Original Article

Single pararectus approach combined with three-dimensional guidance for the treatment of acetabular fracture

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Background: Surgery for acetabular fractures involving both columns is difficult and traumatic, making it necessary to explore a minimally invasive and accurate surgical method.

Methods: This retrospective case-control study analyzed the clinical data of 34 patients and divided them into two groups: a control group (9 males and 8 females) and a research group (11 males and 6 females) with acetabular fractures involving the anterior and posterior columns. All patients were placed in the supine position via the pararectus approach. A three-dimensional (3D) guide was placed at the position where the posterior column screw was inserted in the second window, and a posterior column screw was placed percutaneously on the medial side of the iliac spine in the research group. The operation time, intraoperative blood loss, and fracture union time of the two groups were recorded. Pelvic radiographs and computed tomography (CT) scans were routinely performed before and after surgery to evaluate reduction and fixation. Residual gap and step displacement were measured using a standardized CT-based method after the surgery. Hip mobility was assessed according to the modified Merle, d'Aubigné, and Postel criteria.

Results: All patients were followed up for 6–30 (16.941±6.571) months. The operation times of the two groups were 126 [interquartile range (IQR), 95–133] min (control group) and 110 (IQR, 85–124) min (research group), the intraoperative blood losses were 430 (IQR, 290–550) mL (control group) and 380 (IQR, 260–500) mL (research group). All patients achieved bone healing, with a union time of 15 (IQR, 12–17) weeks (control group) and 13 (IQR, 11.5–15) weeks (research group). According to the standardized CT-based method, the reduction after surgery was acceptable in 13 (control group) and 14 (research group) of these patients (defined as a gap <5 mm or a step-off <1 mm), and the anatomical reduction rates were 76.47% and 82.35%, respectively.

Conclusions: The use of a single pararectus approach combined with 3D guide-assisted percutaneous anterograde posterior column screws can shorten the operation time and place effective posterior column screws precisely with minimal invasiveness. At the same time, the acetabular reduction and functional recovery are satisfactory, and there are fewer postoperative complications, which makes this procedure an ideal surgical option.

Keywords: Acetabulum; fracture; surgical approach; posterior column screw; three-dimensional guide (3D guide)

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Introduction

With the development of industrialization and the transportation industry, the incidence of acetabular fractures caused by high-energy injuries such as falls from heights and traffic accidents is increasing every day (1-3). Surgery for acetabular fractures has always been a huge challenge for orthopedic surgeons. Judet and Letournel established a classification system for acetabular fractures and advocated for aggressive surgical treatment to replace the previous conservative treatment. They and their successors gradually introduced an anatomic reduction of the articular surface, combined with rigid internal fixation and early mobilization, as the standard treatment for acetabular fractures, which is still used today (4-7). Minimally invasive surgical treatment has gradually become widely recognized by orthopedic trauma surgeons. The trends in the treatment of acetabular fractures include reducing intraoperative tissue damage, achieving good hemostasis, developing minimally invasive channel screw technology, and paying greater attention to postoperative rehabilitation (8-10).

However, fractures involving both columns of the acetabulum are often violent, extensive, and deep, and important structures such as the peripheral blood vessels and nerves of the acetabulum are complex. Therefore, choosing a less invasive and appropriate surgical method or approach is crucial for fracture reduction and fixation as well as minimizing complications (11). Commonly used surgical approaches include the ilioinguinal, Stoppa, pararectus, Kocher-Langenbeck (K-L), and anterior-posterior combined approaches. Although the combined anterior and posterior approach is fully exposed, it involves a large surgical incision, considerable bleeding, a long operation time, and a high incidence of complications such as postoperative infection, heterotopic ossification, sciatic nerve injury, and lateral femoral cutaneous nerve injury (12-14).

The pararectus approach proposed by Keel *et al.* enters through the extraperitoneal space, and can fully expose the ilium, true pelvic border, quadrilateral, and medial posterior column through a small incision. Given that the direction of the incision is consistent with the direction of the blood vessels and nerves, the fracture can be effectively reduced and fixed intraoperatively, and the excessive stretch of important structures can be avoided. Acetabular fractures involving the anterior column and quadrilateral involve high anatomical reduction rates, the clinical effect is good, and there are fewer complications (15,16). However, there are few reports on the accurate and efficient placement of antegrade posterior column screws, especially full-length posterior column screws in the direction of the ischial tuberosity, and the use of this approach in acetabular fractures involving both columns.

With the increasing maturity of three-dimensional (3D) printing technology, there are more and more applications in the medical field, especially orthopedics. Therefore, we wanted to use 3D printing technology and guided plates to help doctors treat complex acetabular fractures. We hope that this approach can fully reveal and restore the acetabular fracture, enable effective and reliable posterior column fixation, and cause less soft tissue damage. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-548/rc).

Methods

Patient characteristics

The clinical data of 34 patients with acetabular fractures involving anterior and posterior columns admitted to the Department of Traumatology and Orthopedics of Weifang People's Hospital from September 2019 to September 2021. The inclusion criteria were as follows: (I) patients with fresh acetabular fractures involving both columns; and (II) age >18 years. Patients were excluded based on the following criteria: (I) pathological and open fractures; (II) acetabular fractures involving the posterior wall that require surgical reduction and fixation; (III) surgical injuries for more than 3 weeks; (IV) the presence of other injuries that may interfere with rehabilitation exercise.

This retrospective case-control study analyzed the clinical data of 34 patients and divided them into two groups: a control group (9 males and 8 females) and a research group (11 males and 6 females) with acetabular fractures involving the anterior and posterior columns.

A total of 34 patients were involved in this study, including 20 males and 14 females, aged 47 [interquartile range (IQR), 41.5–56] years of the research group, while the control group was aged 44 (IQR, 42–53) years. Among these patients, the causes of injury were as follows: traffic injury (n=17), fall from height (n=12), crush injury (n=5). There were 22 cases with injuries to different body parts, including 4 cases with hemorrhagic shock, 6 cases with multiple rib fractures, and 11 cases with soft tissue injury of upper limb. The mean time of the research group from injury to operation was 7 (IQR, 5.5–10) days, while the

Table 1 Patient demographic and injury data

Variables	Control group (n=17)	Research group (n=17)	P value
Gender			>0.05
Male	9 (52.94)	11 (64.71)	
Female	8 (47.06)	6 (35.29)	
Age (years)	44 (42–53)	47 (41.5–56)	
Acetabular fracture type			>0.05
Both columns	8 (47.06)	9 (52.94)	
Anterior column and posterior hemitransverse	5 (29.41)	4 (23.53)	
T-type	3 (17.64)	2 (11.76)	
Transverse fracture	1 (5.89)	2 (11.76)	
Mechanism of injury			>0.05
Fall from a height	6 (35.29)	6 (35.29)	
Motor vehicle accident	8 (47.06)	9 (52.94)	
Injured by a heavy object	3 (17.65)	2 (11.76)	
Delay to surgery (days)	6 (4–10)	7 (5.5–10)	>0.05

Data are presented as n (%) or Q2 (Q1–Q3). Q2, second quartile; Q1, first quartile; Q3, third quartile.

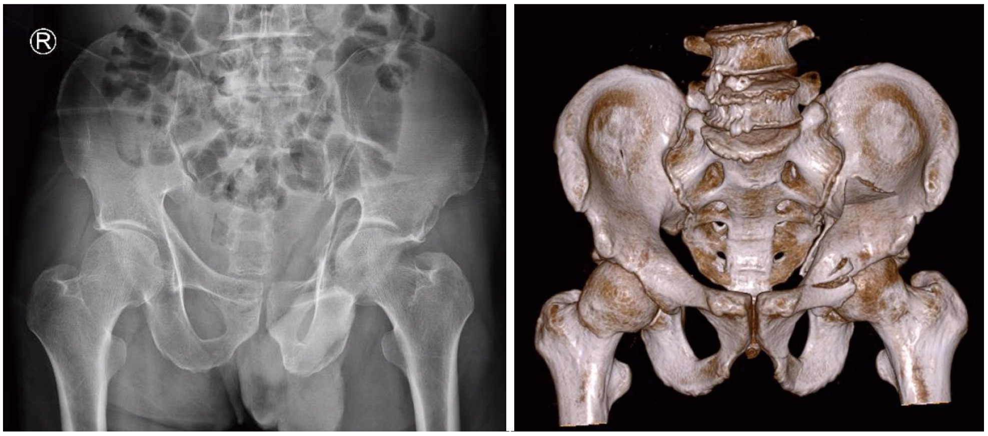

Figure 1 Anterior column with posterior hemi-transverse fracture. The Letournel-Judet classification is an anterior column with posterior hemi-transverse fracture.

control group was 6 (IQR, 4–10) days (*Table 1*). Pelvic X-ray, computed tomography (CT) examination, and 3D reconstruction (*Figure 1*), which were used to print a 3D model of the pelvis and the posterior column screw placement guide, were performed preoperatively (*Figure 2*).

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The studies involving human participants were reviewed and approved by Weifang People's Hospital Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Preoperative preparation

Before the surgery, we obtained detailed data of the patient's CT examination and sent these data to the 3D printing

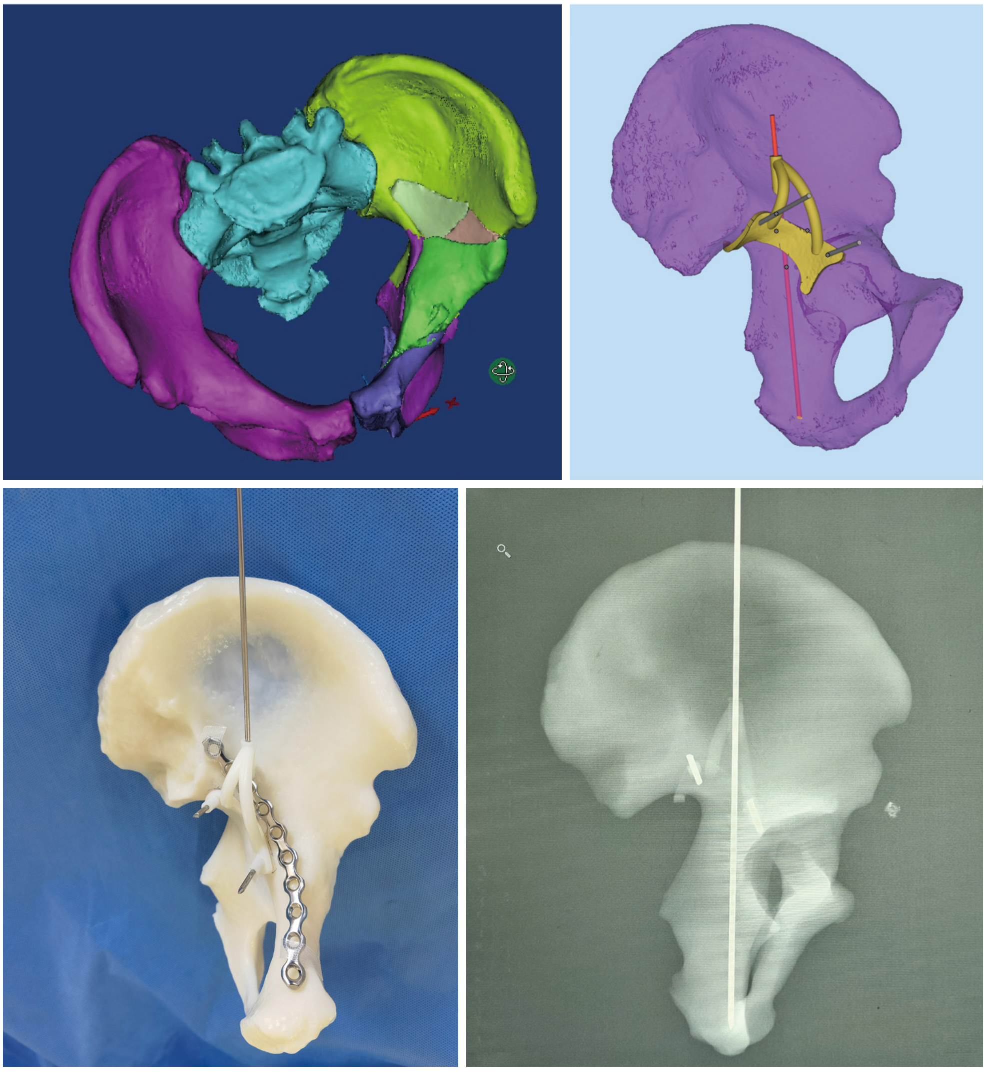

Figure 2 3D reconstruction from CT data. We simulated the reduction, printed the 3D model of the pelvis and the guide plate for placement of the posterior column screws, shaped the bone plate and verified the accuracy of the guide plate, and then sterilized them 1 day before the operation. 3D, three-dimensional; CT, computed tomography.

center of the hospital. A complete electronic model of the affected side was obtained by mirroring the healthy side. In this model, the optimal nailing channel was planned, and in order to find this channel during surgery, we made this guide. This guide was attached to the true pelvic margin, with a proximal hook attached to the ischiatic notch. The proper placement of the guide plate was found during the operation by sticking close to these bony structures. Then, a physical model of the pelvis and guide plate was printed. Medical polymer polyethylene was the material used for printing, which was plasma sterilized 1 day before the operation. In this way, the same channel position can be replicated during surgery. All we needed to do during the operation was find the right position and install the guide plate, and insert the Kirschner needle through the guide hole. Finally, the screw was inserted through the channel of the Kirchner needle.

Surgical methods

Anesthesia, body position, and incision: general anesthesia with endotracheal intubation was employed, and the patient was placed in a supine position.

Skin incision: from the junction of the middle and lower third of the line connecting the umbilicus and the anterior superior iliac spine to the junction of the middle and lower third of the inguinal ligament; the length of the incision was 8–11 cm; the body surface projection was adjacent to the rectus abdominis; and the roof of acetabulum was located just below the surgical incision.

Surgical window exposure

Under the deep fascia, a small oblique incision was made from the medial border of the superficial inguinal ring outward and upward. The external oblique muscle, transversus abdominis, and internal oblique muscle were cut obliquely to the extraperitoneum. Then, the extraperitoneal space was opened, and the rectus abdominis was pulled inward to expose the external iliac arteriovenous sheath. The external iliac vascular sheath was protected using a rubber tube, the rectus abdominis was pulled inward, and the iliopsoas muscle was pulled outward. The anterior column of the acetabulum and the quadrilateral area were exposed outside the vascular sheath. The first soft tissue window was located between the peritoneum and the vascular sheath, which exposed the pubic bone, obturator foramen, corona mortis blood vessels, the anterior wall of the anterior column of the acetabulum, and the lower half of the square area. The second soft tissue window was between the vascular sheath and the iliopsoas muscle, which exposes the anterior column of the acetabulum, the upper part of the square area, and the pelvic ring, and can be exposed to the ischial spine in the deep layer. This window reduces fractures of the anterior column and quadrilateral area and allows direct vision reduction of the posterior column from the medial side of the posterior column of the acetabulum.

Fracture reduction and fixation

The Schanz screw was driven into the greater trochanter with lower extremity traction. At the same time, the anterior column and quadrilateral area were reduced with ejector rods in the first window and temporarily fixed with Kirschner wires (K-wires) after reduction. Next, through the second soft tissue window, we looked directly along the inner side of the square area and peeled down to expose the inner side of the posterior column. Posterior column fractures were reduced by pulling, tilting, and so on, and temporary fixation was achieved with K-wires. In the control group, the posterior column fracture was fixed with a common lag screw directed at the ischial spine because the length and angle of the incision were limited. In the research group, a pre-printed 3D guide was placed on the back and top of the square area, and an incision (about 1 cm in length) was made on the medial border of the iliac spine (*Figure 2*). Subsequently, a cannula was placed along the space between the inner plate of the iliac wing and the iliopsoas muscle to protect the surrounding tissue. A 2.5 mm K-wire was selected and passed through the cannula, and under the guidance of the guide plate, the K-wire was placed from the insertion point of the posterior column screw to the ischial tubercle. A C-arm X-ray fluoroscopy machine verified that the needle track was running well, and the K-wire was pulled out. Next, at an appropriate length of 3.5 mm, we inserted screws (100–120 mm in length) along the screw path and fixed the posterior column of the acetabulum with antegrade lag screws.

An anterior column fixation plate, true pelvic edge fixation plate, and ilium wing fixation plate were placed according to the shape and position of the anterior column fracture. Fracture reduction, satisfactory fixation, and no penetration of the screw into the joint were confirmed by fluoroscopy, and wound irrigation was performed. After checking for no active bleeding, we placed 1–2 drainage tubes, sutured the abdominal wall muscles layer by layer, and closed the incision. Combined femoral fractures could be surgically treated in stage I.

Perioperative management

After the patient was admitted to the hospital, supracondylar traction of the femur was performed immediately according to the fracture condition, and symptomatic treatment, such as anti-shock, was also administered. Color Doppler ultrasonography of the bilateral lower extremity venous vessels was performed 1 day before surgery to exclude thrombosis. A clean enema was given 8 hours before surgery, and the patient was fasted, with no water. Postoperatively, a drainage tube was placed in the surgical incision, and the internal and external oblique aponeurosis was sutured at full thickness. After recovery of gastrointestinal function, a liquid diet can be used, and the drainage tube can be removed when the daily drainage volume is less than 50 mL. Broad-spectrum antibiotics were used 30 min before surgery, and low molecular weight heparin was routinely used for anticoagulation 6 hours after surgery to prevent thrombosis. After the operation, the pelvic X-ray films and CT 3D reconstructions were reviewed to evaluate the fracture reduction. X-ray films were taken at 4 weeks, 12 weeks, 6 months, and 1 year after surgery.

Table 2 Postoperative outcomes

Postoperative data	Control group (n=17)	Research group (n=17)	P value
Operating time (min)	126 (IQR, 95–133)	110 (IQR, 85–124)	<0.05
Blood loss (mL)	430 (IQR, 290–550)	380 (IQR, 260–500)	<0.05
union time (weeks)	15 (IQR, 12–17)	13 (IQR, 11.5–15)	>0.05
Reduction quality (standardized CT-based method) acceptable (gap <5 mm or step-off <1 mm)	13 (76.47)	14 (82.35)	>0.05
The modified Merle d'Aubigné score			>0.05
Excellent	7 (41.19)	8 (47.06)	
Good	4 (23.52)	5 (29.41)	
Fair	4 (23.52)	3 (17.65)	
Poor	2 (11.77)	1 (5.88)	

Data are presented as Q2 (IQR, Q1–Q3) or n (%). IQR, interquartile range; CT, computed tomography; Q2, second quartile; Q1, first quartile; Q3, third quartile.

Evaluation standard

The operation time, intraoperative blood loss, and fracture union time were recorded. The standardized CT-based method was used to evaluate the quality of postoperative fracture reduction: Acceptable reduction was defined as a gap <5 mm or a step-off <1 mm (17,18). Follow-up visits were performed at 1, 3, 6, and 12 months after surgery, and every 6 months thereafter. At the 6-month postoperative follow-up, the function of the affected hip was evaluated according to the modified Merle, d'Aubigné, and Postel criteria. The evaluation included a comparison of hip pain as well as walking and joint range of motion between the affected side and the unaffected side. A score of 18 was considered excellent, 15–17 was considered good, 13–14 was considered fair, and <13 was considered poor.

Results

The incision length of the 34 patients in this group was 8–11 cm, with an average of 9.59 cm, the operation times were 126 (IQR, 95–133) min (control group) and 110 (IQR, 85–124) min (research group); the intraoperative blood losses were 430 (IQR, 290–550) mL (control group) and 380 (IQR, 260–500) mL (research group) (*Table 2*). During the operation, 12 patients received autologous blood transfusions and 5 patients received allogeneic blood transfusions. Also, the fractures were successfully reduced under direct vision using the pararectus approach. In the research group, placement of the posterior column screws was also very smooth, several cases had 1–2 directional adjustments, but in the vast majority of cases it could be achieved in 1 attempt. C-arm X-ray fluoroscopy showed that the fractures were well reduced, and a full-length 3.5 mm screw (America, DePuy Synthes, 100–120 mm in length) was placed in the posterior column.

Postoperative X-ray films and CT scans showed that the pelvic and acetabular fractures were well reduced, and the posterior column screws all pointed to the ischial tuberosity and were located in a safe channel throughout the process. The quality of fracture reduction was evaluated according to the standardized CT-based method: 27 cases (control group 13 cases and research group 14 cases) were considered the postoperative reduction was acceptable (defined as a gap <5 mm or a step-off <1 mm) (*Table 2*). Among them, 1 patient developed incision effusion and subcutaneous infection postoperatively, and the infection was finally controlled after debridement. Another case of heterotopic ossification in the quadrilateral area was not given special treatment because there were no obvious symptoms.

Two years after surgery, 4 patients (3 patients in the control group and 1 patient in the research group) developed traumatic arthritis of the hip. Furthermore, 6 cases (control group 4 patients and research group 2 patients) of lower extremity deep venous thrombosis occurred, 3 of which were control group cases that had been implanted with an inferior vena cava vascular filter, and the thrombus was removed successfully after disappearance, and the other case disappeared after treatment with anticoagulant drugs such as

Table 3 Complications

Variables	Control group (n=17)	Research group (n=17)
Peritoneum lesions	2 (11.76)	1 (5.88)
Enteroplegia	5 (29.41)	3 (17.65)
Deep vein thrombosis	4 (23.52)	2 (11.76)
Incision infection	2 (11.76)	1 (5.88)
Traumatic arthritis	3 (17.65)	1 (5.88)

Data are presented as n (%).

low molecular weight heparin and rivaroxaban (*Table 3*).

The patients were followed up for 6–30 (16.941± 6.571) months after surgery. All patients achieved bone healing, and the union times were 15 (IQR, 12–17) weeks (control group) and 13 (IQR, 11.5–15) weeks (research group). Hip joint mobility was evaluated at the last follow-up according to the modified Merle, d'Aubigné, and Postel evaluation criteria: 7 cases were considered excellent, 4 cases were considered good, 4 cases were considered fair, and 2 cases were considered poor in the control group, 8 cases were considered excellent, 5 cases were considered good, 3 cases were considered fair, and 1 case was considered poor in the research group. The excellent and good rate was 76.5%. During the follow-up period, none of the patients developed an inguinal hernia, incisional hernia, or other complications (*Table 2*).

Typical cases

A 57-year-old male patient presented with a left acetabular fracture caused by a traffic injury. His Letournel-Judet classification was an anterior column with a posterior hemi-transverse fracture (*Figure 1*). Open reduction and internal fixation of the acetabular fracture were performed under general anesthesia on the fourth day after injury. Intraoperatively, the patient was placed in the supine position. Percutaneous posterior column antegrade full-length lag screw fixation was performed through a small pararectus incision approach (9 cm in length), with the assistance of a 3D guide. The operation time was 90 min, the intraoperative blood loss was 350 mL, and the patient did not receive a blood transfusion (*Figure 3*). Intraoperative fluoroscopy, postoperative X-ray, and CT 3D reconstruction showed good fracture reduction and internal fixation (*Figure 4*).

Discussion

The purpose of this study, through a simple and safe incision approach and screw placement, was to achieve good results in the surgical treatment of acetabular fracture. The main suggested advantage in comparison to conventional operative method was to simplify the treatment of specific fracture patterns with less operation time, more secure and accurate screw placement. Although the preparation and planning before the operation takes more time, the operation will be more concise and the doctor will be exposed to less radiation.

There was no occurrence of lateral femoral cutaneous nerve and femoral nerve injury among this patient cohort because the pararectus approach perfectly avoids these structures. This approach can be used for the treatment of anterior acetabular fractures, anterior column fractures, simple transverse fractures, anterior column with posterior hemi-transverse fractures, "T" fractures, and both column fractures (especially acetabular fractures with quadrilateral injuries); however, it should be carefully selected when the posterior wall and posterior column are severely crushed (15,16). Fully understanding the displacement characteristics of both column fractures can help to achieve fracture reduction, and the inverse injury reduction mechanism is generally adopted. The comparative study by Märdian *et al.* found that the transrectus approach was superior to the ilioinguinal approach in reducing the interfragment space (19). Usually, the iliac wing is anatomically reduced first, and the iliac wing is used as the template for reduction. Following temporary fixation after reduction of the anterior column fracture, the reduction of the posterior column will also become easier. Next, the fixation of the rear column becomes an important issue.

The lag screw technique is widely accepted and recommended as an effective fixation for complex acetabular fractures, such as transverse and T-shaped fractures (20). Posterior column lag screw fixation of acetabular fractures is a difficult technique due to the complex anatomy of the pelvis and acetabulum coupled with the abnormally narrow passage of posterior column screws. Also, there is a potential risk of vascular nerve injury, especially with full-length posterior column screws directed to the sciatic tubercle. This is difficult for the vast majority of physicians to place, except for highly experienced specialists with strong procedural skills (21).

We noticed that the application of 3D printing technology can provide considerable fracture-related

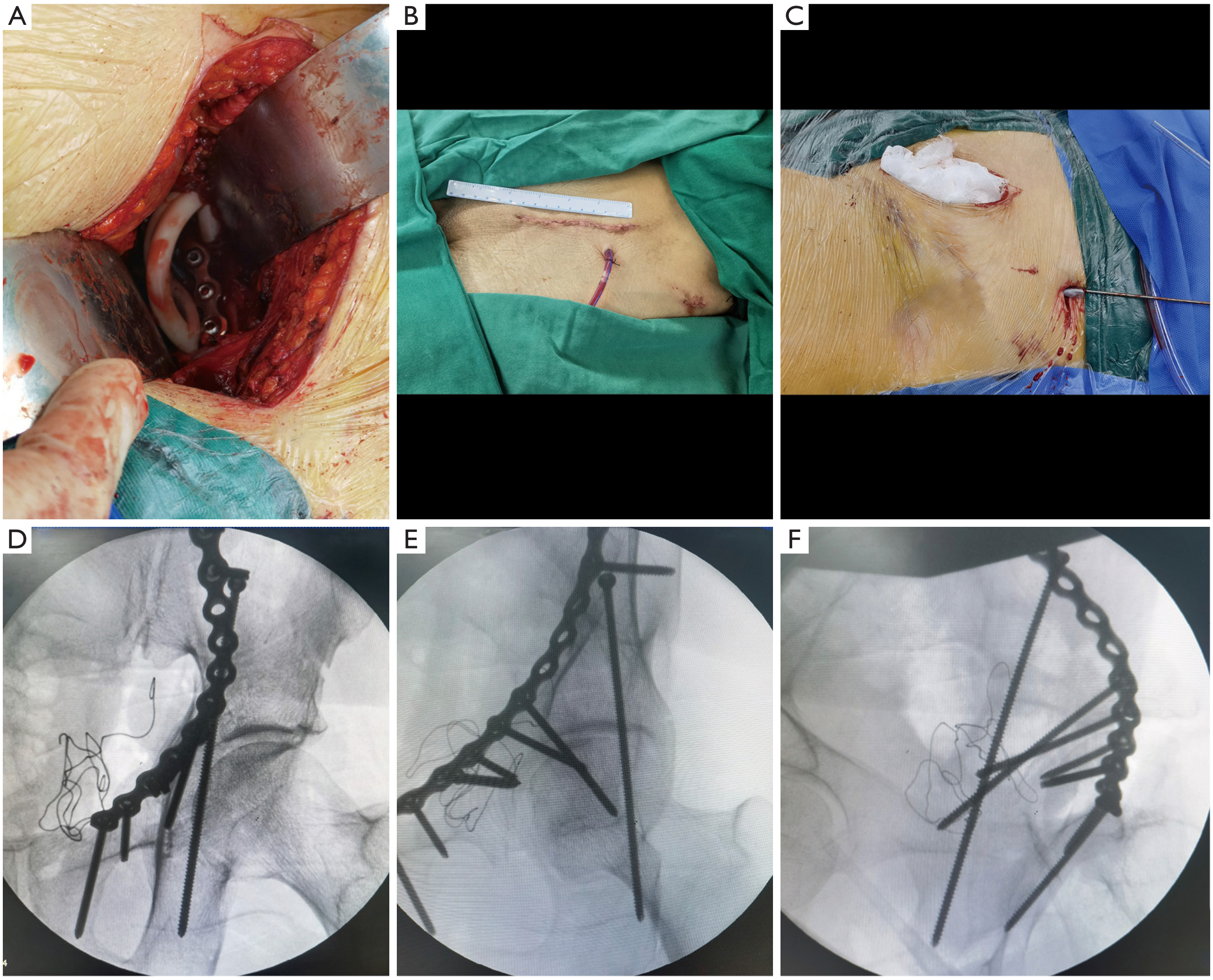

Figure 3 Open reduction and internal fixation of acetabular fractures and intraoperative fluoroscopy. (A-C) The patient underwent open reduction and internal fixation of the acetabular fracture under general anesthesia, and was placed in the supine position intraoperatively. (D-F) Intraoperative fluoroscopy showed that the fracture reduction was satisfactory, and the posterior column screws were placed safely.

information before pelvic surgery (22). We were able to visually observe the details of the acetabular fracture in the preoperative 3D printed model, and pre-bend the bone plate on the simulated reduction model. It was also found to reduce the operative time, intraoperative blood loss, and surgical complications of patients compared with control group (23,24). In order to place the full-length posterior column screw accurately, efficiently, and safely, we designed and produced an individualized guide template based on the 3D model of each patient's pelvis. In the above study, we validated its feasibility and accuracy in previous cases. In order to reduce the blocking effect of soft tissue, the percutaneous incision was located 1–2 cm medial to the iliac spine. After incision of the skin and deep fascia, a retrograde separation was made between the iliopsoas muscle and the iliac wing in the pararectus incision to the percutaneous incision. A 2.5 mm diameter K-wire was placed anterogradely with the aid of the guide plate, and intraoperative X-ray fluoroscopy verified that the guide wire was located in the safe channel. Next, a 3.5 mm diameter screw or cannulated lag screw was inserted.

We note that Chen *et al.* designed a universal guide that is placed through the iliac fossa with excellent results (25). Although some studies of cadaveric specimens provide an anatomical basis for posterior column screw fixation, the position of the screw entry point of the posterior column

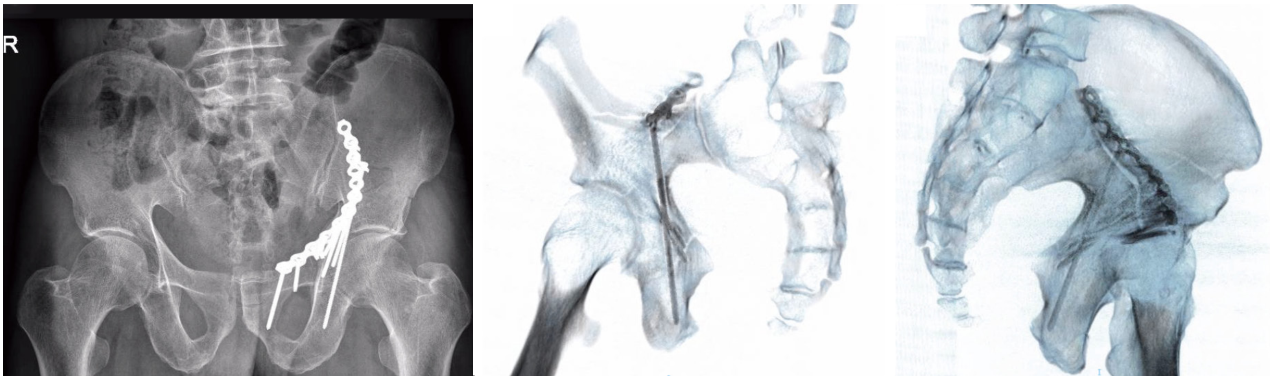

Figure 4 Postoperative X-ray films and CT 3D reconstruction. The postoperative X-ray films and CT 3D reconstruction showed good fracture reduction and internal fixation. CT, computed tomography; 3D, three-dimensional.

and the angle of the screw can be determined. However, there are certain differences in the insertion point, angle, diameter, and length of the posterior column lag screw in individuals with different genders, races, and body sizes (21,22). So, this one-size-fits-all guide may not work for everyone. However, our template is individualized. We found the safe passage of the posterior column in each patient's pelvic model and made their own guide plate. Using the arcuate line of the inner edge of the true pelvis and the greater sciatic notch (incisura ischiadica major) as positioning markers. Our experiments with *in vitro* models can be almost perfectly placed into the safe passage (*Figure 2*). However, during the actual surgical operation, there will be a slight deviation of the angle due to factors such as fracture reduction, soft tissue interference, and the degree of fit of the guide plate. We were surprised to find that some experts have conducted similar studies, and in the literature they have also encountered problems with guide plate error (26); the difference is that they were based on cadaver studies, the plates were bigger and more complex, and we believe that there will be more trouble in the actual operation. Our recommendation is to monitor the position and direction of the guide wire and screw under fluoroscopy during the entire placement process. Once it is found that the placement position has deviated or the guide needle path may be outside the safety channel, the guide plate position should be re-adjusted, not after the guide needle has passed through the safety channel to form a nail path, as the formation of the wrong nail track can seriously interfere with the insertion of the guide wire.

Our guide plate has several advantages. Firstly, the installation is simple. Although the early stage is somewhat onerous, including pelvic CT data collection and processing, 3D model creation, channel planning, data measurement, and rapid prototyping of guide plates, intraoperatively, the operator only needs to attach the guide template tightly to the anatomical structure. Secondly, the positioning is accurate. By positioning directly on bony anatomy, the accuracy of the guide will not be compromised by changes in body position. Thirdly, the guidance is precise. The part of the guide plate where the guide pin is placed is suspended, so the guide plate will not be affected by the steel plate and screws of the front pillar when it is placed (*Figure 4*). The above advantages will greatly reduce the amount of X-ray irradiation, operation time, and operation adjustment times during the operation.

The limitation of this design is that the guide plate is only suitable for anterior antegrade lag screw fixation. Theoretically, the anterior surgical approaches can be applied, including the ilioinguinal, pararectus, and Stoppa approaches. However, this study only selected cases of the pararectus approach to highlight the minimally invasive nature of this surgical approach. In the ilioinguinal approach, the guide plate can be placed directly in the incision while the rectus abdominis is placed percutaneously medially to the iliac spine. Although we placed from the iliopsoas and iliac wing space and there were no serious complications in this group, there is a possibility of iliopsoas and femoral nerve injuries. Before placing the guide plate, the anterior column must be repositioned satisfactorily and the fixation or temporary fixation of the steel plate must be completed. In addition, the posterior post must be repositioned satisfactorily and maintained. It should also be noted that even with the use of this precise guide, X-ray monitoring and experienced intraoperative surgeons are still required to complete the screw placement.

In future studies, we hope to further improve the volume and shape of the guide plate to make it easier to place in more minimally invasive incisions. Auxiliary cannulas that can be assembled and removed will also be designed to provide a more stable direction for the insertion of guide pins and screws. A major limitation of this study is the small size of the study from a single institution. Due to the short follow-up time of this study, the medium- and long-term clinical efficacy needs further follow-up. In the future, we will increase the sample size, follow-up time, and conduct a multi-center study to further verify the feasibility and advantages of this method.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-548/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-548/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The studies involving human participants were reviewed and approved by Weifang People's Hospital Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

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