

The Clinical Efficacy of Anterior Pelvic Wall Locking Plate Fixation Through the Lateral Rectus Approach for Treating Quadrilateral Surface Acetabular Fractures

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Abstract

Background:

Cases of acetabular fractures involving the quadrilateral surface are increasing annually. Quadrilateral surface surgery is complex, involves combined approaches, and the quality of fracture reduction closely depends on the surgical procedure. This study aimed to explore the clinical effects of the anterior pelvic wall locking plate through the lateral rectus approach for treating acetabular fractures involving quadrilateral surface.

Methods:

A retrospective analysis of 35 patients with acetabular fractures involving the quadrilateral surface treated with anterior pelvic wall-locking plates at the First Affiliated Hospital of Soochow University from June 2016 to December 2020. Patients included 25 males and ten females; age 23-82 years, average 52.4 years. The fracture classification was based on the Letournel-Judet classification: 13 cases of double-column fractures, seven cases of T-shaped fractures, seven cases of anterior wall with posterior semi-transverse fractures, and eight cases of transverse fractures. All patients were exposed through the lateral rectus approach, and fractures were fixed with the anterior pelvic wall-locking plate combined with the reconstruction plate. The Matta imaging standard assessed the quality of fracture reduction, and hip joint function was assessed according to the modified Merled'Aubigné-Postel scoring standard.

Results:

Patients meeting the inclusion and exclusion criteria were followed up for 12-42 months, with an average of 26.1 months. At the last follow-up, Matta imaging evaluation showed that 24 cases were anatomically reduced (68.6%, 24/35), seven cases were satisfied (20%, 7/35), and four cases were dissatisfied (11.4%, 4/35). The satisfaction rate was 88.6% (31/35), according to the modified Merled'Aubigné-Postel scoring standard. The hip function was excellent in 23 cases, good in six cases, fair in four cases, and poor in two cases. The excellent and good rates were 82.9% (29/35).

Conclusion:

The acetabular fracture involving the quadrilateral surface is clearly revealed through the lateral rectus approach. The anterior pelvic wall-locking plate combined with the reconstruction plate can fix well, with satisfactory clinical effects.

Background

High-energy trauma is increasing because of the developments in the construction and transportation industries. Incidences of acetabular fractures are rising annually. Besides simple anterior and posterior wall fractures, other acetabular fractures involve the quadrilateral surface [1]. In 1964, Judet and Letournel defined the inner wall of the acetabulum as a quadrilateral surface [2]. The quadrilateral

surface has a deep anatomical location and irregular shape adjacent to the surrounding essential blood vessels and nerves, surrounded by thin bones and other characteristics [3, 4]. Therefore, the quadrilateral surface fracture must be fully exposed during the operation, making fractures challenging to reduce and fix.

Quadrilateral surface fractures are intra-articular fractures that require anatomical reduction to stabilize the fracture end and restore the matching relationship between the femoral head and the acetabulum. Otherwise, they easily cause central dislocation of the hip joint, traumatic arthritis, eventually affecting clinical efficacy [1, 5]. Presently, the clinical treatment of quadrilateral surface fractures involves anterior fracture exposure. The anterior column is fixed with a reconstruction plate, and the posterior column is fixed with a lag screw or a plate through the posterior K-L [6]. However, it is challenging to fix well and block fractures in the quadrilateral surface using this fixation method [7].

Therefore, Weigao designed a new type of plate locking for the front wall of the pelvis, which fixes well and blocks the bones in the quadrilateral surface. In this study, the surgical exposure of the lateral rectus directly overlooked the quadrilateral surface, which simplified the surgical process, enabled good reduction and strong fixation. Since June 2016, the First Affiliated Hospital of Soochow University used the anterior pelvic wall-locking plate combined with the reconstruction plate to treat quadrilateral surface acetabular fractures. The clinical data of this group of patients were retrospectively analyzed, and the early follow-up of clinical results was satisfactory.

The first report is as follows:

Equipment introduction

The front wall of the pelvis locking plate (J-shaped locking reconstruction plate) (Shandong Weigao Orthopedic Materials Co. Ltd., Shandong, China) is a titanium alloy with an arcuate edge plate and two locking plates. It is a J-shaped integrated structure. The arcuate rim plate includes an iliac hole, the pubic hole, and a locking hole where locking screws or cortical screws can be inserted. The two J-shaped structures are in a cross structure with a gap in between to observe the reduction.

The J-shaped structure blocks the bone in the quadrilateral surface from the medial to the outer side. The nail holes between the J-shaped structures are inserted into the locking screw, distributed like a fence to effectively prevent the bone in the quadrilateral surface from shifting to the medial side. Simultaneously, the J-shaped structure properly blocks the bones in the quadrilateral surface. The locking plate placed in the anterior pelvic wall blocks the bones in the quadrilateral surface from the inside out during the operation, properly stabilizing the acetabular fracture. This type of plate is suitable for acetabular fractures that involve bones in the quadrilateral surface (Fig. 1–2).

Clinical Data

1.1 Patient selection criteria

Inclusion criteria:

1. Patients who underwent surgical treatment for acetabular fractures in the First Affiliated Hospital of Soochow University from June 2016 to December 2020;
2. Age 18-82 years old, regardless of gender, including patients with acetabular fractures according to Letournel-Judet classification and acetabular fractures to the quadrilateral surface;
3. Acetabular fractures involving the quadrilateral surface, such as an anterior wall or anterior column with posterior semi-transverse, T-shaped fracture, double-column fracture, transverse fracture;
4. Patients previously exposed to the lateral rectus approach, combined with the anterior pelvic wall locking plate;
5. The follow-up time is more than one year, and the data is complete.

Exclusion criteria:

1. Open fractures of pelvis and acetabulum;
2. Failure to use locking plate of the anterior pelvic wall during the operation;
3. The above reasons combined with severe medical diseases such as liver and kidney insufficiency, circulatory system, respiratory system, and blood system diseases, and those undergoing surgery;
4. Those with incomplete medical records and imaging data.

1.2 General information

From June 2016 to December 2020, the First Affiliated Hospital of Soochow University used the anterior pelvic wall locking plate to treat 35 patients with quadrilateral surface acetabular fractures, including 25 males and ten females; 23-82 years old, with an average age of 52.4 years. The fracture classification was based on the Letournel-Judet classification, including 13 cases of double-column fractures, seven cases of T-shaped fractures, seven cases of anterior wall with posterior semi-transverse fractures, and eight cases of transverse fractures. Twenty-nine cases involved pelvic fractures. Ten cases were injured by falls from more than 2 meters high, 22 cases involved car accidents, and the remaining three patients fell from a point equivalent to their own height. The duration from injury to surgery was 2-15 days, an average of 5.2 ± 2.7 days. The Ethics Committee of the First Affiliated Hospital of Soochow University approved this study. All selected patients signed an informed consent form.

1.3 Preoperative preparation

Admitted patients received anti-shock and other treatments following the principles of pelvic and acetabular fracture rescue. They also completed pelvic X-rays, iliac vessels CTA and three-dimensional reconstruction. The adjacent relationship between the displaced bone block and the iliac vessels was clarified, and patients were given tibial tuberosity traction treatment. Nine cases of complex comminuted acetabular fractures were 3D-printed before surgery, and the 1:1 3D-printed acetabular fracture model was used for the *in vitro* simulated surgery. The fracture block displacement was directly viewed to formulate

individualized reduction methods. Plate pre-bending and screw pre-positioning were performed to determine the nail position, angle, and depth. The internal iliac artery was selected for embolization before the operation in four patients with progressive hemoglobin decline. After the hemoglobin stabilized, low-molecular-weight heparin was routinely used for anticoagulation until the day before the operation. All patients were treated with cefathiamidine for anti-infection 30 minutes before the operation, which took over 3 hours, An additional antibiotic was used during the operation. Excluding the contraindication of thrombosis, all patients were given an intravenous drip of tranexamic acid 20 minutes before operation.

1.4 Surgical process

The patient is placed in the supine position on the operating table to ensure that the C-arm machine can see through the operation site during the operation. The affected lower extremity is routinely disinfected to facilitate the hip flexion operation and traction to reduce acetabular fractures. The exposure of the belly button and pubic symphysis facilitates the determination of anatomical landmarks during the operation. The lateral rectus approach is taken to complete the operation. The iliopsoas muscle space is the first window, the iliopsoas muscle and the external iliac blood vessels are the second window, while the iliopsoas muscle, the external iliac blood vessels, and the obturator nerve vessels are the third window. The third window reveals the anterior column of the acetabulum, the symphysis pubis, the quadrilateral plate, the sacroiliac joint, and the iliac surface. Once the quadrilateral plate and the fracture ends are fully revealed, the flexion hip traction and Schanz nail are placed in the femoral neck by traction reduction. On seeing that the fracture end is satisfactory, the pelvic anterior wall locking plate is inserted through the third window (Shandong Weigao Orthopedic Materials Co.Ltd. Company, Shandong, China). The Kirschner wire temporary is used for fixation and acetabular reduction forceps for clamping the anterior superior iliac spine and the plate. The C-arm machine fluoroscopy shows if the position of the fractured end and the plate is satisfied, and the 3.5 mm AO cortical screw (Synthes company, Switzerland) is inserted in combination with Weigao Company locking nails. The AO reconstruction plate is fixed on the fracture of the iliac bone. The C-arm machine once again checks the fracture reduction and the position of the plate screw to ensure that the screw did not enter the joint cavity (Figure 3). The operation time and intraoperative blood loss were routinely recorded.

1.5 Postoperative treatment

Cefathiamidine was routinely used to prevent postoperative infection within 48 hours. Anti-thrombotic pressure bands were worn after surgery to prevent venous thrombosis of the lower extremities. Low-molecular-weight heparin was used for anticoagulation on the first day after surgery. Patients with drainage tubes should be removed when the drainage volume is less than 50 ml/d after surgery. The hip joint is actively and passively moved on the second day after the operation, and the walker is used to perform functional exercises within six weeks after the operation. All patients undertook pelvic X-rays to evaluate the fracture reduction. Patients were asked to take pelvic X-rays at 1, 3, 6, and 12 months after

the operation and the last follow-up. In some patients, a three-dimensional pelvic CT examination was required.

1.6 Efficacy evaluation

The quality of fracture reduction was evaluated according to the Matta imaging standard. The fracture displacement <1 mm implied anatomical reduction, 1-3 mm implied satisfactory reduction, and >3 mm implied unsatisfactory reduction. The hip joint function was evaluated according to the modified Merled'Aubigné-Postel scoring standard. The score evaluation involves three aspects: pain, walking, and range of joint motion, where 18 is considered excellent, 15-17 is good, 12-14 is fair, and 3-11 is poor.

Results

The 35 patients who met the inclusion criteria were followed up. The operation time was 120–450 minutes, average 245.1 ± 65.3 minutes, and the intraoperative blood loss was 300-2100ml, average 825.7 ± 429.3 ml. All the 35 patients achieved bony union 3–9 months post-operation, and the X-ray fractures were followed up for an average of 4.6 ± 1.7 months. At the last follow-up, Matta imaging evaluation showed that 24 cases were anatomically reduced (68.6%, 24/35), seven cases were satisfied (20%, 7/35), and four cases were dissatisfied (11.4%, 4/35). The satisfaction rate was 88.6% (31/35), according to the modified Merled'Aubigné-Postel scoring standard. The hip function was excellent in 23 cases, good in six cases, fair in four cases, and poor in two cases. The excellent and good rates were 82.9% (29/35). Deep vein thrombosis occurred in two patients after surgery. All patients' incisions healed well. There were no complications such as femoral head necrosis, traumatic arthritis, and large blood vessel rupture.

Discussion

Quadrilateral surface fractures often involve the anterior and posterior acetabulum columns, and the traditional anterior and posterior approach using reconstruction plate fixation is unsatisfactory [6, 7]. There are various new steel plates for treating acetabular fractures involving the quadrilateral surface, with satisfactory clinical results [8–10]. This study used the Weigao anterior pelvic wall locking plate to expose and fix the quadrilateral surface fracture through the lateral rectus approach. The postoperative Matta imaging evaluation of patients showed an 88.6% (31/35) satisfaction rate, according to the modified Merled'Aubigné-Postel scoring standard. The excellent and good rates of hip joint function were 82.9% (29/35). At the last follow-up, all fractures were healed. The belief is that the anterior pelvic wall locking plate has the following advantages:

1. Quadrilateral surface fractures often involve the anterior and posterior columns of the acetabulum. When fractures occur, the quadrilateral surface bones tend to shift to the medial side. The anterior pelvic wall plate has a J-shaped design, which is placed on the inside of the ilium, on the arcuate edge, the pubic branch, and the bone is displaced inward. This approach provides a blocking effect from the inside to the outside required to fix the fracture.

2. For comminuted fractures in the quadrilateral surface or a bone that is not well blocked, the J-shaped design allows a locking screw to be inserted through the fixation hole on the front wall, providing a fence and blocking the bone in the quadrilateral surface. Therefore, the block is shifted to the inside. Clinical studies and biomechanical experiments have shown that the steel plate placed on the inside of the arcuate edge has good fixation effects on the bone masses involved in the quadrilateral surface of the acetabular fracture and effectively prevents the bone mass from outside shifting to the medial side [11, 12]. In this study, the anterior pelvic wall plate was placed on the inner side of the arcuate edge. After follow-up, there were no displacements of the quadrilateral surface to the medial side, and the fixation effect was satisfactory.
3. The steel plate is easily placed. The arcuate edge of the acetabulum, the iliac pubic bulge, and the anatomical structure of the suprapubic branch are uneven. If the steel plate is placed here, it is difficult to shape and attach during surgery. Moreover, the acetabular anterior, the posterior column, and the quadrilateral surface bone blocks become limited at fixation [13].

The iliac arteries and veins and the femoral nerves are close to the iliac pubic tuberosity and the superior pubic branch. Therefore, the ilioinguinal approach requires the anatomy of the inguinal ligament, pubic ligament, and other structures to expose the blood vessels, nerves, and bone surface before the plate can be easily placed. This process increases the difficulty of operation [14].

This research employed the lateral rectus approach. After separating the second and third windows, the steel plate was inserted from the third window. The steel plate was placed on the inside part of the iliac bone through the field of view exposed by the second and third windows, arcuate edge, suprapubic branch, and the J-shaped structure inside the quadrilateral surface, properly fixing the bone in the quadrilateral surface.

The reduction quality of acetabular fractures of the quadrilateral surface is closely related to surgical exposure [15]. However, quadrilateral surface exposure is a difficult procedure in the intraoperative treatment of acetabular fractures involving the quadrilateral surface.

Several methods are applied to expose the quadrilateral surface. Letournel first reported the traditional ilioinguinal approach in 1993 for treating acetabular, anterior column fractures [15]. The surgical approach shows the pubic branch, arcuate edge, sacroiliac joint, iliac fossa, etc., and indirectly exposes the quadrilateral surface of the acetabulum.

The modified Stoppa approach [16, 17] reveals 79% of the inner true pelvis, 80% of the square area, 2cm above the true pelvic rim, and 5cm below it. This approach is suitable for the exposure and fixation of quadrilateral surface fractures, but not in severely obese patients and has developed abdominal muscles. It is difficult to expose and fix the fracture in patients with bladder injury or surgery using this approach. The method should be combined with the iliac fossa approach if an ipsilateral iliac bone fracture accompanies the fracture.

Keel [18] first reported in 2012 that the pararectus approach was used for treating acetabular fractures. It suitably treated the anterior column with square fractures. This approach is characterized by small surgical trauma and minimal invasiveness. Presently, this single approach can treat patients suitable for the Letournel-Judet classification and does not involve posterior wall fractures.

In this study, the lateral rectus approach was used to expose the square bone mass, the anterior wall of the acetabulum, the arcuate edge, the sacroiliac joint, and the medial edge of the iliac bone. The window was exposed during the operation. At this point, it was necessary to identify the arteries and veins under the abdominal wall, ligate them as a breakthrough, and then dissect the surgical window. The 35 patients in this study were exposed to the quadrilateral plate through the lateral rectus approach. The operator needed to be familiar with the anatomy, gentle intraoperative movements to avoid breaking the peritoneum, and familiar with separating the inferior abdominal arteries and veins for ligation.

The second window required gentle separation of the iliac blood vessels and femoral nerves to avoid damaging the vascular and nerve tissues. Simultaneously, a clear vision is required when inserting steel plates and screws to avoid damaging the blood vessels when inserting nails.

The choice of internal fixation is critical for maintaining the quality of acetabular fracture reduction. The key to surgical treatment is to prevent inward and downward displacement of the bone in the quadrilateral surface. Presently, there are numerous methods for internal fixation when treating fractures in the quadrilateral surface. They include: wire cerclage combined with nail plate system [19], percutaneous screw technology [20], reconstruction plate combined with square area steel plate elastic fixation [21], quadrilateral surface titanium plate and screws that are directly fixed, anatomical type, and 3D printed quadrilateral plates [22]. However, no internal fixation device can solve all the fracture problems involving the quadrilateral plate.

In this study, a locking plate on the anterior pelvic wall was adopted to treat the acetabular fracture involving the quadrilateral surface through the lateral rectus approach. The follow-up results were satisfactory, and the hip joint function was good. Therefore, the fracture can be exposed from a single approach and well fixed. This study is preliminary with a small number of cases and can only be discussed from clinical follow-up. This study showed that the anterior pelvic wall plate fixes acetabular fractures and fractures involving the quadrilateral surface from the inside-out with satisfactory reduction and good hip joint function. The clinical follow-up shows that the clinical effect of using the anterior pelvic wall plate to treat fractures involving the quadrilateral surface is satisfactory. However, the internal fixation lacks biomechanical experiments.

Conclusion

In short, the anterior pelvic wall locking plate provides strong and reliable fixation for acetabular fractures involving the quadrilateral surface. Combining a single lateral rectus approach with the anterior pelvic wall locking plate provides good fixation with satisfactory clinical efficacy.

Abbreviations

CT: computed tomography scan; CTA: computed tomography artery scan

Declarations

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Authors' contributions

All authors made substantive intellectual contributions to this study to qualify as authors. ZW, ZW, RZ and HY contributed to study design, acquisition of data, analysis of data, and interpretation of results. GC and MG contributed to study coordination. ML contributed to statistical analysis. ZW, ZW, HY and RZ contributed to manuscript preparation. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to continuing research using this data, but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study has been performed in accordance with the Declaration of Helsinki and has been approved by the local independent ethics committee (the First Affiliated Hospital of Soochow University) in December, 2015 (2015-182). And all selected patients signed informed consent forms.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

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Figures

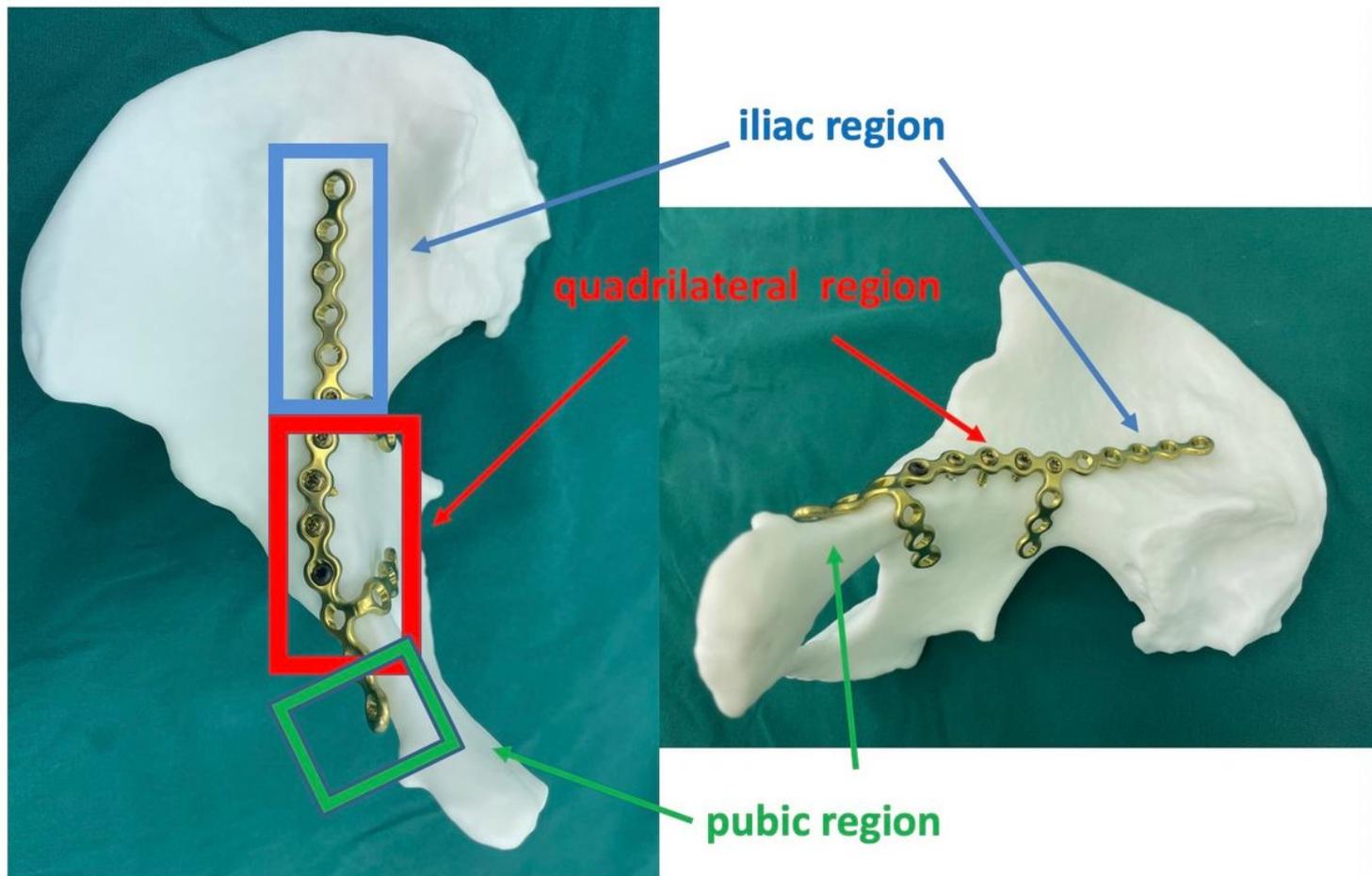


Figure 1

The structure and components of anterior pelvic wall locking plate. It is a titanium alloy with an arcuate edge plate and two locking plates. It is a J-shaped integrated structure. The arcuate edge plate is placed on the anterior edge of the acetabulum. The two locking plates are distributed in a J-shape to block or fix the quadrilateral surface. According to the placement trajectory on the pelvis, the anterior pelvic wall locking plate was divided into three parts: the iliac region, the quadrilateral region, and the pubic region.

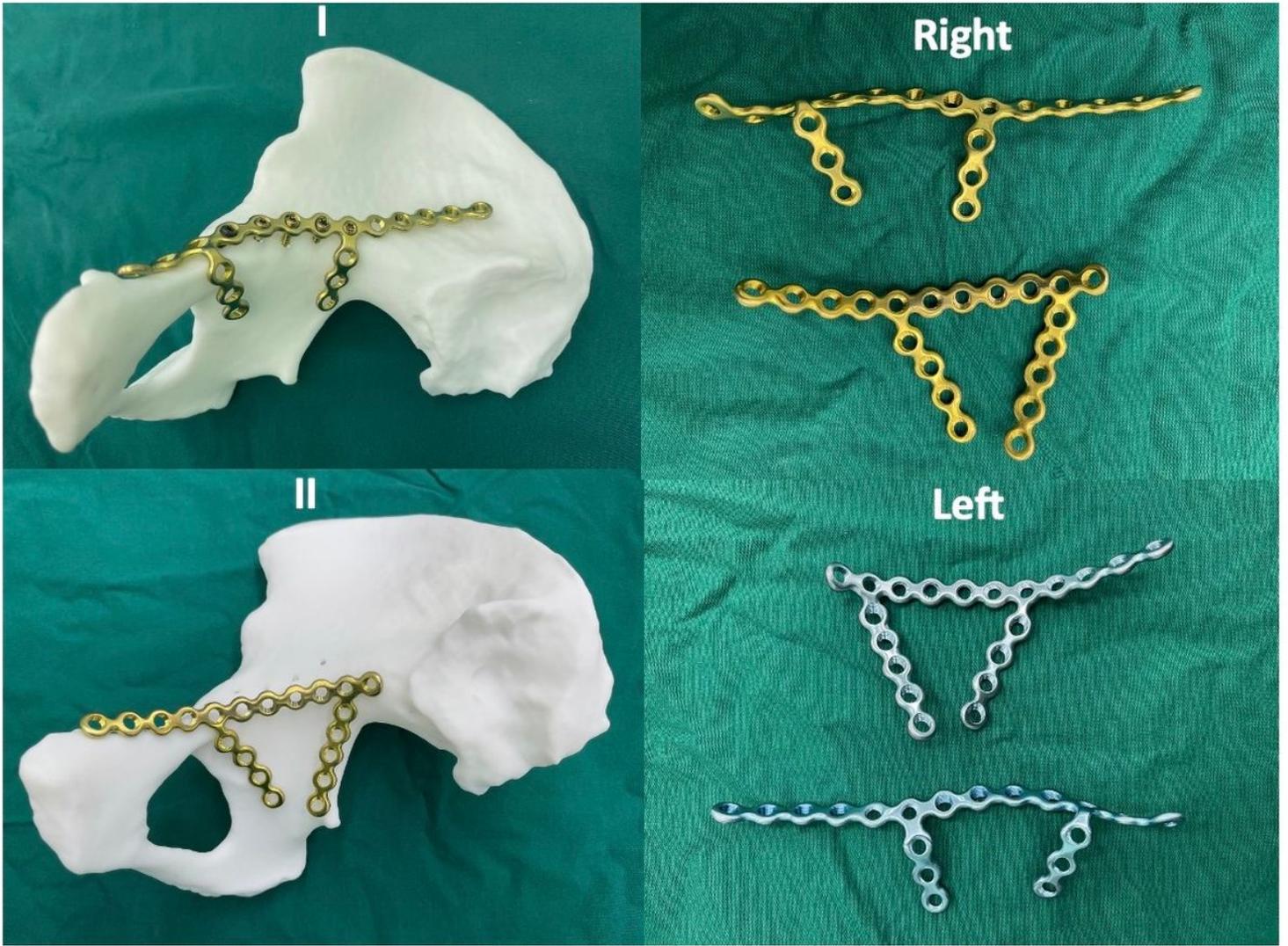


Figure 2

Two different models of the anterior pelvic wall locking plate. Yellow represents the right side, blue represents the left side, select the specific type of steel plate according to the shape of quadrilateral surface fractures. Anterior pelvic wall locking plate have been divided into two models: I, II.



Figure 3

A 44-year-old man presented with anterior column and posterior hemitransverse fracture of the right acetabulum following a traffic accident. The case involved pelvic fractures. Preoperative AP (a) iliac oblique position (b) obturator oblique position (c) and 3D CT reconstruction (d–e) of the pelvis have confirmed the fracture pattern. On the 7th day after the injury, fixation was performed through the lateral rectus approach using the anterior pelvic wall-locking plate combined with the reconstruction plate. Postoperative AP (f, l, n) iliac oblique position (g, j, m) obturator oblique position (h, k, o) and 3D CT reconstruction (q, r) showing Matta's X-ray evaluation was scored as excellent. The modified Merle d'Aubigné evaluation was scored as excellent and the hip function of flexion (o, p) was satisfied. f, g, h are x-rays postoperative 3 days; i, j, k are x-rays postoperative 3 month; l, m, n are x-rays postoperative 1 year; q, r are 3D CT reconstruction postoperative 1 year.