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Original Research

# A novel hybrid fixation (percutaneous anterior pelvic bridge with K-wire) for the treatment of traumatic pelvic ring injury: A prospective study

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ABSTRACT

*Background:* The aim of the study was to introduce a novel percutaneous technique for the treatment of pelvic ring injuries using a percutaneous anterior pelvic bridge (PAPB) with K-wire.

*Methods:* From December 2010 to November 2016, a prospective study of 86 patients with anterior pelvic ring fracture (42 utilizing PAPB with K-wire and 44 utilizing PAPB). Patient data was retrieved from electronic charts. Radiological results were assessed based on the Matta criteria system to evaluate the quality of the reduction and time to union. Functional outcomes were evaluated using the Majeed scoring system. Postoperative complications were also recorded.

*Results:* Age, sex, cause of injury, type of fracture, functional recovery, American Society of Anesthesiologists classification, union time, Majeed scoring and complications did not differ significantly between the two groups. The quality of the reduction and pain scoring differed between groups (all p-values $< 0.05$). Group A got better reduction and less pain scoring.

*Conclusions:* The novel percutaneous technique with hybrid fixation using PAPB with K-wire is a successful alternative for the treatment of pelvic ring injuries, which results in better quality of reduction and less pain scoring outcomes comparing to PAPB. May the PAPB + K-wire could provide more stability.

## 1. Background

Pelvic injuries represent a relatively small rare injury, making up between 2 and 8 per cent of all fractures of the human body [1,2]. Most of the fractures are high-energy fractures which often result in mechanical instability of the pelvic ring. These injuries are with high mortality rate of 5–20% [3,4]. The reason for this is attributed to high level of blood loss, which leads to hemodynamic shock and multi-organ failure [5]. Anterior pelvic external fixation (APEF) is generally regarded as a quick and easily applied form of fixation used to rapidly stabilize a disrupted pelvic ring. APEF treatment for unstable pelvic ring disruptions has demonstrated a reduction in morbidity and mortality to rates comparable with those in patients sustaining stable pelvic injuries [6].

However, there are still many shortcomings and deficiencies for the APEF treatment of pelvic fractures. Wound infection, fixator loosening, and impingement of the fixator on the skin are problems that can develop after APEF management of pelvic ring injuries [7,8]. In such cases, an external fixator not only directly interferes with the operative field, but has also been shown to increase the risk of pin tract infections by up to 50% [9].

In recent years, percutaneous internal fixation technology is rapid developed. Coleand Moazzam et al. [10] and Cole et al. [11] recently described a new method in which subcutaneous plates are placed through small incisions over the ilium and fixed to the contralateral ilium or pubic symphysis (PS) or both. They termed this method as the anterior pelvic bridge. Anterior pelvic bridge (APB) is a good solution to the lack of external fixation.

Is this technology perfect for the unstable pelvic fracture? Rahul's group [12] reported retrospective review for the complication for the technology. Early revision surgery was required in a total of six of the 91 patients (7%). Losing reduction and unfamiliarity with pedicle screw

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caps were the reason for the revision surgery. What's more, a biomechanical stability study of four kinds of internal fixation methods for the anterior pelvic ring fracture were numerically investigated by the finite element method. The percutaneous anterior pelvic bridge (PAPB) was found to be the worst [13]. Maybe the plate was located upon the subcutaneous inguinal ligament like a “bridge” over the anatomical structures including lateral femoral cutaneous nerve, ilioinguinal nerve, iliohypogastric nerve, and femoral artery, femoral vein, and femoral nerve [14].

Thus, biomechanical instability and poor reset may be the main flaws of the percutaneous anterior pelvic bridge (PAPB). In our clinical treatment, our team applied PAPB with Kirschner wire to assist fracture reduction and increase stability. Our aim was to compare the two ways to illustrate the advantages of PAPB with Kirschner wire.

## 2. Patients and methods

The prospective study was approved by the Ethical Review Boards of the People's Hospital of XX City (affiliated hospital of XX Medical College) to evaluate the short-term results of PAPB with Kirschner wire versus PAPB for unstable pelvic fractures. What's more, all the research was performed in accordance with relevant guidelines. The work has been reported in line with the STROCSS criteria [15]. Demographic data of patient and mechanism of injury were recorded. AP-pelvis radiographs were used in conjunction with computed tomography and fluoroscopic manual examination under anesthesia to classify the fractures. Pelvic fractures were graded separately by an orthopaedic resident and 2 fellowship-trained orthopaedic trauma surgeons using the Tile classification system. The American Society of Anesthesiologists (ASA) scores were defined by a staff anaesthetist blinded to the treatment groups.

Inclusion criteria: the patients would be included if they were older than 18 years; had stable vital signs and stayed sober; obtained fine pulse of arteria dorsalis pedis; had no other severe medical diseases; were to receive treatment of surgery in less than 3 weeks; were without any surgical contradictions; and were with an unstable pelvic fracture in which the surgeon believed there was a need for anterior fixation.

Patients were excluded if they had substantial soft tissue injury precluding safe anterior pelvic incisions. Patients who had immature skeletons or medical contraindications, such as combined neurovascular injuries or diabetes, were excluded. What's more, pregnant patients were also excluded. Finally, an informed consent was attested for all the study participations.

From December 2010 to November 2016, there were 122 patients with unstable pelvic ring injuries who underwent definitive anterior fixation with PAPB with Kirschner wire or PAPB (with or without posterior fixation). All the patients were our institution and had a minimum of 12 months follow-up. Twenty-six patients in our database were not included because of loss of follow up (31 patients) or early death (5 patients). 86 patients would enroll the prospective study. PAPB with Kirschner wire was defined as group A(n = 42), while PAPB was group B(n = 44).

### 2.1. Surgical technique

All patients underwent general anesthesia. Patients with a simple anterior ring fracture were in a supine position. An anterior ring fracture with posterior ring fracture of the pelvis or iliac-wing fracture were in floating position. The posterior pelvis was prioritized and fixed first in all cases requiring posterior stabilization. For the anterior ring fracture, a 2–3 cm incision was made over each anterior superior iliac spine and a 4–5 cm incision was made centered over the pubic symphysis. Separate rectus abdominis in the pubic symphysis incision, then in the anterior superior iliac spine incision, a periosteal stripper was used to blunt dissection of the inguinal ligament and organization to the musculus obliquus externus abdominis. A subcutaneous tunnel was created in the lateral extrasolar muscular superficial layer carefully, the contoured plates were then placed through the tunnel overlying the external obliquus fascia.

For the group A, the MIPPO technology was applied to reduce the pubic fractures, low pubic fractures and pubic symphysis separation can be directly reset under direct vision, and we should not be excessive damage the local blood supply, high pubic fractures can be closed reduction. Our finger can help the reduction, then a 3.0 mm Kirschner wire to be used to fix the fracture line. Sometimes, if the finger reduction is not easy, the Kirschner wire can help, we can drive the K-wire in the fracture line in symphysis side, and reduction would be finished with finger and the K-wire, then the K-wire was drove across the fracture line. A 3.5-mm locking pelvic reconstruction plates (Synthes) was applied as the bridge. If rami fracture only occurred on a single side, then a single reconstruction plate was used from the anterior iliac crest of the injured side to the pubic symphysis. The plates were fixed to the anterior pelvis using a combination of 3.5-mm locking and cortical bone screws. If bilateral anterior lesions occurred, then a plate was applied to each side, overlapping in the middle at the level of the pubic symphysis. The lateral femoral cutaneous nerve (LFCN) in the proximal and the spermatic cord (if female is round ligament) in the distal must be confirmed when the bridge plate through across the tunnel.

For group B, the procedure was mostly similar, the only difference was no K-wire to do the reduction and fixation.

### 2.2. Postoperative managements

Beside regular wound checks, the nursing is unrestricted with regard to patients positioning. Patients were encouraged to perform non-weight bearing exercises when pain could be tolerated. Partial weight bearing was allowed at that time and progressed gradually according to the condition of each patient's associated injuries. All patients were followed up at 6 weeks, 3 months, 6 months, and 12 months postoperatively and annually thereafter. Internal fixation will not be routinely removed.

### 2.3. Outcome evaluation

Radiographic analysis focused on determining if fracture union was present and if the reduction obtained initially was maintained during the duration to healing. Union of pelvic fractures was determined by the presence of bridging callous seen at the fracture site on follow-up radiographs. All radiographs were viewed on the electronic Picture Archiving and Communication System (PACS) by an independent examiner, the orthopaedic research fellow, and all measurements were made using Picture Archiving and Communication System related software. Nonunion, malunion, or other complications were noted, union beyond 12 weeks was defined as “delayed union” and beyond 24 weeks as “non-union.” Radiographic union was defied as bridging callus on anteroposterior and lateral radiographs.

For the quality of reduction, Matta criteria system was used [2]. We measured the maximal displacement of the fracture on the pelvic X-ray at 3 locations with PACS system (anteroposterior, entrance and exit). The displacement was divided as follow: excellent: $\leq 4$ mm; good: 5–10 mm; fair: 11–20 mm; poor: $> 20$ mm.

Functional outcomes were evaluated using the scoring system described by Majeed [16], including pain, work, sitting, sexual intercourse, and standing at the final clinical follow-up or by phone survey. The scoring system was divided into 4 levels: excellent: $> 85$ points, good: 70–84 points, fair: 55–69 points, poor: $< 55$ points.

We also tracked patients for the following complications: nonunion, malreduction, implant failure, wound infection, heterotopic ossification (HO), need for revision surgery, delayed ambulation, and lateral femoral cutaneous nerve (LFCN) or perineal dysesthesia.

### 2.4. Statistical analysis

Statistical analysis was performed with SPSS 17.0 software for Windows. Continuous data with a normal distribution were expressed as the mean ± standard deviation. Continuous variables with non-normal distributions were analyzed with the Mann-Whitney *U* test. Non-paired *t*-test was used for comparison of continuous data that appeared to be approximately normally distributed. Categorical data were statistically analyzed using Fisher's exact test ($n < 40$ or $t < 1$). A p value of $< 0.05$ was considered statistically significant.

## 3. Results

### 3.1. Demographic data

Finally, a total of 86 pelvic fractures were reviewed during the study period. In group A, there were 25 males and 17 females, with a mean age of 46.83 years (range, 18–80 years). According to the Tile classification, there were 24 Type-B fractures and 18 Type-III fractures. Traffic accident (20 fractures) was the primary injury mechanisms, besides falling accident (14 fractures), and others (8 fractures). The average time from initial injury to operation was 5.6 days and the ASA score was 2.5. While group B consisted of 25 males and 19 females, with a mean age of 46.21 years (range, 20–70 years). 24 Type-B fractures and 20 Type-C fractures were included. Similarly, the injury mechanisms were also traffic accident (22 fractures), traffic accident (16 fractures), and others (6 fractures). The average time from initial injury to operation was 5.48 days and the ASA score was 2.18 (Table 1). There were no significant differences between the two groups regarding sex, age, fracture classification, injury mechanisms, average time from initial injury to operation, or ASA classification ($p > 0.05$). Seven patients in group A had combined femoral ($n = 4$), tibiofibular ($n = 2$), and lumbar ($n = 1$) fractures. Eight patients in group B had combined femoral ($n = 5$), forearm ($n = 2$), and lumbar ($n = 1$) fractures. Those fractures were simultaneously treated with open or closed reduction and internal fixation, and bone healing was achieved in all cases.

### 3.2. Radiographic outcome

There has been no case of nonunion from a traumatic fracture in the PAPB + K-wire group, but there was one patient with fracture nonunion in the PAPB group (Fig. 1). For the other patients, no statistically significant difference was found in time to union between the PAPB + K-wire group (12.43 weeks; range, 9–17 weeks) and PAPB group (12.64 weeks, range 9–16) with $p = 0.594$.

Patients in the group A had significantly greater quality of reduction compared with the group B ($p = 0.015$) at the final follow-up. There were 30 excellent cases and 12 good cases in the group A, while 20 excellent cases and 24 good cases in the group B. (Table 2). And none of the implants in the two groups broke during the treatment period.

**Table 1**
Comparison of the general characteristics of the two groups.

| General Information | PAPB + K Group | PAPB Group | P Value |
|---|---|---|---|
| | N = 42 | N = 44 | |
| Age (yr) | 46.83 ± 12.97 | 46.21 ± 14.01 | 0.416 |
| Genderrowhe | | | 0.799 |
| Male | 25 | 25 | |
| Female | 17 | 19 | |
| Tile classification | | | 0.808 |
| Type-B | 24 | 24 | |
| Type-C | 18 | 20 | |
| Injury mechanism | | | 0.791 |
| Traffic accident | 20 | 22 | |
| Falling accident | 14 | 16 | |
| Other causes | 8 | 6 | |
| Time to operation (days) | 5.6 ± 3.61 | 5.48 ± 3.39 | 0.876 |
| ASA | 2.5 ± 1.0 | 2.18 ± 0.90 | 0.318 |

### 3.3. Functional outcome scores

At the final follow-up, most patients got a satisfactory function. In terms of pelvic function recovery, there appeared to be no significant difference in the score of patients between the group A (91.43 ± 4.69) and group B (89.37 ± 5.86). About the level, 27 excellent cases, 15 good cases in the group A (Fig. 2), and 28 excellent cases, 16 good cases in the group B.

However, for each term of Majeed system, the pain was significant different between two groups ($p = 0.001$). Group A (27.14 ± 3.15) got a better result compared to group B (24.43 ± 3.92). While, there was no difference in other terms (Table 3).

### 3.4. Complications

In terms of surgical and fracture-healing complications during follow-up. Infection at the surgical site was noted in 6 cases of two groups. It is just a superficial wound infection which was resolved after a 7-day course of oral antibiotics and local wound care. There was no deep infection and other wound-healing complications.

Six of the 42 patients in the group A and 8 of the 44 patients in the group B sustained a LFCN palsy. Most were minor and could be from numbness to paresthesia that resolve quickly. One patients developed neuropathic pain requiring management with neuropathic analgesia, and the patient's symptoms resolved following removal of the implant.

For the HO, there were 7 patients in the group A and 8 patients in the group B. And there were no symptoms related to HO. For all the complications between two groups, there was no significant difference ($p < 0.05$).

While, there was a patient with nonunion in the PAPB group, the patient just fell a little pain, and did not want the second operation (Table 4).

### 3.5. Removal of implants

Implants were typically removed after 6 months or when the fracture has demonstrated healing on x-ray. The average time to removal was greater than 6 months as often patients are scheduled for the removal but patient or scheduling issues delayed the procedure and this number also includes several patients who did not want to have it removed when we suggested.

## 4. Discussion

Clinical and biomechanical studies [17] have shown that the anterior pelvic ring (pubic symphysis and pubic branch) stabilizes the pelvic ring by 40% and the posterior structure by 60%. For the patients with partly unstable pelvic fracture, a simple anterior fixation can get good results. Therefore, the anterior pelvic ring fixation plays an important role in the treatment of unstable pelvic surgery [18].

Fixation fractures of the anterior pelvic ring with raditional anterior pelvic surgery, especially the ilioinguinal approach, become more trauma, bleeding and more shortcomings, and even iatrogenic injury of the blood vessels, nerves risk [19]. External fixation is a time-tested method for rapid stabilization of a disrupted pelvic ring and has been shown to reduce morbidity and mortality rates to levels comparable with patients sustaining stable pelvic ring injuries [6]. The disadvantage is that it is usually less stable than ORIF because of the distance of the external fixation from the bone. Others are a high pin-tract infection rates and discomfort for the patients, which makes it difficult for patient mobility. Thus, the use of external fixation is limited [20].

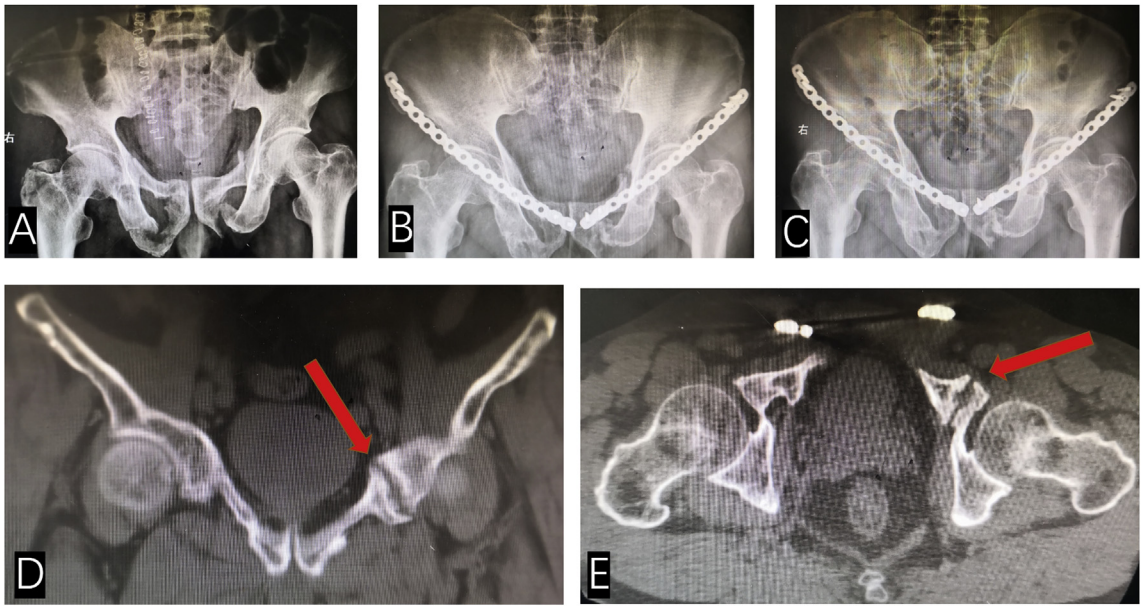


**Fig. 1.** This was a 48 years old male with anterior pelvic ring fracture caused by car accident. A showed the bilateral public ramus fracture. B was the X-ray after operation fixed with PAPB. C was the X-ray of 9 months after operation. There was still a gap between the fracture line. D and E was the CT scan of the 9 months after operation. It seems like a hypertrophic nonunion with widened and dense public ramus. The red arrow showed the nonunion fracture line. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

**Table 2**
Fracture union time and quality of reduction.

| | PAPB + K Group | PAPB Group | T or $X^2$ value | P Value |
|---|---|---|---|---|
| Time to union (weeks) | 12.43 ± 1.93 | 12.64 ± 1.67 | t = 0.535 | p = 0.594 |
| Quality of reduction | Excellent:30<br>Good: 12 | Excellent:20<br>Good: 24 | $X^2$ = 5.96 | p = 0.015 |

Physicians are always seeking better ways to provide treatment to their patients. This fixator would need to provide minimal discomfort for the patient, be relatively easy and quick to apply, require minimal radiation load, provide appropriate immediate stability and rigidity of the fixation. All the aforementioned considerations led to the development of a new generation of internal fixation methods. The “Pelvic Bridge” subcutaneous plate method is recently described and provide emerging clinical options that may offer improvements over traditional treatments [11,21].

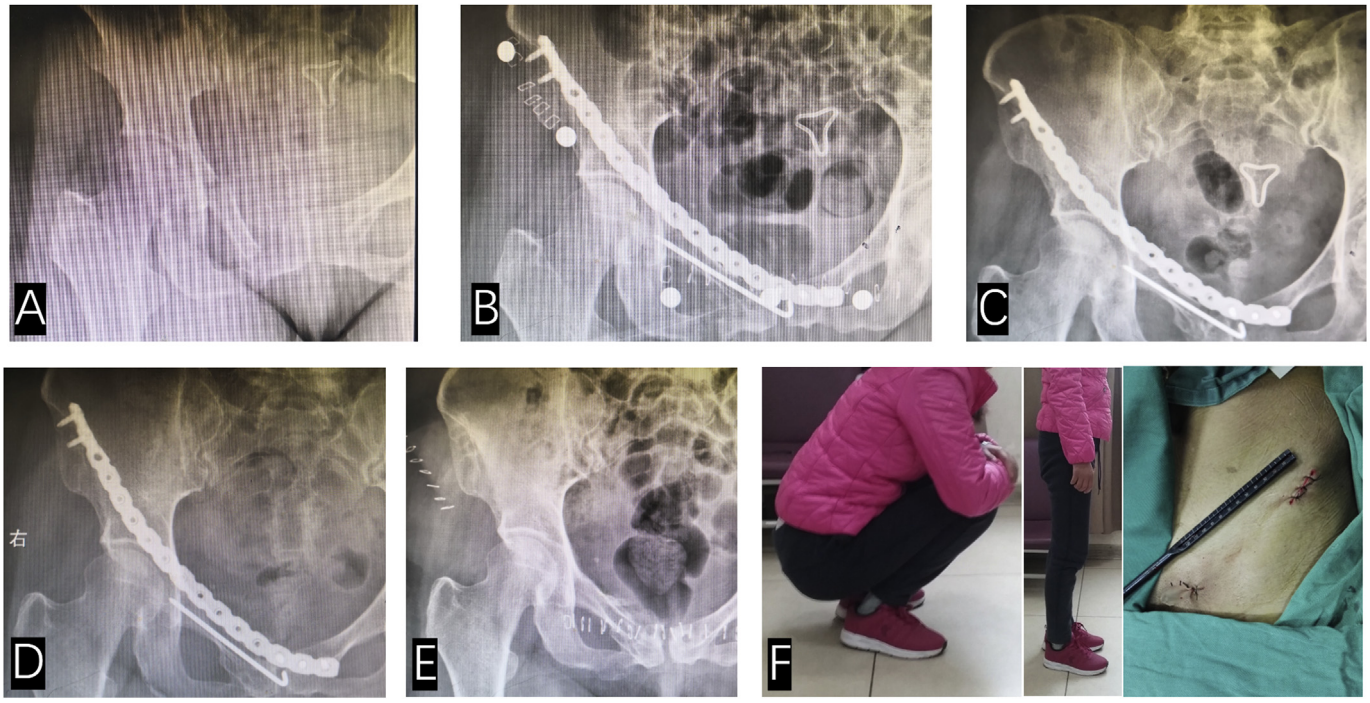


**Fig. 2.** This was a 38 years old female with right side public ramus fracture. It was also caused by car accident. A showed the multi-segment public ramus fracture. B was the X-ray after operation fixed with PAPB + K-wire. C was the X-ray of 6 months after operation. D was the X-ray of 12 months after operation, the fracture was union. E was the X-ray of removal implants. F showed the hip function at the last fellow-up and the percutaneous minimally invasive incision.

**Table 3**
The functional outcome according to Majeed scores for the two groups.

| | PAPB + K Group | PAPB Group | P Value |
|---|---|---|---|
| | (x ± s) | (x ± s) | |
| Pain | 27.14 ± 3.15 | 24.43 ± 3.92 | **0.001** |
| Working | 17.33 ± 2.01 | 17.36 ± 2.72 | 0.954 |
| Sitting | 9.19 ± 1.09 | 9.14 ± 1.02 | 0.811 |
| Sexual intercourse | 3.90 ± 0.30 | 3.89 ± 0.32 | 0.784 |
| Standing | 33.86 ± 1.89 | 34.55 ± 1.52 | 0.066 |
| Total | 91.43 ± 4.69 | 89.37 ± 5.86 | 0.075 |

**Table 4**
Comparison in the two groups.

| Complications | PAPB + K Group | PAPB Group | P Value |
|---|---|---|---|
| | N = 42 | n = 44 | |
| Wound-healing complications | 2 | 4 | 0.431 |
| Superficial infection | 2 | 4 | |
| Deep infection | 0 | 0 | |
| Hematoma | 0 | 0 | |
| Wound-edge necrosis | 0 | 0 | |
| LFCN injury | 6 | 8 | 0.625 |
| HO | 7 | 8 | 0.853 |
| Nonunion | 0 | 1 | 1 |
| Total | 15 | 21 | 0.259 |

The percutaneous anterior pelvic bridge (PAPB) was minimally invasive percutaneous plate for the treatment of anterior pelvic ring fracture without peeling iliopsoas, femoral vessels and nerves. Thus, it is not only less trauma, less blood loss, but also no damage to femoral vessels and nerves. The Pelvic Bridge also proved to be a useful treatment adjunct in osteoporotic insufficiency fractures of the anterior pelvis in elderly patients: it provided quick pain relief and enabled rapid postoperative mobilisation along with minimal surgical insult. In our study, both groups achieved good treatment without serious complications, all the fracture got healed at last. Just some superficial infection, LFCN injury and HO were reported, no significant vascular and nerve damage occurred. M. Dahill [22] reported the results of pelvic internal fixator, of the 47 patients included in the study, 46 (98%) achieved radiological union. The radiological union rate in two study was nearly the same, and comparable with other study [23].

There are also some shortcomings of the percutaneous anterior pelvic bridge (PAPB). He YQ et al. compared biomechanical performance of several fixations for the fixing pelvic anterior ring fracture, they found that the PAPB produces worse stability as shown in the comparison of displacements at the fracture site compared to the transramus intraosseous screw, the open reduction and the laparoscopic-assisted plate [13]. What's more, Vaidya R et al. reported the complications of the minimally invasive surgery, they found that the revision surgeries occurred for six of 91 (7%) cases. Loss of reduction occurred in three of 91 cases (4%) [12]. In our study, for the quality of reduction, though the two groups all got a good end (excellent and good), the group B is not as well as the group A. In our opinion, it is possible that K-wire in group A played a role in the reduction and PAPB combined K-wire may provide more stability for the fractures. Moreover, the pain score at the final follow-up, patients in group A experience less pain compared to group B. Another study found that 4 patients (9%) underwent revision pelvic surgery for the anterior pelvic internal fixator. Some of patients were due to the malreduction of the sacroiliac joint [22]. So, the PAPB may not provide a precise reduction and enough stability for the anterior ring fracture.

The patient with fracture nonunion in the PAPB group, we made the CT scan. It seems like a hypertrophic nonunion with widened and dense public ramus. It also an explanation that the PAPB may not provide an enough stability for the anterior ring fracture.

We chose to use the Majeed functional outcomes score as it is easy to perform, but shows similar validity when compared with other accepted methods of evaluating functional outcomes of pelvic fractures [24]. Most results in our study were statistically inconclusive. The two groups got the similar results except the pain score. Previous research which also use the Majeed system found the clinical outcome at 1 year was “excellent” in 29 patients and “good” in 8 patients. That was comparable with this study [25].

The incidence of permanent LFCN injury is high, occurring in 16% of patients. This is a less finding to other published series which report nerve damage in 30% of patients [12,23]. We believe this requires further study and patients should be warned about the possible injury to the lateral femoral cutaneous nerve when doing the procedure and that it is usually temporary.

Heterotopic ossification was a common finding in our review and was noted in 15 of 86 patients (17%) in two groups. It was asymptomatic in all patients even at latest follow-up. No specific treatment was performed. During hardware removal, one always has the opportunity to remove HO as well. We have conducted this several times when it was present but have not made it a routine practice. The subcutaneous fixator is intended as a temporary treatment with removal typically performed after fracture healing. The device requires removal in the operating room, unlike an external fixator that may be removed in an outpatient setting.

For this minimally invasive surgery, we got some our experience of technical lessons. (1): Anterior and posterior ring fracture should be fixed at the same time, due to a single ring fixation is not stable enough. (2): doctors must pay attention to the early preoperative traction and reduction, because it is more difficult to do a reduction for pelvic fracture more than 10 days. and preoperative traction reduction will make it easier to do intraoperative reduction and fixation. (3): The key to reduce complications lies in the shaping of the steel plate, the steel plate must be located in the subcutaneous and arched arches, to avoid oppression of the iliopsoas deep surface of the femoral nerve, femoral head, spermatic cord or uterine ligament and other tissues. (4): When doing subcutaneous tunnel, firstly we puncher hole with a long closed vascular clamp, then then use oval pliers to expand the tunnel, so as not to damage the subcutaneous blood vessels. (5): PAPB with K-wire is more beneficial to do reduction and fixed and keeping K-wire can provide more stability to the fractures.

There are a number of limitations in the present study. First, this was a prospective review and the number from each site was small (42 and 44 patients). Even with these small numbers, we found the approach easy to use and had similar outcomes and similar complications. Additionally, prospective studies in orthopaedic trauma do not necessarily allow for identification of factors influencing implant selection. Fracture pattern, soft tissue injuries, and surgeon comfort level with implants lead to inherent selection biases with clear potential to influence outcomes. Overall, many of our shortcomings could be addressed with future, prospective, and randomized investigations.

## 5. Conclusion

The percutaneous anterior pelvic bridge (PAPB) is a good choice for the anterior pelvic fracture fixation, PAPB combined with K-wire could provide a better outcome with higher quality of reduction and less pain. This clinical experience lends support to the PAPB with K-wire could be definitively recommended for general use with more stability compared to the PAPB.

## Ethical approval

The study was approved by the Ethical Review Boards of the People's Hospital of Jianyang City (affiliated hospital of Chengdu Medical College).

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## Author contribution

H.G.P designed and performed study and wrote the paper. J.X.F designed study and supervised the project. C.L.Y., Y.J., Y.Z., M.X.P, Z.Q.M., H.F.Y., and Z.Z.Y. performed study.

## Conflicts of interest

The authors have no conflicts of interest to declare.

## Research registration number

The Unique Identifying Number (UIN) from the Research Registry of the study is researchregistry4515.

## Guarantor

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## Provenance and peer review

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## Appendix A. Supplementary data

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