followed-up for 16 to 42 months ( $30.2 \pm 4.6$ ). All fractures were healed between 3 and 9 months postoperatively ( $4.9 \pm 2.7$  months). According to the Matta standard assessment, 18, 7, and 1 cases were excellent, good, and fair, respectively, with a 96.2% (25/26) rate of satisfaction. Neither reduction loss, fixation failure, nor infection occurred; complications included 1 patient with fatal liquefaction, 1 patient had lateral femoral cutaneous nerve injury, and 1 patient complained of discomfort in the inguinal area due to fixation stimulation.

Minimally invasive internal fixation for pelvic anterior ring injury in Tile C pelvic fracture has the advantages of less damage, safer manipulation, less complications, and good prognosis.

**Abbreviations:** ASIS = anterior superior iliac spine, CT = computed tomography, DCO = damage control orthopedics, ISS = injury severity score.

**Keywords:** fracture, fracture fixation, internal fixation, minimally invasive surgical procedure, pelvis

## 1. Introduction

Pelvic fractures comprise 6% to 8% of all fractures,<sup>[1,2]</sup> as well as 20% of multiple traumas.<sup>[1]</sup> According to the Tile classification,

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The datasets generated during and/or analyzed during the current study are publicly available.

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type C fracture, which is the most serious pelvic fracture type as it combines rotational and vertical instability of the pelvis, is a treatment challenge due to its complexity, massive bleeding, and multiple associated traumatic injuries.<sup>[3]</sup> Almost all Tile C fractures involve anterior and posterior ring injuries of pelvis. In the past, most anterior ring injuries were treated conservatively. However, a growing number of studies have shown that ignorance of instability or excessive displacement of anterior ring fractures could increase the chance of nonunion, lead to long-term pain with limited mobility and result in severe complications, such as deep vein thrombosis, decubitus, or muscle dystrophy.<sup>[4–6]</sup> Some mechanical tests have demonstrated that fixation of both anterior and posterior ring can bring greater stability of the pelvis and had better prognosis than simple posterior ring fixation in Tile C pelvic fractures.<sup>[2,4]</sup> Therefore, anterior ring injury in Tile C fracture is now an absolute indication for surgical management.

External fixation with close reduction and open reduction internal fixation have been the main surgical procedures to treat pelvic anterior ring injuries. However, both of these methods have apparent disadvantages. The mechanical strength of the external fixator is too weak to stabilize the fracture and the rate of pin site infection is as high as 50%.<sup>[4,7]</sup> On the contrary, open reduction internal fixation can cause extensive soft-tissue

damage, wound infection, and iatrogenic injury of the nerve and vessels.<sup>[8,9]</sup> Recently, minimally invasive internal fixation has become the focus of research because it avoids the limitations of these traditional methods.<sup>[1,2,10–14]</sup> Yet, few studies have reported the indications for surgical approach and fixation type. We retrospectively reviewed 18 cases of Tile C pelvic fracture with 26 anterior ring injuries treated with minimally invasive internal fixation to evaluate the clinical outcomes of this surgical technique, discuss the indications of surgical approach and fixation according to types of pelvic anterior ring injury, and determine the key points of the procedure.

## 2. Materials and methods

### 2.1. General information

Patients surgically treated for anterior ring injuries of Tile C pelvic fractures in our hospital between January 2012 and August 2016 were retrospectively reviewed. The research was approved by the ethics committee of our hospital.

Inclusion criteria included all of the following: closed fracture without suprapubic drainage; anterior ring injuries were treated with minimally invasive reduction and internal fixation; there were no other anterior incisions, and posterior ring injuries were treated through a posterior approach; and patients had no other medical conditions.

A total of 18 patients (12 males, 6 females) aged between 25 and 62 years (average  $34.2 \pm 7.4$ ) were included in our study. Thirteen cases were injured in traffic accidents and 5 cases were caused by high falls. There were a total of 23 fractures among these 18 patients: 2 pubic symphysis diastasis; 15 anterior ring fractures, 7 of which were bilateral; and 1 vertical displacement of the pubic symphysis associated with rami comminuted fracture. According to Tile classification, 8, 4, and 6 were C1, C2, and C3, respectively. All cases were associated with multiple injuries, which include 1 head injury, 10 chest injuries, 2 abdominal injuries, 2 genitourinary injuries, 3 lumbosacral nerve plexus injury, and 9 limb or lumbar vertebral fractures.

### 2.2. Methods

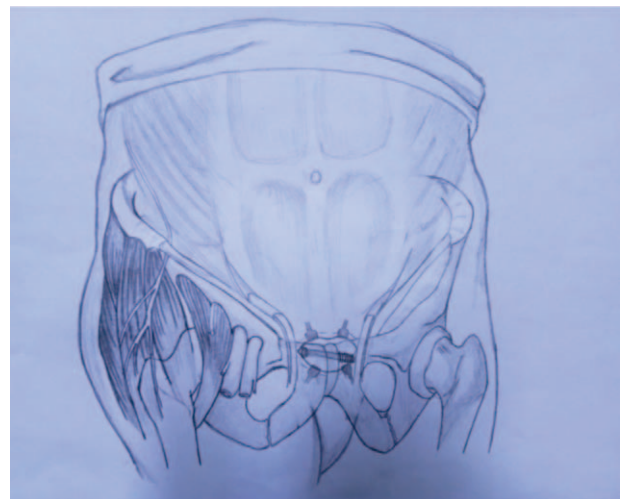
**2.2.1. Preoperative preparation.** All patient injuries were evaluated using the injury severity score (ISS) upon admission and patients were managed with a corresponding treatment protocol. Ten patients were treated with damage control orthopedics (DCO), 7 were temporarily treated with external fixators, while the remaining 3 received traction treatment. All associated injuries were treated by related specialists from different departments, and the definitive operations of pelvic injury were performed until the general conditions of the patient were stable (vital signs were stable, the assay index showed normal hemodynamics and blood clotting time). Anticoagulation schemes were implemented based on the patient's blood coagulation time test results. Seven patients were diagnosed with deep venous thrombosis, 4 of whom received filters implanted in their inferior vena cava because the embolus was located above the knee. The period from injury to operation varied from 5 to 32 days (average,  $11.2 \pm 3.7$  days). Anterior-posterior inlet and outlet X-rays of the pelvis, as well as pelvic 3-dimensional computed tomography (CT) scans were conducted for all patients. Fourteen patients who were to undergo minimally invasive incisions with locking reconstruction plate fixation underwent CT arteriography and venography to exclude close

contact between the superior ramus of pubis and the corona mortis (if exists).

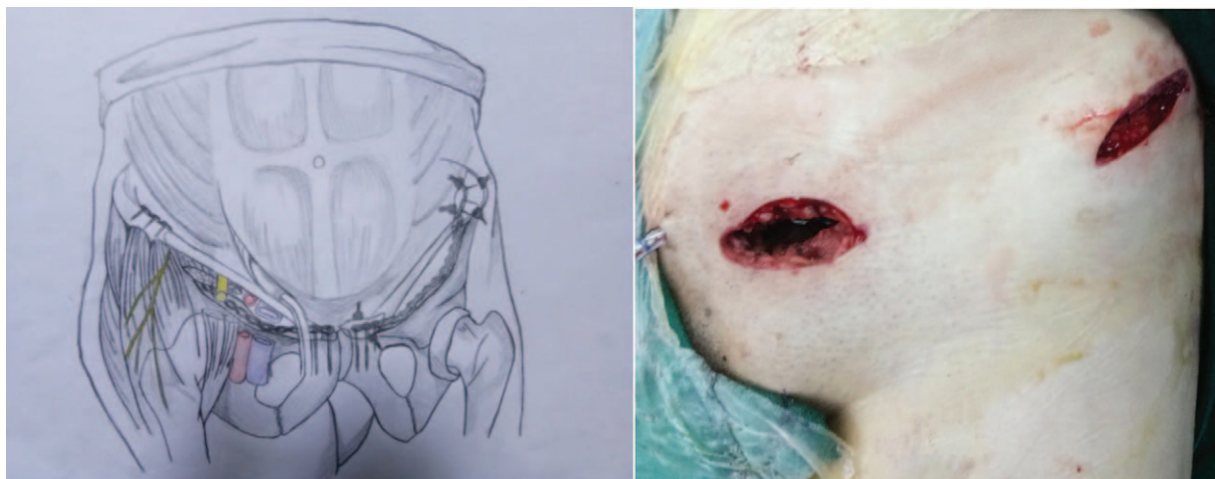
**2.2.2. Fixation of pelvic posterior ring.** All posterior ring injuries were reduced and fixed simultaneously with the treatment of anterior ring injuries, but the surgical procedures for the anterior and posterior ring on the pelvis were rigidly separated. The incisions for the treatment of posterior ring injuries were made in the posterior area of pelvis to avoid overlap with the anterior ring incisions. Iliosacral screws were applied in 5 cases; lumbopelvic fixations were applied in 5 cases, M-shaped anatomical locking plates were applied in 4 cases, and triangular fixations were applied in 4 cases.

**2.2.3. Procedure of minimally invasive internal fixation on pelvic anterior ring.** All operations were performed by the same team of surgeons. A 2nd generation cephalosporin was administered intravenously 30 minutes prior to operations for infection prevention. All operations were performed with the patients under general anesthesia and in the supine position. Time of operation and volume of bleeding were recorded. For patients with 2 injuries of the anterior ring, the surgical procedure treating 1 injury was finished completely before treating the 2nd injury and surgical data were recorded as 2 independent operations.

**2.2.3.1. Minimally invasive internal fixation of pubic symphysis diastasis.** An external fixator was used to restore the normal width of the pubic symphysis by fluoroscopy monitor. Once satisfactory reduction was obtained, a 1-cm incision was made at the position of the pubic tubercle and a 5.5-mm diameter half-thread cannulated screw (General Electronic company (USA, hoosier state)) was inserted through the superior pubic rami bilaterally to fix the symphysis. The location of the screw between both pubic tubercles and just puncturing the bilateral cortexes was confirmed by fluoroscopy intraoperatively (Fig. 1). If closed reduction was not successful, a modified Pfannenstiel incision was applied to expose the injured part. A 5-cm transverse incision was made 1 cm superior to the pubic symphysis, then dissected bilaterally to both sides of the pubic tubercles. The exposure of the spermatic cord or round ligament of the uterus was not



**Figure 1.** Modified Pfannenstiel incision inserted with cannulated screw to treat pubic symphysis.



**Figure 2.** Medial and lateral combined incisions with locking reconstruction plate subfascial insertion to treat pelvic anterior ring fracture lateral to the obturator.

unnecessary, but all procedures were limited medially to the bilateral pubic tubercles. Open reduction was performed with a pointed reduction clamp or a reduction screw technique and the cannulated screw was inserted. The operator assessed the damage level of fibrous cartilage intraoperatively, and cartilage removal associated with symphysis fusion was performed if the damage was severe. This surgical technique can also be applied to the interlocking treatment or vertical displacement of pubic symphysis.

**2.2.3.2. Minimally invasive internal fixation of anterior ring fracture.** The anterior ring fractures were treated by 2 different methods according to the location of the fracture line.

1. With fracture lines located medial to the obturator, a modified Pfannenstiel incision was made to the affected half and direct exposure was obtained by releasing and pulling away the soft tissue close to the pubic tubercles. The fractures were then reduced by an external fixator or reduction clamp. If the medial fragment was large enough, a 5.5-mm diameter cannulated screw (General Electronic company) was inserted retrogradely across the fracture line and penetration of the bilateral cortex was ensured. If the fragment was not large enough, the cannulated screw was inserted anterogradely, identical to the pubic symphysis diastasis fixation. Full-thread and half-thread screws were selected in comminuted and noncomminuted fractures, respectively. Intraoperative fluoroscopy was necessary in both procedures.
2. With fracture lines lateral to the obturator, in addition to the modified Pfannenstiel incision to the affected half, an extra 5 cm incision was made from 1 cm posterior to the anterior superior iliac spine (ASIS) to the anterior 3rd of the iliac crest. The anterior muscles were detached from the medial iliac plate. Then, a blunt end stripper was inserted into the lateral incision and stripped subperiosteally above the pubic superior ramus to prepare a connected channel between the 2 incisions from the medial ilium to the pubic symphysis and beneath the deep fascia. Part of the abdominal rectus was removed and the affected hip and knee were continuously flexed to relax the iliopsoas and protect the inguinal nerve and vessels during the stripping procedure. Indirect reduction was obtained with minimally invasive instruments, such as a small pointed clamp

or a gun-shaped reduction forceps, under fluoroscopy. K-wire was used to fix the fracture temporarily. Then a preshaped 3.5 mm reconstruction locking plate (ZIMMER company (USA, hoosier state)) was inserted through the subfascial channel to ensure good attachment with the superior pubic ramus. Two or 3 locking screws were inserted into each side (pubic ramus or ilium) to fix the plate through each incision (Fig. 2).

All wounds were irrigated and a negative pressure drainage tube was inserted in the medial incision. X-ray examination was performed to reconfirm reduction and fixation prior to suture.

Among these 18 patients (26 injuries), cannulated screws were applied in 4, while locking reconstruction plates were applied in the other 14 (22 fractures).

### 2.3. Postoperative management

A 2nd generation cephalosporin was administered intravenously for 1 to 3 postoperative days, dependent on the length of the operation and the volume of intraoperative bleeding. The drainage tube was removed when the fluid volume was <50 mL per 24 hours. Anticoagulation therapy, consisting of compression stockings and low molecular weight heparin, was initiated 24 hours postoperatively. Patients were encouraged to mobilize their lower limbs without weight bearing from 2 days postoperatively and were transferred to a rehabilitation department 2 weeks after suture removal.

### 2.4. Treatment outcome evaluation

Patient follow-ups were performed at 2 weeks, 1 month, 3 months, 6 months, 9 months, and 1 year postoperatively, and then every 6 months. Anterior-posterior inlet and outlet pelvic X-rays were obtained at each follow-up to countercheck reduction redisplacement or fixation failure and to determine if the fracture was healed. CT scans were conducted when it was difficult to confirm fracture healing. We evaluated the quality of reduction with the Matta standard of reduction assessment. As there is no scoring system which can accurately evaluate the outcome of anterior ring injury treatment individually, we judged patient outcomes with a subjective inquiry of the pelvic anterior ring area at the final follow-up.



### 3. Results

Operation times ranged from 30 to 65 minutes (average,  $42.8 \pm 18.7$  minutes); intraoperative bleeding ranged from 30 to 150 mL (average,  $66.5 \pm 22.8$  mL). The operation times for patients who underwent minimally invasive incisions with locking reconstruction plate fixation were between 35 and 65 minutes (average,  $49.3 \pm 15.6$  minutes), with 50 to 150 mL of intraoperative bleeding (average,  $93.6 \pm 17.2$  mL). There were no iatrogenic injuries to major nerves, vessels, or the spermatic cord. Patients were followed up continually from 16 to 42 months until the recovery of normal life (average  $30.2 \pm 4.6$  months). All anterior ring fractures healed between 3 and 9 months, postoperatively (average  $4.9 \pm 2.7$  months). According to the Matta standard of reduction assessment, there were 18, 7, and 1 excellent, good, and fair cases, respectively; furthermore, the rate of satisfaction was 96.2% (25/26), among which the satisfied ratio of displaced fracture reductions was 95.5% (21/22). One patient complained of an uncomfortable feeling around the pelvic anterior ring area; all other patients reported normal sensations at the final follow-up. There were no cases of fixation failure, redisplacement of reduction, or infection. The complications included 1 case of suprapubic wound exudation on the fourth postoperative day. Since the bacterial culture was negative, the abnormality of wound could be explained with fat liquefaction due to obesity. We reopened the wound to provide sufficient drainage, dressed daily for 7 days, and resutured. The wound was successfully healed 2 weeks later. Another case experienced numbness of the anterior and lateral part of the affected thigh from the 2nd postoperative day because of intraoperative injury to the lateral femoral cutaneous nerve. He was treated with oral mecobalamin and the symptom resolved 3 months later. Additionally, 2 other patients who underwent plate insertion complained of discomfort in the affected inguinal area when they began full-body weight-bearing in the 3rd postoperative month, but their daily activities were not affected. This may have resulted from irritation of the soft tissues surrounding the internal fixation. Both patients fully recovered through physical therapy and rehabilitation 6 months later.

### 4. Discussion

#### 4.1. The advantage of minimally invasive internal fixation to treat anterior ring injury of pelvis

Currently, the 2 main approaches to expose and fix pelvic anterior ring injuries are the Pfannenstiel incision, which can expose the pubic symphysis and medial fractures of the superior pubic ramus, and the classic or modified ilioinguinal approach, which is used to expose lateral superior pubic ramus fractures. However, both of these approaches have obvious deficiencies. Firstly, bilateral spermatic cords or round ligaments of the uterus have to be dissected during classic Pfannenstiel incision exposure, which damages the superficial inguinal ring. Furthermore, the rectus abdominis and pectineal muscles must be removed so that the plate can be placed above pubic symphysis, which exacerbates iatrogenic soft-tissue damage. Secondly, exposure by the ilioinguinal approach is relatively difficult because of the anatomical complexity, which can lead to prolonged operation time, increased intraoperative bleeding, and the increased possibility of iatrogenic damage to the vessels or nerves.<sup>[9,11,15]</sup> The modified ilioinguinal approach can restrict the opening to a medial and lateral window, which avoids exposure of the femoral

vessels and nerves; however, bleeding is still massive during the exposure of the iliac fossa, and this procedure does not contribute to the treatment of anterior ring injuries.<sup>[16,17]</sup> In this study, we applied minimally invasive techniques to treat pelvic anterior ring injury, which had significant advantages:

- The modified Pfannenstiel incision ensured sufficient space to manipulate during the operation of pubic symphysis diastasis or anterior ring fractures medial to the obturator, making it unnecessary to expose the spermatic cord or round ligament. Moreover, intraosseous screw fixation avoids soft damage above the pubis from plate insertion, so that the blood supply around the fracture was maximally protected.
- Using a closed subfascial channel connection between the medial and lateral incisions associated with preshaped reconstruction locking plate insertion to treat pelvic anterior ring fractures lateral to the obturator can not only supply the same exposure as an ilioinguinal incision, but also lessens the iatrogenic damage to the patient, which can reduce operation time and intraoperative bleeding.

Furthermore, all the patients in our study had Tile C type pelvic fractures, which required simultaneous surgical treatment of the anterior and posterior ring. Since the reduction and fixation of posterior ring injuries are much more complicated, require longer operation times, and result in increased intraoperative bleeding than in anterior ring injuries, rapidity and minimal invasion during the operation of anterior ring injuries are vital. We demonstrated shorter operation times, less intraoperative bleeding, and fewer postoperative complications with these minimally invasive internal fixation methods of treating anterior ring injuries of the pelvis compared with other methods.<sup>[1,7,9,11]</sup>

#### 4.2. Indications for different pelvic anterior ring approaches and fixation types

Most surgeons agree that external fixation is not the definitive treatment for pelvic anterior ring injuries, except in some special cases, and that internal fixation should be the priority.<sup>[1,3,6,12,14,18]</sup> Currently, there are 3 primary types of internal fixation used to treat pelvic anterior ring injuries, an internal fixator (INFIX), a reconstruction plate, and a cannulated screw. All 3 can be inserted with this minimally invasive technique. INFIX refers to a series of internal fixators which can indirectly reduce and fix pelvic anterior ring injuries with the advantages of short operation time, less intraoperative bleeding, and low infection rates.<sup>[19–21]</sup> However, this fixation is not our preference because it only provides the same mechanical strength as an external fixator, which is not enough stability,<sup>[22]</sup> and has complications, such as an increased risk of lateral femoral cutaneous nerve injury, painful implant impingement, and femoral nerve palsy caused by connecting rod compression.<sup>[23–25]</sup> Comparisons of the fixation strength between the reconstruction plate and the cannulated screw are inconsistent in different mechanical studies.<sup>[26–29]</sup> On the contrary, in clinical reports, the failure rates of these 2 fixations were similar and much lower compared to other types of fixation,<sup>[9–11,15–17,30,31]</sup> which indicate that both could treat anterior pelvic ring injuries reliably and effectively.

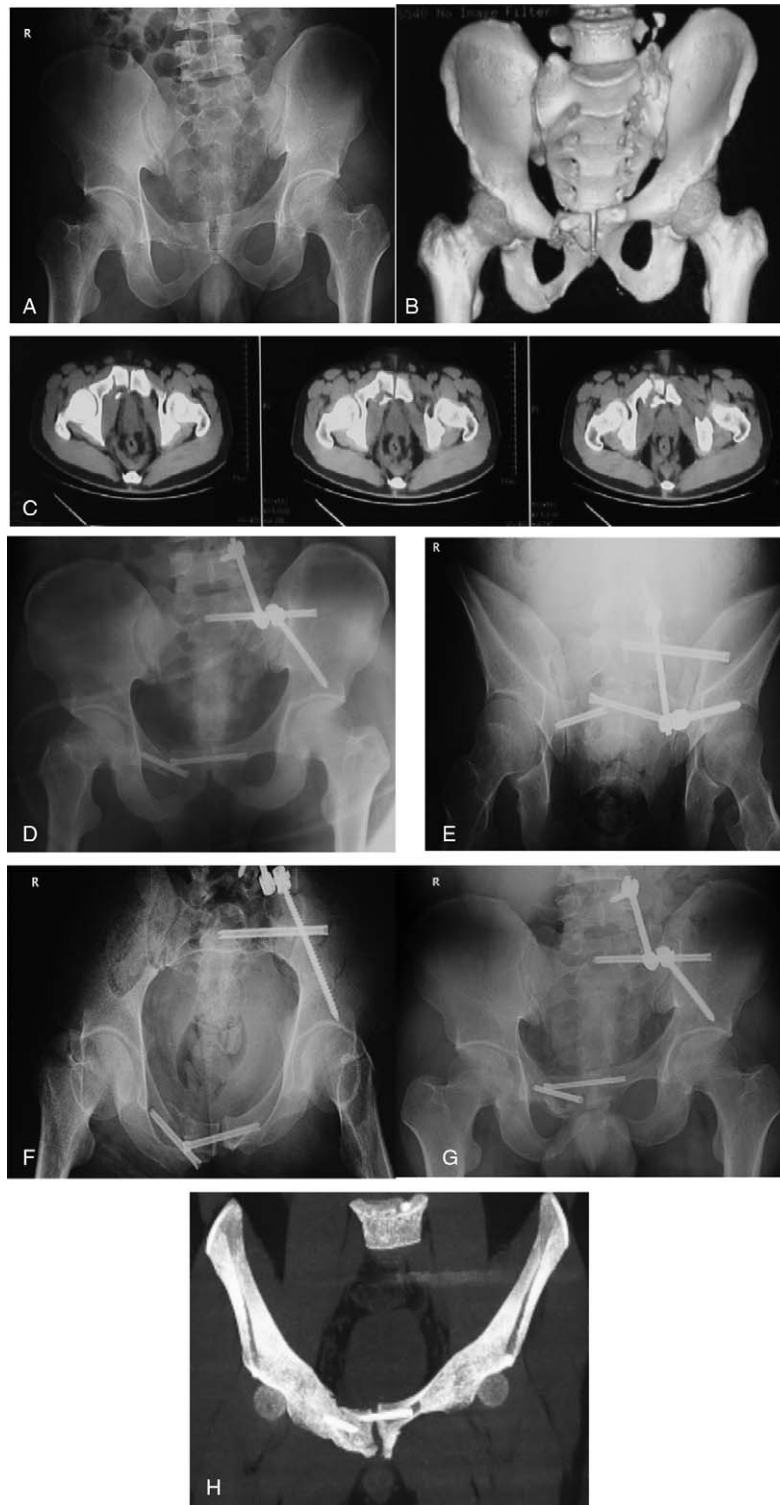
However, choosing the most suitable approach and internal fixation for different types of anterior ring injury is difficult. In our study, selections were based on the location of the injury. If the fracture line was medial to the obturator, a modified



**Figure 3.** (A–C) Male, 44 years old, C1.3 pelvic fracture caused by traffic accident. (D) M-type plate to fix right sacral fracture. Bilateral superior rami fractures treated with combined incisions with locking reconstruction plate subfascial insertion. (E) The fractures were healed 6 months postoperatively and the patient was satisfied.

Pfannenstiel incision with a cannulated screw was chosen for multiple reasons. Firstly, it can reduce intraoperative exposure and avoid damage to the muscle above the pubis caused by plate insertion. Secondly, a sufficient amount of screws may not be

inserted into plates on the pubis if the fracture line is located too medially, which will decrease stability and lead to fixation failure. Finally, because healing of the superior pubic ramus medial to the obturator is easier than in other areas, limited open reduction and



**Figure 4.** (A–C) Male, 34 years old, C1.3 pelvic fracture caused by falling from a high place. (D–F) Triangular fixation was applied to the left sacral fracture. Modified Pfannenstiel incision associated with cannulated screw was applied to treat vertical displacement of the pubic symphysis, and the comminuted superior pubic ramus fracture was simultaneously fixed with a cannulated screw. (G, H) Both pubic symphysis osseous fusion and superior ramus fracture healing were obtained 6 months postoperatively and the patient was back to work normally.



fixation can be performed regularly wherein surgeons can observe the procedure under direct vision, which avoids frequent intraoperative fluoroscopy and lessens radiation damage.

When the fracture line is lateral to the obturator, a modified Pfannenstiel and small crest incisions associated with locking reconstruction plates were chosen for several reasons. Firstly, the insertion of a cannulated screw in this area is difficult and dangerous. McLachlin et al<sup>[4]</sup> declared that the diameter of a cannulated screw must be no <4.5 mm and penetrate the bilateral cortexes of the pubis to obtain the same stability as a reconstruction plate in the treatment of pubic fractures. These requirements are attainable in the treatment of superior pubic ramus fractures, which are medial to the obturator, because the screw length can be short and the operation can be performed under direct vision to ensure the correct location of the screw and avoid damage to important nerve and vessels. However, if the fracture line is located lateral to the obturator, the length of the cannulated screw must be longer and operator manipulation must depend only on the fluoroscopy monitor. These conditions enhance the difficulty of the operation, require excellent surgical skill, and a good match between the screw and the anatomic morphology of the superior pubic ramus. The more laterally the fracture lines are located, the more rigid these requirements. Compared to plate fixation, screw insertion requires a longer operation time, needs more fluoroscopy, and induces more massive bleeding and iatrogenic injury. Secondly, the medial fragment space ensures sufficient screw insertion to keep the fixation stable if the fracture line is lateral to the obturator. Lastly, medial and lateral incisions can facilitate indirect reduction of the superior pubic ramus fracture more accurately with instrument insertion from both sides (Fig. 3), and the fixation strength with the use of a locking plate can be greatly enhanced.

#### 4.3. Key points of the procedure

The existence of corona mortis is dangerous in the operation combining small incisions associated with plate insertion through the subfascial channel. This is because injury during the process of subperiosteal stripping is highly possible if the aberrant vessel is close to superior pubic ramus and uncontrolled massive bleeding will occur. Therefore, patients with pelvic anterior ring fracture suitable for this procedure must first undergo CT arteriography and venography examinations to exclude close contact between the ramus and the corona mortis, if it exists. Furthermore, closed subperiosteally stripping must be performed precisely and carefully.

Several reports showed good outcomes when treating symphysis diastasis with closed reduction and cannulated screw fixation.<sup>[16,17]</sup> However, since the healing ability of fibrous cartilage in the pubic symphysis is poor, nonunion of this conjunction is highly likely if the damage is severe, and the patient will suffer from chronic pain if this happens. Meanwhile, internal fixation might fail due to sustained micromotion of the fracture. Thus, we suggest open exposure of the symphysis to assess the damage level of the fibrous cartilage, and cartilage removal associated with bone grafting to fuse the conjunction if the damage is severe.

Different pelvic anterior ring injury types may occur in the same patient, whereby various combinations of minimally invasive techniques can be flexibly utilized (Fig. 4).

## 5. Conclusion

This retrospective study has limitations. First, there was no control group and the sample size was small; therefore the clinical reliability is lower. Furthermore, the patient follow-up period was limited.

In conclusion, we recommend minimally invasive internal fixation for treating pelvic anterior ring injury in Tile C fractures, as our results demonstrate less damage, safer manipulation, fewer complications, and good prognosis.

## Author contributions

**Conceptualization:** Jianmin Wang, Zhaojie Liu.

**Data curation:** Wei Tian.

**Writing – original draft:** Xiaochen Sun, Huimin Yan.

**Writing – review & editing:** Jian Jia.

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