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Original Article

Therapeutic effects of minimally invasive adjustable and locking compression plate for unstable pelvic fractures via posterior approach

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Abstract: Objective: Unstable pelvic fractures are clinically complex injuries. Selecting appropriate treatment remains a challenging problem for orthopedic physicians. The aim of this study is to compare the clinical effects of minimally invasive adjustable plate and locking compression plate in treatment of unstable pelvic fractures via posterior approach. Methods: From January 2009 to June 2012, fifty-six patients with unstable pelvic fractures were included. After at least 12-month follow-up, forty-four patients treated with two methods were enrolled in the study and divided into two groups: minimally invasive adjustable plate (group A) and locking compression plate (group B). Preoperative and postoperative radiography was taken to assess the fracture displacement and reduction quality. The size of incision, operation duration, blood loss, duration of X-ray exposures, Majeed postoperative functional evaluation and Lindahl postoperative reduction evaluation were analyzed. Results: The mean follow-up in group A was 27.3 months (range, 13-48 months), and that in group B was 21.8 months (range, 12-42 months). There were no iatrogenic neurovascular injuries during the operations in the two groups. In group B, malunion was observed in one patient, and infection of incision was observed in one case. The operation duration, blood loss, and size of incision of group A were significantly less than that of group B. There was no significant difference in the duration of X-ray exposures between the two groups. The Majeed functional evaluation score in group A was significantly higher than that in group B. The difference of the imaging score of the retained displacement was not statistically significant. Conclusions: Both the two methods can effectively stabilize the unstable pelvic fractures. However, the minimally invasive adjustable plate has the advantages of minimally invasive, less radiation exposure, technically safe and time saving. Minimally invasive adjustable plate is a good supplementary option for treating posterior pelvic ring injuries.

Keywords: Unstable pelvic fractures, fracture fixation, internal, minimally invasive reduction, posterior approach, minimally invasive adjustable plate

Introduction

Pelvic fractures are clinically complex injuries, accounting for 3.64% of fractures in adults [1], and occur as a result of high-energy trauma, such as falls and motor vehicle accidents. 68.3% of pelvic fractures are unstable fractures, which are serious injuries, and the mortality rate is up to 19% [2-4]. Selecting appropriate treatment for unstable pelvic fractures remains a challenging problem for orthopedic physicians. The stability of the pelvis is mainly related to the integrity of posterior pelvic ring [5]. Therefore, the treatment of unstable pelvic fractures need to restore the continuity and stability of posterior pelvic ring as far as possible.

Treatments of unstable pelvic fractures include conservative treatment and operative treatment. Conservative treatment has a significant chance of long-term complications: nonunion and malunion, pain, and neurologic dysfunction, more recently, scholars advocate operative treatment [6, 7]. Although the external fixation has the advantages of small wound and easily operation, there are some disadvantages of less stiffness, infection and loose [7, 8]. Greater stability of posterior pelvic ring can be achieved by internal fixation [9]. There are a

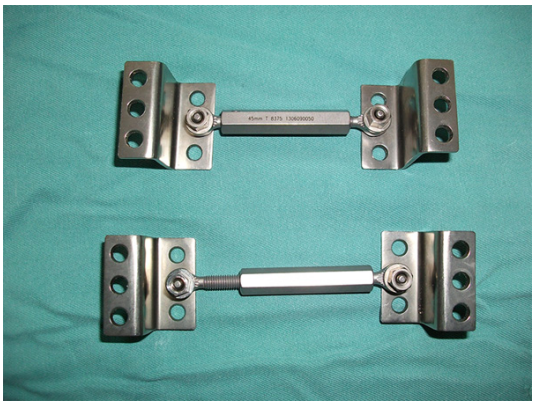

Figure 1. Structure of minimally invasive adjustable plate (MIAP).

variety of methods available, including iliosacral (IS) screws, sacral bars, tension band plate (TBP), triangular osteosynthesis and so on.

IS screw fixation is a well-recognized technique for treating the posterior pelvic ring disruption. It is implanted in the supine or prone position and has such merits as short operative time, slight trauma and minimal invasion [10-12]. However, it remains a technically demanding procedure, and both doctors and patients are exposed to large amounts of radiation as continuous fluoroscopic or computerized tomography (CT) guidance for appropriate screw insertion [13]. In addition, higher rates of iatrogenic injury is one of the disadvantages [14-16], seriously affecting the clinical use of this technology.

Pelvic posterior approach is a safe path, which can clearly expose the structure of posterior pelvic ring and avoid impairing the nerve, blood vessels and viscera in front of sacroiliac complex. Locking compression plate (LCP) is one of the common technologies for stabilizing the posterior pelvic ring [17, 18]. But pre-bending of LCP for adapting the structure of posterior pelvic ring, which can reduce the strength of the plate or damage the threads of screw holes, affects pelvic stability fixed with LCP [19]. To address these limitations, we introduced a novel minimally invasive adjustable plate (MIAP) according to the structure characteristics of posterior pelvic ring (Patent NO. ZL20081-0079334.7) (**Figure 1**). In this study, we retrospectively compared MIAP with LCP for treatment of unstable pelvic fractures.

Materials and methods

The study was approved by the Ethics Committee of our hospital.

General data

A prospective study was conducted, and all patients presented to our department were recruited. Inclusion criteria were as follows: (1) unstable pelvic ring fracture, (2) aged over 18 years, (3) hemodynamic stability, (4) clear consciousness, and (5) without serious medical conditions. The exclusion criteria were: (1) history of previous injury or pelvis deformities, (2) pathologic fractures, and (3) amputation. From January 2009 to June 2012, 56 patients with unstable pelvic ring fractures were included in this investigation and randomly divided into two groups. After at least 12-month follow-up, 2 patients died and 10 patients failed to be followed up. Finally, 44 patients were enrolled in this study. Of these, 22 patients had injury caused by traffic accident, 15 by fall from height, and 7 by crush. All patients in this study had associated anterior pelvic ring disruption. Of these, 28 patients suffered from fracture of the superior and inferior rami of pubis on both sides and the other 16 patients had separation of pubis symphysis with fracture of superior and inferior rami of pubis at one side. Combined fixation via posterior and anterior approaches was adopted in this group. Internal fixation or external fixation were used to stabilize the anterior pelvic ring. Internal fixation with MIAP via posterior approach was used in 20 patients (group A), and internal fixation with LCP via posterior approach was used in 24 patients (group B). In group A, the pelvic injuries were AO/OTA 61-Type B in ten cases (4 Type B1, 4 Type B2, 2 Type B3) and Type C in ten cases (6 Type C1, 3 Type C2, 1 Type C3). In group B, the pelvic injuries were AO/OTA 61-Type B in sixteen cases (8 Type B1, 6 Type B2, 2 Type B3) and Type C in eight cases (5 Type C1, 3 Type C2). The average duration from injury to operation was 7.9 days (range, 2-20 days) in group A and 8.0 days (range, 1-16 days) in group B. Of the 20 cases in group A, twelve were associated with multiple injuries, including head injury in one case, hemopneumothorax in two, L4 lumbar fracture in one, acetabular fracture in two, extremities fractures in seven, urethral disruption in three, laceration of perineum in two, bladder injury in two and renal contusion in one. Of the 24 cases

Table 1. Comparison of the general situation between two groups

Index	Internal fixation with minimally invasive adjustable plate group (n=20)	Internal fixation with locking compression plate group (n=24)	*P* value
Age (years)	39.513.2	34.310.1	0.152
Gender (male:female)	11:9	13:11	0.956
ISS score	14.06.2	12.45.3	0.355
Fracture type (B:C)	10:10	16:8	0.263
duration from injury to operation (days)	7.94.8	8.03.8	0.913

in group B, seventeen cases were associated with multiple injuries, including head injury in two cases, haemopneumothorax in one, pulmonary parenchyma wounded in two, acetabular fracture in three, extremities fractures in twelve, urethral disruption in two, laceration of perineum in one, bladder injury in three and renal contusion in three. The mean Injury Severity Score (ISS) [20] of group A was 14.0 (range, 9-29), and that of group B was 12.4 (range, 9-25). Comparison of the general data between the two groups was presented in **Table 1**. The statistical analysis showed that the age, gender ratio, ISS score, fracture type and duration from injury to operation were all comparable.

Imaging examination

All patients received plain X-ray films (anteroposterior, inlet, and outlet views) of the pelvis before operation and an experienced radiologist (Z.Z.K.) was assigned to read these films. Computed tomography (CT) scanning and three-dimensional (3-D) reconstruction were performed to determine the involved fracture portion, the type of fracture, and stability of the pelvis.

Treatment method

All fractures were temporarily fixed and the wound was bandaged after hospitalization. The debridement and suturing, urethral reunion operation or repair of ruptured bladder was performed if necessary. Skeletal traction at the affected side was performed when the posterior pelvic ring fracture presented obvious vertical displacement or associated with fracture of lower limb. The tractive weight was 1/6 to 1/4 of the body weight and the bed legs were blocked up to counteract the skeletal traction. Generally, traction persisted for 3-7 days.

To restore the stability of the pelvic ring, fixation of the anterior and posterior pelvic ring should be done at the same stage. Under general anesthesia or continuous extradural anesthesia, the patient was put in prone position and the posterior pelvic ring was fixed using MIAP or LCP. Then, supine position was adopted to perform fixation of anterior pelvic ring with internal fixation or external fixation. In the minimally invasive adjustable plate group, bilateral longitudinal incisions 4-6 cm long were made along the posterior superior iliac spines (PSISs). The bilateral PSISs were exposed after the soft tissue had been dissected, between which a subcutaneous tunnel was created. After reducing the pelvic ring fractures, the Z-shaped bracket was placed with the web plate close to the medial surface of the PSIS and the upper wing lying on the dorsal surface of the PSIS. Some long cancellous screws were inserted through the holes of the upper wings in order to secure the Z-shaped bracket on the ilium. Some screws were inserted into the sacral ala if possible. The assembled connection bar was placed through the tunnel and fastened to the brackets. We would made 2-3 cm longitudinal incision in the midline of sacrum or oblique incision from one side of PSIS for resecting the median sacral crest if the crest obstructed the bar. The hexagonal tube was rotated to shorten or elongate the bar under C-arm X-ray fluoroscope, which in turn reduced the separated fracture or distracted the compressed fractures, respectively (**Figure 2**).

In the locking compression plate group, a transverse incision was made through the bilateral PSISs, its length being 20-25 cm. The skin, subcutaneous tissue, and superficial fascia had been dissected in turn. The gluteal muscles were stripped off, in order to expose the outer plate of the ilium. The displacement of posterior pelvic ring was reduced by extrusion, traction

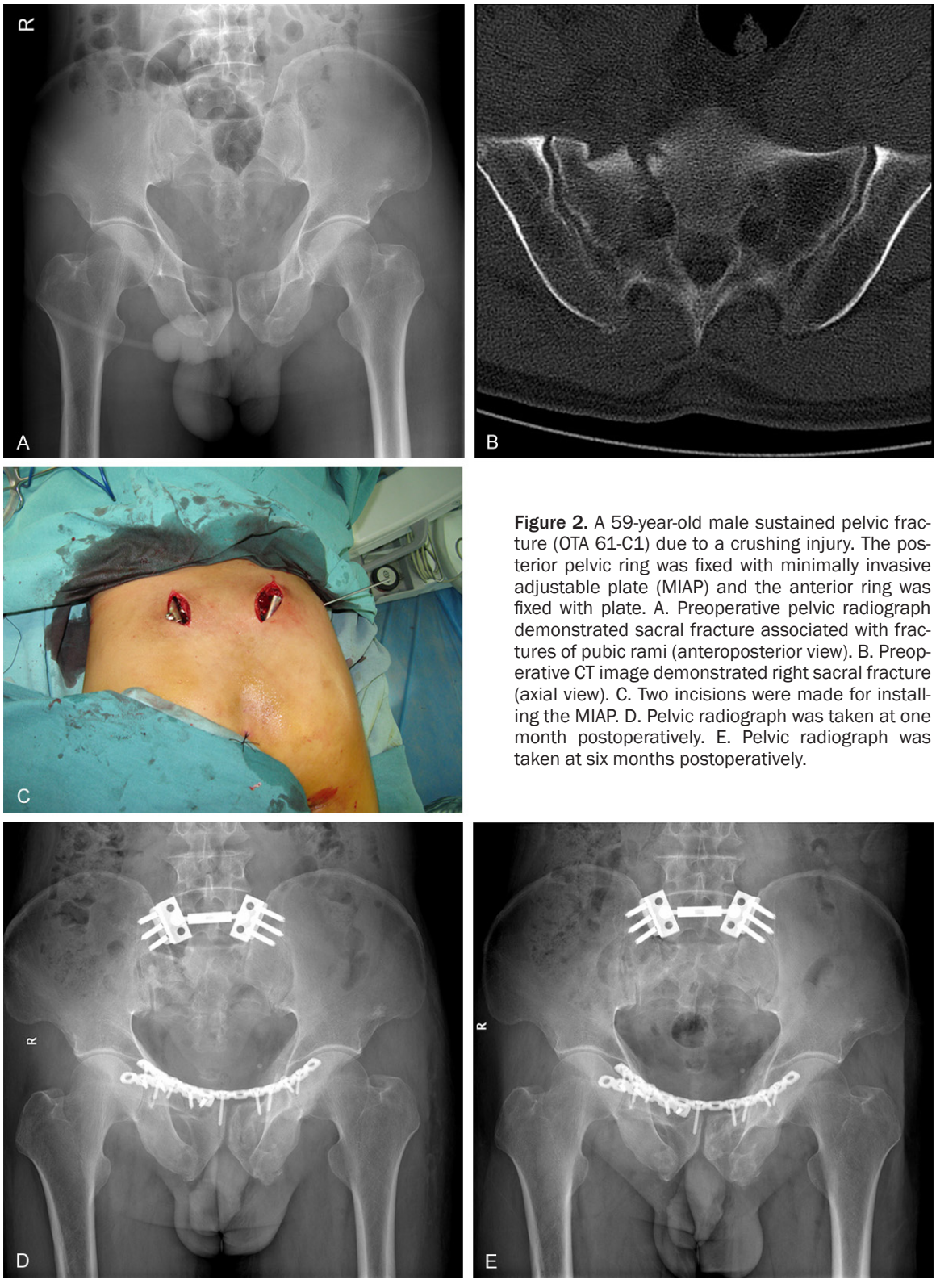

Figure 2. A 59-year-old male sustained pelvic fracture (OTA 61-C1) due to a crushing injury. The posterior pelvic ring was fixed with minimally invasive adjustable plate (MIAP) and the anterior ring was fixed with plate. A. Preoperative pelvic radiograph demonstrated sacral fracture associated with fractures of pubic rami (anteroposterior view). B. Preoperative CT image demonstrated right sacral fracture (axial view). C. Two incisions were made for installing the MIAP. D. Pelvic radiograph was taken at one month postoperatively. E. Pelvic radiograph was taken at six months postoperatively.

or poking. A locking compression plate with length suitable was selected and each end of the plate was bent for fitting the outer plate of the ilium before fixation. The screws were tightened respectively. Each screw should penetrate the lateral bony cortex (**Figure 3**).

Figure 3. A 40-year-old female sustained pelvic fracture (OTA 61-C1) due to a fall from a 3.5-m height. The posterior pelvic ring was fixed with locking compression plate (LCP) and the anterior ring was fixed with external fixation. A. Preoperative pelvic radiograph demonstrated sacral fracture associated with fractures of pubic rami (anteroposterior view). B. Preoperative CT image demonstrated right sacral fracture (coronal view). C. Pelvic radiograph was taken at one month postoperatively. D. Pelvic radiograph was taken at twelve months postoperatively.

Postoperative management

The suction drains were taken away within 24 h usually. All patients were put in a non-weight-bearing position, postoperatively. The patients were encouraged to take active exercises 3-4 days after operation. Crutch-assisted walking was allowed after two weeks. Partial weight-bearing began at six weeks postoperatively. Progression to full weight-bearing was determined on the basis of osseous union on pelvic radiographs. Follow ups were done and the pelvic radiographs were taken at one month, three months, six months, one year and final follow-up.

Parameters for investigation

Relevant data, such as size of incision, operation duration, blood loss, duration of X-ray exposures, ect., were collected. The retained displacements measured on the radiographs was evaluated according to the criteria proposed by Lindahl et al. (excellent, 0-5 mm;

Table 2. Comparison of operative data between the two groups (xs)

Index	Internal fixation with minimally invasive adjustable plate group	Internal fixation with locking compression plate group	*t* value	*P* value
Operation duration (min)	75.513.2	161.031.7	-10.605	< 0.001
Blood loss (ml)	207.039.2	319.291.3	-5.110	< 0.001
Size of incision (cm)	9.01.4	15.05.2	-5.006	< 0.001
Duration of X-ray exposures (s)	8.20.9	7.81.4	1.134	0.263
Majeed functional evaluation score	85.17.8	78.99.0	2.433	0.019

good, 6-10 mm; fair, 11-15 mm; poor, more than 15 mm) [21]. Postoperative functional recovery was assessed with the Majeed score standard [22], which includes five aspects: standing (36 points), pain (30 points), working ability (20 points), sitting (10 points), and sexual life (4 points). The maximum score is 100 points, with excellent ≥ 85 points; good 70-85 points; fair 55-69 points; and bad ≤ 55 points.

Statistical analysis

All the statistical analyses were performed with SPSS version 16.0 software (SPSS Inc., Chicago, IL, USA). Measurement data were presented as mean and SD and t-Test was used for comparison. The enumeration data were compared with chi-square test. $P < 0.05$ was considered as statistically significant.

Results

Forty-four patients were followed up. The mean follow-up in group A was 27.3 months (range, 13-48 months), and that in group B was 21.8 months (range, 12-42 months). There were no iatrogenic neurovascular injuries during the operations in the two groups. In group B, malunion was observed in one patient, and infection of incision was observed in one case, who healed after dressing. The other fractures healed without internal fixation loosening or breakage. The operation duration (75.5 ± 13.2 min), blood loss (207.0 ± 39.2 ml), and size of incision (9.0 ± 1.4 cm) of group A were significantly less than that of group B ($P < 0.01$). There was no significant difference in the duration of X-ray exposures between the two groups (**Table 2**).

After operation, the imaging score of the retained displacement in group A was as follows: excellent in 14 patients, good in 5, and fair in 1, corresponding to an excellence rate of 95%, and that in group B was as follows: excellent in 13 patients, good in 8, and fair in 3, corresponding to an excellence rate of 87.5%. But the difference was not statistically significant ($x^2 = 0.112$, $P > 0.05$). The Majeed functional evaluation score in group A (85.1 ± 7.8 points) was significantly higher than that in group B (78.9 ± 9.0 points) ($P < 0.05$).

Discussion

Unstable pelvic fracture is a common clinical severe trauma. If improperly treated, they could be complicated with disunion or malunion at the late period, leading to lower limb function limitation and lower back pain and affecting the patients' daily life and work [23]. The treatment of unstable pelvic fractures remains a major challenge for the surgeon. Open reduction or minimally invasive reduction internal fixation is the main method for the treatment of unstable pelvic fractures.

The treatment for anterior pelvic ring injury has been controversy. Chen et al [24] did biomechanical experiments and confirmed there was no obvious abnormality on the mechanical conduction of the pelvis when the pubic symphysis separation is less than 2.5 cm. Matta [25] also considered conservative treatment was effective if the separation is less than 2.5 cm. However, some scholars advocated open reduction and fixation [26]. Studies have shown that posterior fixation combined with anterior fixation seemed to be beneficial for the vertically unstable pelvis, and anterior external fixators and internal fixators were equally adequate for treating the anterior injury [27, 28]. In this study, all patients with anterior pelvic ring disruption were treated with external fixators and internal fixators. Combined with the fixation of posterior pelvic ring, most of these patients achieved satisfactory effects. According to Lindahl imaging score, the excellence rate of group A was

95% and that of group B was 87.5%. The difference was not statistically significant.

Posterior pelvic ring fractures caused by high-energy trauma belong to the unstable fractures. Dislocation of sacroiliac joint and sacral fractures are complex injuries, accompanied with vertical and rotational instability. Early reduction and fixation can greatly reduce long-term complications such as pain, abnormal gait and posture. If the fracture is not reduced and fixed promptly, the operative outcomes are unsatisfactory and the postoperative residual symptom and dysfunction are also common [29]. Therefore, early surgical treatment for posterior pelvic ring injury is beneficial [30]. However, there is no consensus on the optimal fixation technique for these injuries [31].

Locking compression plate fixation has been widely used for posterior pelvic ring injury. Before fixation, it is necessary to pre-bend the plate according to the irregular structure of posterior pelvic ring. This procedure is technically demanding. Repeated bending the plate may reduce the strength of the plate or even damage the threads of screw holes [18]. The plate between the bilateral PSISs are located in the subcutaneous and easily stimulate the local soft tissue. Meanwhile, this procedure is open surgery, associated with grave wound and higher incidence of postoperative complications of soft tissue. Infection of incision was observed in one patient of group B. The wound healed by using antibiotics and dressing. This process not only added the patient's burden, but also increased the workload of physicians. The reduction function of LCP is limited, and it has not effective reduction for the compression or separation of sacral fracture. Moreover, the LCP is not applied for the fixation of bilateral iliac fractures, especially comminuted fractures.

To address these limitations of the LCP, we introduced a novel minimally invasive adjustable plate. The MIAP was designed according to the structure of posterior pelvic ring and functioned as a suspension bridge structure similar to the sacroiliac complex. The Z-shaped brackets were fixed directly without pre-bending. And the MIAP had a role in reducing the separated or compressed fractures/dislocations by adjusting the length of the connection bar, which was fixed to the bilateral Z-shaped brackets. Compared with LCP, the MIAP had effectively reduced soft tissue irritation because most parts of MIAP were closed to the dorsal surface of sacrum. In this study, these was no soft tissue irritation in group A.

Biomechanical experiments and initial clinical application showed the MIAP provided rigid stabilization for posterior pelvic ring injuries. The Denis type I vertically sacral fracture models were fastened to the Electroforce 3520-AT Bose biomechanical testing machine in sitting position and fixed with MIAP and LCP, respectively. Under 600 N vertical load, the average displacement of the pelvis fixed with MIAP was 1.3 mm, significantly less than the average displacement of 1.8 mm fixed with LCP [32]. In this study, the Majeed functional evaluation score in group A was significantly higher than that in group B ($P < 0.05$).

The fixation of MIAP is a minimally invasive procedure and easy to perform. During operation, two small incision were made for placing the MIAP, which effectively reduced the blood loss and shortened the operation time. In our study, the average operation duration (75.5 min), blood loss (207.0 ml), and size of incision (9.0 cm) of group A were all significantly less than that of group B ($P < 0.01$). In addition, the MIAP is economically-friendly, being about one third price of an LCP, which is beneficial to its widespread application, especially in the developing countries [19].

There are some limitations in this study. The case series represents a small sample size. More cases should be treated using the two methods in order to evaluate the efficiency in future. In addition, MIAP fixation was not compared with IS screw fixation, which was a common method for the fixation of unstable pelvic fractures. The future plan is to compare the clinical effects of MIAP and IS screws in treatment of unstable pelvic fracture.

Base on the results of this study, we conclude that both the MIAP and LCP can effectively stabilize the unstable pelvic fractures. However, the MIAP has the advantages of minimally invasive, less radiation exposure, technically safe and time saving. It can be used to reduce the separated or compressed sacral fractures and sacroiliac joint dislocations. The use of MIAP can achieve favorable clinical and radiological

outcomes, which is a good supplementary option for treating posterior pelvic ring injuries.

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Disclosure of conflict of interest

None.

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