



## CLINICAL ARTICLE

# The novel infra-pectineal buttress plates used for internal fixation of elderly quadrilateral surface involved acetabular fractures

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**Objectives:** In geriatric acetabular fractures, the quadrilateral surface (QLS) was frequently involved in acetabular fracture patterns and accompanied by medial displacement. It was important to buttress the medial displaced QLS and reconstruct the congruity of the affected acetabulum. To evaluate the clinical effectiveness of the novel infra-pectineal quadrilateral surface buttress plates for the treatment of geriatric acetabular fractures.

**Methods:** Twenty-three geriatric patients who were treated for acetabular fractures involving QLS with the novel infra-pectineal buttress plates (NIBP) through a single supra-ilioinguinal approach between January 2015 and June 2019 were retrospectively analyzed; all patients received at least 1 year's follow-up. All patients were aged  $\geq 60$  years old and including 18 males and five females. Radiologic and clinical outcomes of patients involved in the study were collected and analyzed according to the Matta scoring system and the Merle D'Aubigné-Postel scoring system. The functional recovery scoring was compared using q-test.

**Results:** All 23 consecutive patients had relatively satisfactory clinical treatment effectiveness. Average ages, length of incision, operation time, and intraoperative blood loss were  $69.8 \pm 6.1$  years,  $12.1 \pm 2.6$  cm,  $166.5 \pm 43.5$  min, and 500 (500,700) ml, respectively. According to the Matta scoring system, 14 cases of reduction were graded as excellent, five as good, and four as fair. At the last follow-up, the clinical outcome evaluation was excellent in 13 cases, good in seven cases, and poor in three cases with the use of the Merle D'Aubigné-Postel scoring system. The difference of modified Merle D'Aubigne-Postel score at 3 months, 6 months and last follow up was statistically significant ( $F = 21.56$ ,  $p < 0.05$ ). Postoperative lateral femoral cutaneous nerve injury occurred in three patients and heterotopic ossification occurred in one patient.

**Conclusions:** For the treatment of geriatric acetabular fractures, the NIBP could provide stable and effective fixation to the QLS involved acetabular fractures, and related satisfactory clinical results with few complications were noted.

**Key words:** Buttress; Geriatric acetabular fractures; Internal fixation; Medial displacement; Quadrilateral surface

## Introduction

Acetabular fractures, with an incidence rate of 2.72% and an annual incidence of three patients per 100,000 persons,<sup>1,2</sup> are relatively rare but a challenging injury for orthopedic surgeons. As the aging population increases, the incidence of geriatric acetabular fractures in patients who

with osteoporotic bone changes are also increasing resulting from low energy injuries. The rate of patients aged 60 years and over with acetabular fractures has risen from 10% to 24%.<sup>3</sup> The quadrilateral surface (QLS) was frequently involved in elderly patients. Open reduction and internal fixation is still the most suitable treatment method to restore

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the stability and congruity of hip.<sup>4,5</sup> However, it is difficult for orthopedic surgeons to manage this particular type of injuries due to co-morbidities associated with age-related bone quality and osteoporosis resulting in comminuted fractures of QLS.<sup>6</sup>

Traditionally, alternative methods have been used to treat QLS involved acetabular fractures, including anterior/posterior plates, anterior column plates with iliosciatic plates, or long screws surrounding the joint.<sup>7-10</sup> However, the variant type of traditional internal fixation methods has the following disadvantages. Trauma for patients and complicated surgical barriers. Especially for the insertion of long screws surrounding the joint, it requires a surgeon who is highly skilled as the risk of damaging vessels and nerves and screws insertion into the joint is high, despite the use of intra-operative variant pelvic position fluoroscopy.<sup>4,11-13</sup> The original reconstruction plate has to be remolded repeatedly because of the irregular surface of the pelvis, which leads to increased duration of surgery and decreased strength of the plate. The shaped plate mostly cannot be attached entirely to the pelvic surface, and may lead to secondary displacement of the reduced fragments.<sup>14</sup> Therefore, designing and producing a suitable acetabular internal fixation apparatus to resist QLS and form a stable frame is urgently needed for clinical application.

Recently, some scholars have developed some novel internal fixation apparatus and methods to treat acetabular fractures with QLS involving. Chen *et al.*<sup>10</sup> published a bio-mechanical comparison of different fixation techniques for typical acetabular fractures in the elderly, which proved that the pivotal effectiveness of resisting intra-pelvic movement of

QLS. Zha *et al.*<sup>15</sup> developed a quadrilateral resistant plate, introducing the importance of quadrilateral resistance and presenting an innovative concept. Kistler *et al.*<sup>16</sup> designed a novel quadrilateral buttress fixation method and compared buttress plates with traditional plates, which emphasized the significance of resisting the displacement of quadrilateral fracture fragments. Karim *et al.*<sup>17</sup> introduced a new fixation technique using a buttress screw to fix and resist the intra-surface of the QLS. The different internal fixation methods and novel internal plates could satisfy the clinical surgical needs; however, the clinical popularization and application of some methods have been restricted owing to intra-operative performance, insufficient quadrilateral resistance, and unsatisfactory fixation strength.

Based on the experience and research results of some scholars,<sup>17,18</sup> we designed and produced the novel infra-pectineal buttress plates (NIBP). The NIBP was designed with two types. The novel plate was an anatomical designation without extra repetitive intra-operative remolding, and the designation of the screw canal and the placement of the plate were kept from the joint, which avoided repetitive fluoroscopy, reducing the operation time, and increasing the surgical safety and clinical efficiency.

The purpose of this study was: (i) to illustrate the advantages and disadvantages of this novel acetabular quadrilateral anatomical plate for the treatment of QLS involved acetabular fractures; and (ii) to summarize the clinical efficacy of the novel acetabular quadrilateral anatomical plate.

## Materials and Methods

### Inclusion and Exclusion Criteria

Data from all patients with acetabular fractures who underwent surgical treatment at our trauma center were collected between January 2015 and June 2019.

The patients who meet the following conditions were included: (i) age  $\geq 60$  years; (ii) complete data; (iii) follow-up time  $\geq 1$  year; and (iv) management of the fractures with the NIBP. Patients who had the following conditions were excluded from our research: (i) age  $< 60$  years; (ii) coexistence of pathological fracture or open fracture; (iii) received second or more surgical treatment of ipsilateral acetabulum; (iv) incomplete follow-up data; and (v) follow-up duration less than 1 year.

Finally, 23 patients were included in this retrospective study (Figure 1). According to the Letournel-Judet acetabular classification, three patients had anterior column fractures, four had T-shaped fractures, four had anterior column posterior hemi-transverse fractures, nine had both-column fractures, and three had transverse fractures associated with QLS fractures (Table 1). The operations were performed by the same surgeon (X. D. G.). The study received approval from the institutional review board (S1060), and consent was obtained from all the patients included in the study.

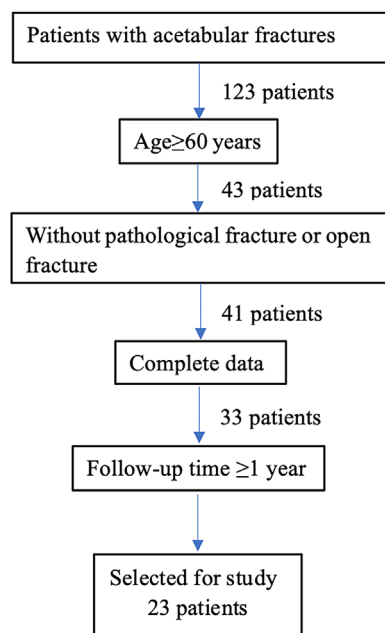


Fig. 1 Study flow diagram

### Radiographic and Clinical Management

Preoperatively, comprehensive pelvic radiography including anteroposterior (AP) pelvic, obturator oblique, and iliac oblique views, computed tomography (CT) + 3D reconstruction, computed tomography angiography of the iliac artery, and color Doppler ultrasonography of the lower limb vessels were performed to reconstruct the anterior lateral view to acquire a direct visualization at the QLS and assess the existence or absence of thrombus.

### Designation of NIBP

The NIBP is made of titanium (TA3) and consists of two structural parts, the curved infra-pectineal main plate and the QLS blocking plate, which are directly connect to each other. The overall structure of the plate is designed according to the anatomical shape of the QLS, forming a baffle. The NIBP is divided into two types. The large-size plate has 16 screw holes and the small-size plate has 16 screw holes, which allows for the insertion of 3.5mm-diameter screw. The large-size NIBP is usually used for buttressing QLS that fractures that are low, but the small-size NIBP is usually used for buttressing QLS that fractures that are high. In the large-size NIBP, holes fourth to seventh and tenth and twelfth are not screwed in to prevent penetration into the joint. While, in the small-size NIBP, tenth and thirteenth holes are not

screwed. The QLS blocking plate has the role of both iliosciatic and ischiopubic plate, replacing the posterior column screw and infra-acetabular screw.

### Surgical Technique

#### Anesthesia and Position Selection

All patients were operated in the supine position under general anesthesia on a flat radiolucent operative table in the operating room equipped with a C-arm machine, and the skin disinfection range was extended to the ipsilateral ankle joint.

#### Approach Selection and Exposure

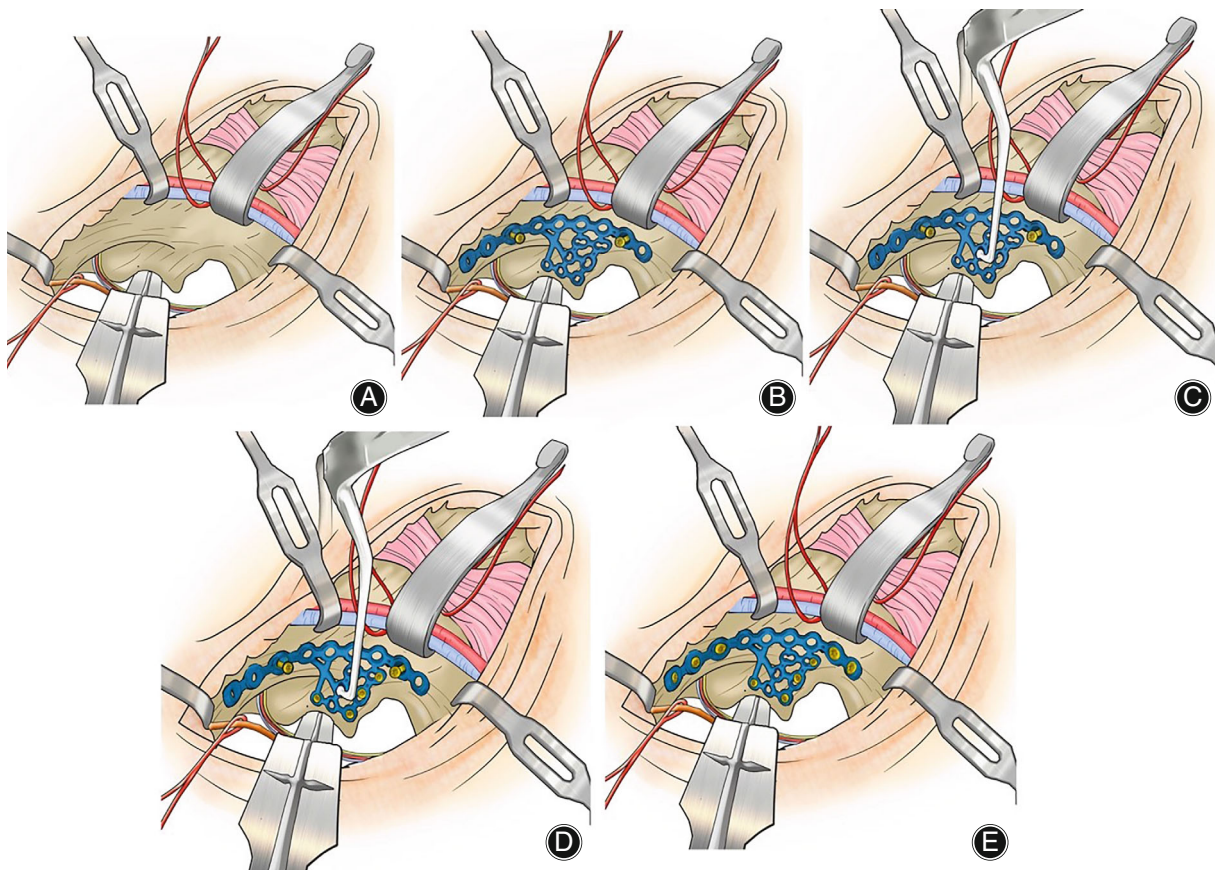
All patients underwent a single anterior supra-ilioinguinal approach and were fixed with the NIBP.<sup>19</sup> The surgeon was positioned on the side contralateral to the surgical side. The incision was made at the junction of the lateral-middle 1/4 of the line connecting the ipsilateral anterior superior iliac spine with the navel and ended at the junction of the middle-medial 1/3 of the line connecting the ipsilateral anterior superior iliac spine with the pubic symphysis, and the length of the incision could be extended bilaterally depending on the fracture type.<sup>19</sup> Direct visualization of all fracture sites was made as clearly as possible, especially where the joint exists to ensure that the articular surface was smooth. (Figure 2(A)) It is important to note that the procedure of exposure should be gentle, especially to protect the spermatic cord (male)/the round ligament of the uterus (female) and the external iliac vessels. The hip and knee flexion positions were maintained during the surgery.

#### Reduction and Fixation

The presence of an iliac wing fracture is crucial to obtain priority processing, and if it is there, evaluation of the reduction situation of the fractured anterior column according to the assessment of the existence of severe impaction, overlapping, and twisting between the fractured bones of the ilium can be done. After a satisfactory reduction of the iliac swing, Kirschner wires were used to form a temporary fixation and then fixed with lag screws or reconstruction plates. The NIBP was placed after the existing iliac fracture was treated. First, two 3.5 mm-diameter cancellous screws were inserted into the third and eighth canal temporarily in order to immobilize the plate without full screw insertion. (Figure 2 (B)) Second, a bucking bar was used to withstand the quadrilateral part of the NIBP, and 2–3 screws were inserted to fix the plate of the quadrilateral part, which also fixes the posterior column fracture. (Figure 2(C),(D)) Finally, the screws positioned in the terminals were tightened, and the remaining screw canals were inserted with cancellous screws to strengthen the fixation, except for the fourth to seventh canals, because these canals were closer to the joint. (Figure 2(E)) Moreover, owing to the restrained surgical space and to avoid the screws being inserted into the joint, it was necessary to follow the orientation to the ischial

**TABLE 1 Patient demographics**

Variable	(n = 23)
General data	
Age (years)	69.8 ± 6.1
Gender:male/female	18/5
Operation time (min)	166.5 ± 43.5
Blood loss (ml)	500 (500,700)
Length of incision (cm)	12.1 ± 2.6
Time to operation (days)	8.65 ± 2.66
Mechanism of injury	
Falling	8 (34.78%)
Vehicle accident	13 (56.52%)
Crashing	2 (8.70%)
Concomitant fractures	
Spine	12 (52.17%)
Limp	8 (34.78%)
Rip	9 (39.13%)
Letourmel classification	
T-shaped fracture	4 (17.39%)
Both column fracture	9 (39.13%)
Anterior and posterior hemi-transverse	4 (17.39%)
Tranverse fracture	3 (13.04%)
Anterior column	3 (13.04%)
EINahal QLS classification	
QLS1	8 (34.78%)
QLS2	9 (39.13%)
QLS3	6 (26.09%)
Complications	
Infection	0
Lateral femoral cutaneous nerve	3 (13.04%)
Vascular injury	0
Heterotopic ossification	1 (4.30%)
Atrophy of the rectus	0



**Fig. 2** The painting exhibits the steps of how to place the NIBP according to the supra-ilioinguinal approach. (A) According to the supra-ilioinguinal approach, the surface of the entire QLS is directly visualized with the soft traction using some apparatus. (B) The insertion of two cancellous screws in the third and eighth canals to temporarily fix and maintain the position of the plate without full tightening. (C) With the use of a bucking bar to push the quadrilateral part plate in order to attach the bone surface. (D) Three screws are inserted to canals of the QLS to fix the plate. (E) Inserting screws to the first, second and ninth holes and tightening the third and eighth screws

tuberosity and the posterior column when the screws were inserted in the QLS. Finally, after the completion of screw insertion, the internal fixation formed a “frame + buttress” structure for the broken QLS and after examination for the nonexistence of screws inserted into the joint using the C-arm machine, the incision was sutured.

#### **Outcome Measures**

Detailed clinical data of patients were recorded, including time to surgery, surgical time, blood loss, complications, quality of reduction, clinical outcome, and radiographic information. The clinical-radiographic outcomes were evaluated by the authors (Y.Z.W and K.F.C).

#### **Matta score**

Based on radiographs of the pelvis, the quality of reduction was evaluated according to the Matta scoring system: 1 mm

or less was an excellent reduction; 2 mm to 3 mm, good reduction; and greater than 3 mm, poor reduction.<sup>20</sup>

#### **Merle D’Aubigné–Postel Score**

The final follow-up clinical outcome, including pain, gait and range of hip activity, was evaluated using the Merle D’Aubigné–Postel scoring system: 18 to 17 points was an excellent outcome; 16 to 15 points, good; 14 to 13 points, fair; and less than 13 points, poor according to evaluation of pain, walking ability, range of motion, and function of the hip joint.<sup>21</sup>

#### **Postoperative Management**

All patients were requested to undergo pelvic radiography in three positions and CT + 3D reconstruction after the surgery. Patients were asked to follow up at 1, 3, 6, and 12 months after operation to evaluate the quality of bone healing and function recovery. The follow-up time was at

least 12 months. Patients were not allowed to perform any weight bearing exercises within 4 weeks postoperatively but were allowed to walk with a pair of crutches 4–8 weeks after the surgery, with a single crutch 8–12 weeks after the surgery and without crutches 12–16 weeks after surgery.

### Statistical Analysis

The data was processed using SPSS (version 26.0; SPSS, Chicago, IL, USA). The measurement data were expressed as mean  $\pm$  standard deviation, and the postoperative comparisons at different time points were performed by repeated measures ANOVA, and the q-test was used for two-way comparisons. A value of  $p < 0.05$  was regarded as significantly different in this study.

## Results

### Follow-up

All the 23 patients were followed up according to outpatient department or telephone with standard questionnaire survey at 1, 3, 6 months and 1 year postoperatively, and then annually thereafter.

### General Results

The 23 consecutive patients with QLS involved acetabular fractures were treated with NIBP through a single supra-ilioinguinal approach. Ten patients were treated with large-size NIBP, and 13 patients were treated with small-size NIBP. All plates were well attached to the surface of the acetabulum without extra remolding. The average age was  $69.8 \pm 6.1$  years, the average surgical time was  $166.5 \pm 43.5$  min, the average blood loss was 500 (500, 700) mL, and the average incision length was  $12.1 \pm 2.6$  cm. (Table 1).

### Clinical Improvement, Radiographic Improvement and Implants Evaluation

Pelvic separation test and percussion pain were not observed. All patients achieved clinical healing of fractures. There was no occurrence of re-displacement of fractures during follow-up. No breakage, displacement or failure of implants were observed.

### Functional Evaluation

According to the Matta scoring system, 14 cases of reductions were graded as excellent, five cases good, and four cases fair with an excellent/good rate of 82.61%. According to the Merle D'Aubigné-Postel scores, the clinical outcomes at the last follow-up were excellent in 13 cases, good in seven cases, poor in three cases with an excellent/good rate of 86.96%. (Table 2) The modified Merle D'Aubigné-Postel score at 3 months was  $12.61 \pm 2.10$  (range, 9–16), 6 months was  $15.22 \pm 2.24$  (range, 12–18) and last follow up was  $16.43 \pm 1.67$  (range, 13–18), respectively, the difference was statistically significant ( $F = 21.56, p < 0.05$ ). The difference between the last follow up and 3 months was statistically significant ( $p < 0.05$ ).

**TABLE 2 Postoperative radiological and functional results**

Parameter	Value
Merle D'Aubigne-Postel score	
Excellent (18–17)	13(56.52%)
Good (16–15)	7(30.43%)
Fair (14–13)	3(13.04%)
Poor (<13)	non
Radiological outcome (Matta)	
Anatomical (<1 mm)	14(60.87%)
Imperfect (2–3 mm)	5(21.73%)
Poor (>3 mm)	4(17.39%)

### Complications

Of the consecutive patients, four had slight hip pain, one had pain after activity and recovered after rest, three had slight claudication, two had slight hip flexion limitation, and three had slight limited hip abduction, which might be associated with the time to surgery and condition of the comminuted fracture.

Lateral femoral cutaneous nerve injury was found in three patients, but all three recovered completely 1 month after surgery without any intervention, and heterotopic ossification occurred in one patient. No internal fixation was loose or led to fracture displacement. No inguinal or abdominal wall hernias were observed. No obturator nerve or vascular injury were observed. No traumatic arthritis or avascular necrosis of the femoral head occurred during the follow-up period. (Table 1).

### Discussion

In our study, 23 patients aged  $\geq 60$  years with QLS involved acetabular fractures were treated with the NIBP through a single supra-ilioinguinal approach. Additionally, because the anatomical shape of the plate could supplementally reduce the moved fracture, all patients involved acquired satisfactory postoperative reduction and fixation efficiency. Our team was able to obtain excellent/good reduction in 82.61% of cases; clinical results were evaluated using the Merle D'Aubigné-Postel system at the last follow-up: 86.96% of the outcomes were graded good or excellent. Postoperative results were similar with other published studies.<sup>6,22</sup> The three patients with poor clinical results might be due to their own severe osteoporosis that hindered the union of bone. The incidence rate of postoperative complications was 17.39% including incision-related iatrogenic injuries such as lateral femoral cutaneous nerve injury; these complications generally resolved within 1 month, except for heterotopic ossification. The incidence of neurovascular injuries might be related to the expansion of incision, because we needed a larger view for the QLS to place our plate.

### Characteristics of Geriatric Acetabular Fractures

As the elderly patients displayed a different fractures patterns and fractures characteristics compared to younger patients.<sup>3</sup>

ElNahal *et al.* found that the 77.18% acetabular fractures involved the QLS.<sup>23</sup> However, in elderly patients, the rate of acetabular fractures involved the QLS was 50.8%.<sup>3</sup> In contrast to younger patients, the geriatric acetabular fracture was more difficult to manage, because of the incidence of acetabular roof marginal impaction and comminuted fractures of QLS being high due to osteoporotic bone and other accompanied injuries.<sup>24,25</sup> Also, the injury mechanism of elderly patients was also different. The QLS of the acetabulum of elderly patients was inclined to result in comminuted fractures just by falling from standing height. However, in younger patients, the fracture morphology was prone to be individual and resulted from high-energy factors. It was essential to reconstruct the congruity and anatomical reduction of the QLS with stable internal fixation despite it being thin and not being an area of weight-loading. In our previous clinical experience, if the satisfactory reduction of displaced QLS was not achieved, the incidence of conversion to total hip arthroplasty increased. Hence, we invented the special plate to treat QLS involved acetabular fractures.

Our clinical efficiency reflected that the NIBP could form rigid stability (frame structure) for QLS and resist QLS medial displacement (buttress effect), suitably to form a “frame + resistance” structure, like the bottom of a broken wooden crate repaired with a piece of block. Due to the medial displacement and tendency to comminution of geriatric QLS fractures, the internal fixation should have the ability of reconstructing the integrity and buttressing the broken QLS. The NIBP has larger contact area with QLS, which can afford sufficient buttress effectiveness to resist medial displacement.

#### Definition of QLS

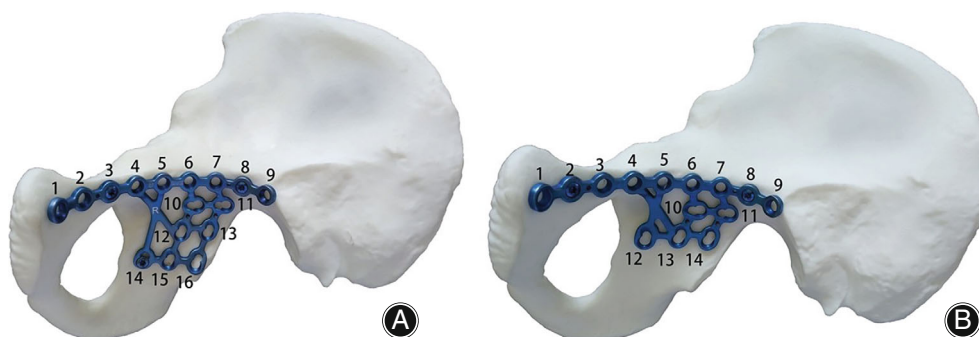
The definition of QLS has been ambiguous in previous published studies, which resulted in the slow development of internal fixation. Herman *et al.*<sup>26</sup> described a new classification of acetabular fracture considering that there was no concept of a column compared with the classification of Judet

and Letournel, but without illustrating the definition of QLS. ElNahal, *et al.*<sup>23</sup> considered it as the trapezoidal area and described that the QLS extended from the pelvic brim superiorly to a line joining the ischial spine and obturator foramen inferiorly, and is bound by the greater sciatic notch posteriorly and the obturator foramen anteriorly. Yang *et al.*<sup>27</sup> identified the borders of the quadrilateral plate, which was same as ElNahal *et al.*, and described a fracture map of QLS. Guyton and Perez<sup>28</sup> considered QLS to be the medial wall of acetabulum, and mentioned that it was located near the femoral head limiting the options for its fixation. However, the restoration of QLS integrity is important to restrain the second central dislocation of femoral head, how to restore and buttress QLS is pivotal. These studies relatively described the definition of QLS accurately, which inspired the design and development of QLS internal fixation apparatus. Based on the different definitions of QLS, our team designed and developed this novel plate, which is specialized to treat QLS involved acetabular fractures.

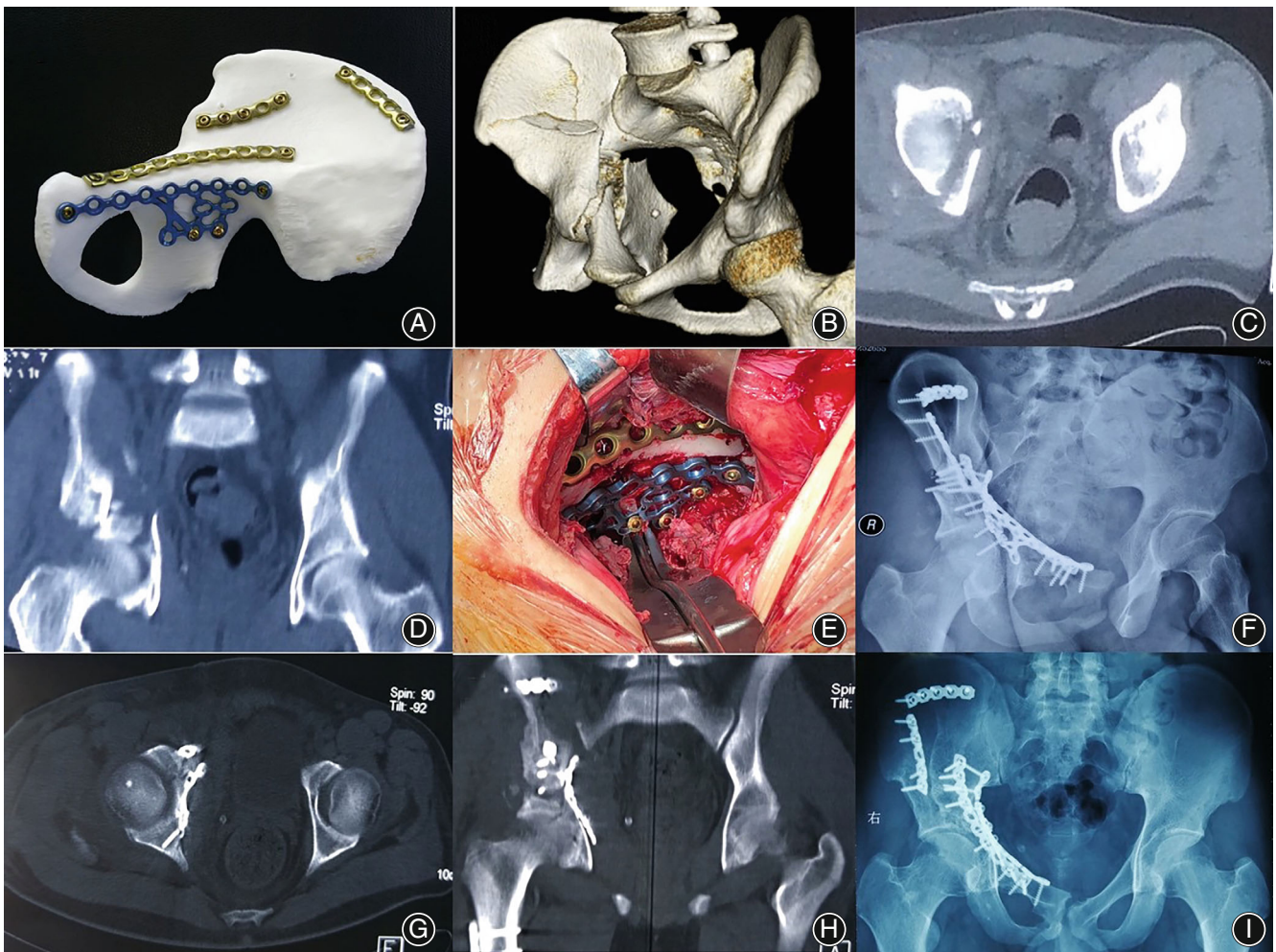
The designation was based on the anatomical structure of QLS, which could afford a reduction model for the broken QLS, forming a frame structure for QLS.

#### Designation and Application of NIBP

A biomechanical study proved that the addition of an intra-pelvic plate could contribute significantly to resist fixation failure.<sup>29</sup> Kistler *et al.*<sup>16</sup> and Sen *et al.*<sup>6</sup> invented a buttress plate to treat QLS involved acetabular fractures, however, this fixation could not entirely buttress the comminuted QLS fractures or low fractures. Based on previous reports and considering the advantages and the disadvantages of some designed products,<sup>18,30</sup> our team invented a special plate that could form an entire frame structure to fix the anterior/posterior columns and buttress QLS. The two types of NIBP were designed based on anatomical morphology of the acetabular medial surface for treating variant comminuted QLS fractures. (Figure 3) The shape of the novel plate could be understood as a net used to pocket the displaced acetabular



**Fig. 3** The figure shows two types of NIBP (large-size and small-size), the structure of the NIBP and the numerical order of the screw holes. The NIBP is designed for the anatomical structure of the infra-pectineal surface. Two types of NIBP were made with titanium alloy and possess a net-shape part to resist the protrusive QLS. (A) The large-size NIBP with 16 screw holes usually used for buttressing QLS that fractures exist lowly. (B) The small-size NIBP with 16 screw holes usually used for buttressing QLS that fractures exist highly

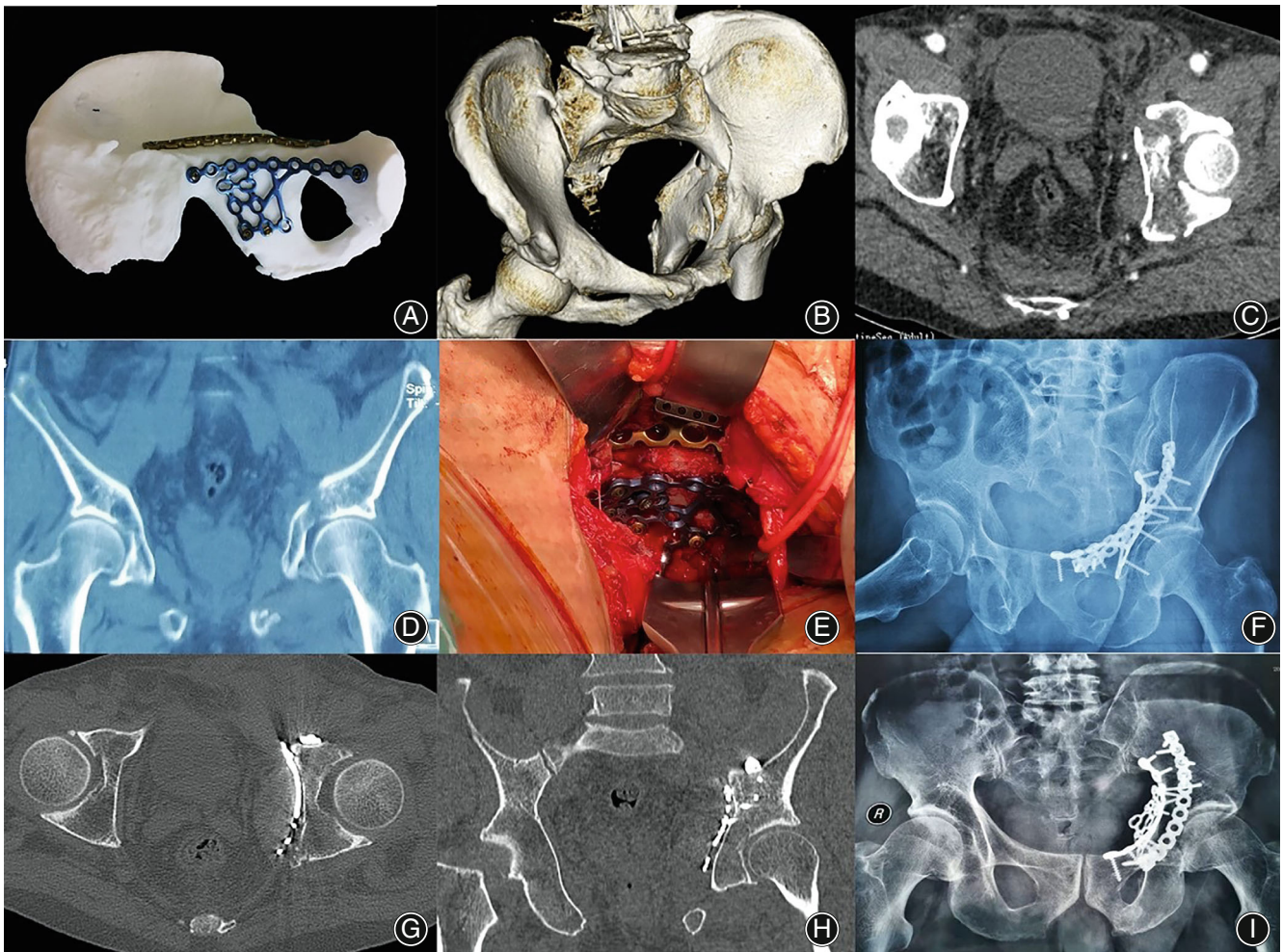


**Fig. 4** A patient, male, 70 years old, right acetabular fracture resulted by traffic accident, was treated with the small-size NIBP. (A) Pre-operative plate placement was simulated on a mirrored model of the healthy side of this patient. (B–D) Pre-operative comprehensive pelvic radiography including 3D reconstruction and CT scan. (E) Intra-operative placement of the small-size NIBP. (F–H) Post-operative comprehensive pelvic radiography. (I) One-year followed-up of this patient

medial wall. Because the novel plate covers the whole/half QLS, surgeons could select plate according to the area of fractures. If the fractures involve the low area of QLS, the large-size NIBP could be used to entirely cover the QLS. If the fracture area is high, the small-size NIBP is enough. Also, because the bone quality of elderly patients is often poor, using tools (bucking bar, reduction clamp) to reduce and stabilize the QLS leads high risk of adding iatrogenic fracture. Hence, due to the anatomical structure of this novel plate and the extended contact area, it could be used as a reduction tool attached on QLS to compress QLS. Based on NIBP, the reduction clamp and bucking bar could be used to apply sufficient and entire buttress force directly in medially displaced QLS, avoiding focusing on one point. Moreover, in our previous biomechanical study proved that this novel plate could provide stiffness and stability comparable to

standard fixation methods.<sup>10</sup> This method could efficiently decrease the incidence of iatrogenic fractures during the process of reduction and afford sufficient buttress effects for medially displaced QLS (Figure 4).

Nevertheless, the following should be noted when using the novel plate: determine whether the plate was attached to the surface of the acetabular medial wall well before placement of screws. The placement of screws must follow a certain order and the use of a cancellous screw is recommended. Firstly, the third and eighth holes should be inserted into to maintain the position of plate without completely tightening. In addition, the length of screws placed at QLS are limited to 10–14 mm and the direction is oriented to avoid penetrating the joint. The bucking bar should be used to withstand QLS until two or three screws are inserted. Finally, screws are not inserted for the fourth to



**Fig. 5** A patient, male, 75 years old, left acetabular fracture resulted by traffic accident, was treated with the large-size NIBP. (A) Pre-operative plate placement was simulated on a mirrored model of the healthy side of this patient. (B–D) Pre-operative comprehensive pelvic radiography including 3D reconstruction and CT scan. (E) Intra-operative placement of the large-size NIBP. (F–H) Post-operative comprehensive pelvic radiography. I One-year followed-up of this patient

seventh hole, and screws are placed in the remaining holes to strengthen the fixation. Because the NIBP was designed based on the general bone structure, it was indispensable to reduce the fractures first before the application of anatomical plates, or it may be difficult to attach plate to proper bone surface (Figure 5).

#### **Selection of Suitable Approach**

It was noted that the NIBP was only suitable for surgery through the anterior approaches. In addition, because the combined structure of the NIBP possessed a relatively large space, it was not convenient to place the plate on the bone surface. Hence, direct exposure and excellent access to QLS were essential for surgeons to conveniently place the plate and insert screws. Selection of a suitable approach for treating QLS involving acetabular fractures is crucial for

surgeons to reduce and fix this particular type of fracture. Some inter-pelvic approaches are recommended for insertion of this novel plate, such as ilioinguinal,<sup>4</sup> pararectus,<sup>31</sup> modified stoppa<sup>32</sup> and supra-ilioinguinal approaches.<sup>19</sup> According to different clinical experiences and surgical proficiency, the above approaches are selectable. However, when compared to other intra-pelvic approaches, our team proposed that the supra-ilioinguinal might be more competent to realize the direct visualization for QLS.<sup>19</sup> Therefore, our team used the supra-ilioinguinal approach to perform operations in this study.

#### **Limitations**

This clinical study provided a novel plate of QLS, the sufficient buttress on medial displaced QLS could be effective in the treatment of geriatric acetabular fractures. However,



this study also has some limitations as its retrospectively performed and the included patient number were limited. More applications of the novel plate should be carried out. Also, the clinical treatment efficiency was not compared with other similar plates. Therefore, a further randomized controlled trial should be designed to confirm our results. Finally, all our operations were performed through the supra-ilioinguinal approach modified by the ilioinguinal approach, which is not a regular operative approach. Further studies should be performed using other anterior intra-pelvic approaches to verify the effects of this novel plate.

### Conclusion

In conclusion, the NIBP can provide an effective solution for QLS involved geriatric acetabular fractures through an anterior surgical approach. The NIBP can afford buttress effects for protrusive QLS and acquires early satisfactory clinical efficiency owing to the anatomical designation, safety, and low incidence of complications. The two types of NIBP can provide different QLS buttress ranges, if the fracture area is high the small-size NIBP can be selected, if the fracture area is low the large-size NIBP can be selected. The novel plates can be applied for geriatric acetabular fractures where QLS is involved. In this study, the novel plate was

applied mainly in elderly patients, it could also be used for younger patients with displacement of QLS, yet the clinical efficiency needs further verification.

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### Conflict of Interest

All authors declared that there are no competing interests.

### Authorship Contribution Statement

YZW and KFC conceived and designed the study. LZ contributed to the data collection. YZQ, YLW and GXH analyzed the data. SY and XDG helped to draft the manuscript. YM carried out the image review. All authors read and approved the final manuscript.

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