



# Fragment specific fixation technique using 2.7 mm VA LCP for comminuted posterior wall acetabular fractures: a novel surgical technique

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## Abstract

**Purpose** The purposes of the study were to introduce surgical technique of fragment-specific fixation technique using multiple 2.7-mm variable-angle locking compression plates (VA LCPs) in comminuted posterior wall acetabular fractures and reported its clinical results.

**Patients and methods** Among the 68 patients, 23 with comminuted posterior wall fractures with  $\geq 3$  fragments in the CT scan and no column involvement with a minimum follow-up duration of 12 months were enrolled in this study. We evaluated the clinical results after the treatment of comminuted posterior wall acetabular fractures via the fragment-specific fixation technique using 2.7-mm variable-angle locking compression plates (VA LCPs) retrospectively.

**Results** The average duration of follow-up was 26.8 months. Anatomical reduction was achieved in eighteen patients. Imperfect reduction was achieved in five patients. 22 patients achieved fracture union and one patient underwent revision surgery owing to acute postoperative infection. There were no complications, including loss of reduction, fixative failures, sciatic nerve palsy, heterotopic ossification, and early posttraumatic arthritis among 22 patients. The average functional outcome was measured as ‘very good’.

**Conclusion** Fragment-specific fixation technique using 2.7-mm VA LCPs for comminuted posterior wall acetabular fractures could be an acceptable alternative means of surgical fixation.

**Keywords** Fixation · Posterior wall acetabular fracture · Comminuted · Fragment specific · Variable-angle locking plate

## Introduction

Posterior wall acetabular fractures are the most common fracture among all types of acetabular fractures, with an incidence rate of 25% up to 47% [1–3]. In the series study by Letournel, the incidence rate of isolated posterior wall fractures was only 24%; however, the majority of such fractures were comminuted or had areas of impaction [4].

Although many determinants could affect the clinical outcome, achieving anatomical reduction is the most important factor of prognosis in surgically treated fractures [4–8]. In addition, maintaining reduction with stable fixations is also a critical factor, especially in highly comminuted fractures [9–11].

The traditional method of treating comminuted posterior wall fractures involves lag screw fixation if fragments were large enough or supplementary spring plating application if fragments were small with peripheral

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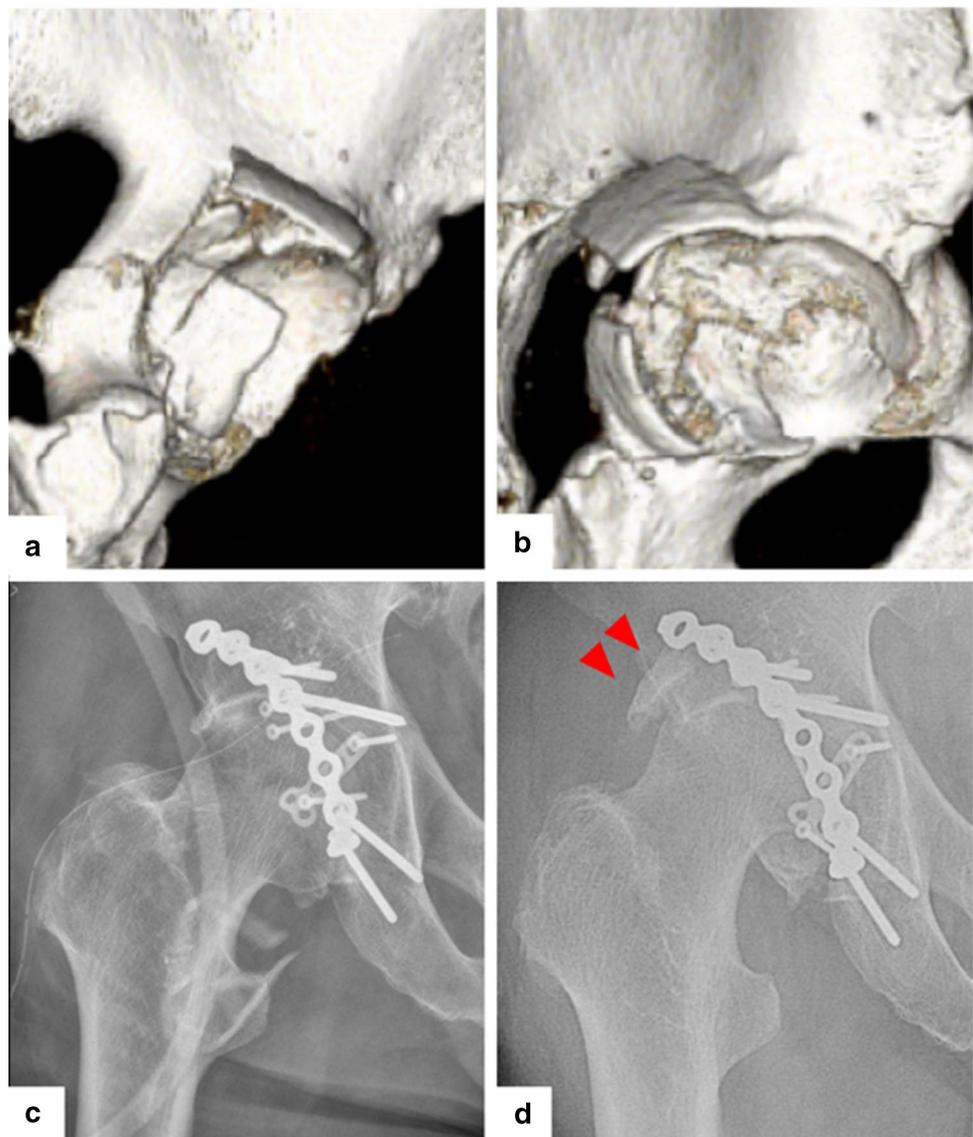
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comminution. After these procedures, 3.5-mm longitudinal reconstruction plates are usually applied for main buttressing function [12–15]. Despite the straight forward strategy of fixation techniques, Saterbak et al. stated that loss of fixation accounts for 32% of cases within the first year of fixation, which could worsen with comminution ( $\geq 3$ ) and involvement of the acetabular roof [10]. Baumgaertner also reported a high failure rate of up to 30% within 1 year after fixation, even when surgically treated by experienced surgeons [1]. These failures resulted from multifactorial reasons; highly comminuted fractures requiring additional fixations were proven to be associated with poorer outcomes [9]. Therefore, it could be assumed that peripheral fixation in severe comminution and buttressing in the roof area using the traditional method can still be challenging [11].

In our clinical case series using the traditional method, we also found that applying longitudinal reconstruction plates is difficult with contouring in the coronal and sagittal areas, especially when the superior roof of the acetabulum should be covered. Consequently, peripherally positioned main plates usually yield difficult trajectories of screw insertion to the gluteal pillar of the ilium and insufficient buttressing (Fig. 1). Moreover, soft tissue dissection for main plating has to be enlarged, which can consequently increase the possibility of heterotopic ossification and iatrogenic sciatic nerve injury.

In an attempt to address these problems, we proposed the novel technique of fragment-specific fixation technique using multiple 2.7-mm variable-angle locking compression plates (VA LCPs) in comminuted posterior wall acetabular fractures and reported its preliminary results.

**Fig. 1** **a, b** A 61-year-old male sustained a right posterior wall acetabular fracture due to a traffic accident. 3D computed tomography (CT) images show comminuted posterior wall fractures which involves the superior acetabular roof. **c** Postoperative radiograph demonstrates comminuted posterior wall fragments are reduced and stabilized with traditional methods. **d** At two weeks follow up, loss of reduction was happened at the fragment which were stabilized with lag screws and longitudinal plate



## Patients and methods

This was an institutional review board approved, retrospective review of case series at two level 1-trauma center. Two orthopaedic trauma surgeons used single surgical technique which was named Fragment Specific Fixation technique from January 2013 to July 2017 for the management of comminuted posterior wall fracture in acetabulum.

A total of 68 patients with posterior wall fracture elements were treated using this technique. Among the 68 patients, 23 with comminuted posterior wall fractures with  $\geq 3$  fragments in the CT scan and no column involvement with a minimum follow-up duration of 12 months were enrolled in this study.

The data of the patient including demographics, medical comorbidity, mode of injury and associated injury were collected. Initial pelvis series X-ray and CT scan were taken preoperatively to evaluate comminution of fracture, involvement of superior acetabular dome and presence of marginal impaction or incarcerated fracture fragment after closed reduction of dislocated hip. Surgical details were recorded in medical chart and a picture archiving and communication system (PACS), with fluoroscopic imaging and intraoperative clinical photos. Operation time was calculated from time markers on fluoroscopic images.

Postoperative radiographs and CT scans were taken to evaluate quality of reduction and presence of screw penetration into the joint [16]. The quality of reduction was measured on postoperative radiographs and CT scan, which were described by Moed et al. [6, 17].

All patients were followed up postoperatively at regular intervals (2 weeks and 1, 2, 3, 6 and 12 months) for a minimum of 12 months. Routine plain radiographs were taken. Any complications including postoperative infection, loss of reduction, fixative failure, heterotopic ossification, avascular necrosis of femoral head, sciatic nerve palsy or early posttraumatic arthritis were documented during follow up.

Fracture union which was defined as the loss of the fracture line and disappearance of joint pain at weight bearing was assessed as a primary outcome [18]. The functional outcome was evaluated by a trained orthopedic surgeon using the modified clinical grading system developed by D' Aubigne and Postel [19] adopted by Letournel and Judet [2] and modified by Matta [15] at final follow-up.

## Surgical technique

### Approach

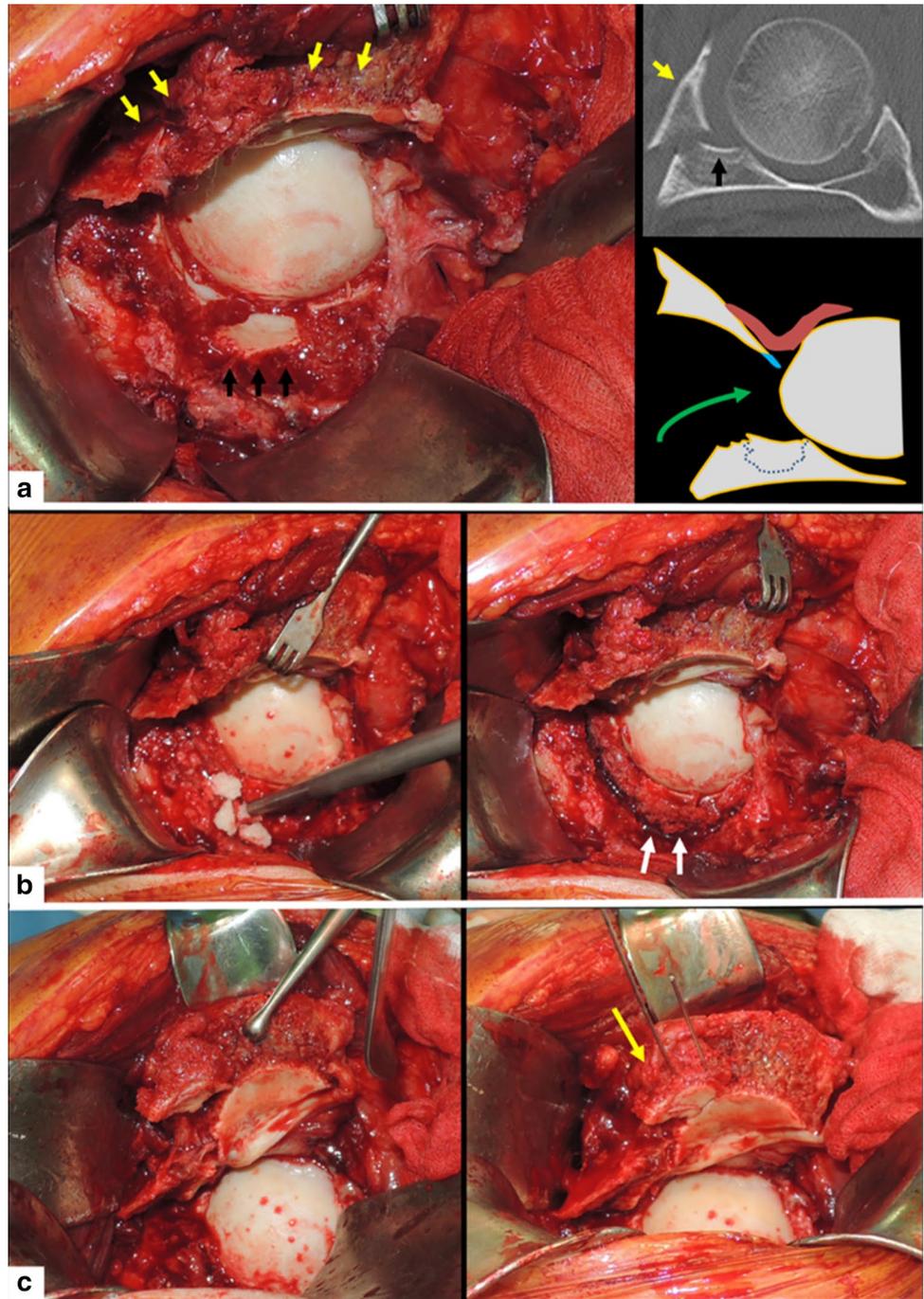
Surgical field was exposed with the conventional Kocher-Langenbeck approach in lateral position. The main

fracture window between the major posterior wall fragments and the intact posterior column was explored, and hematomas were thoroughly cleaned out. Capsuloperiosteal attachment to the major articular fragments was preserved. Gross subluxation or dislocation of the femoral head was reduced via direct manipulation and manual traction on the leg. Any incarcerated free articular fragments within the joint were taken out via the fracture window while the assistants were maintaining the manual traction. The femoral head was then settled back into the intact part of the acetabular socket by releasing manual traction. Subperiosteal dissection was performed along the fracture margins to read the fracture lines during reduction. A majority of the capsuloperiosteal attachment to the posterior wall fragments was preserved. The fracture window was further developed by flipping the posterior wall fragments with the capsule-labral attachment as a hinge. Thereafter, the margins of the acetabular socket were carefully examined to assess marginal impaction, especially when it was identified on the preoperative CT scans (Fig. 2a).

### Reduction and fixation

The marginal impaction fragments along with the underlying cancellous bone were elevated to their anatomical position by shoveling them up using a fine osteotome. Reduction was assessed using the femoral head as a template. Allograft cancellous chip bones were packed into the defect created under the elevated marginal impaction. Thereafter, the articular surface of the posterior wall fragments was evaluated for any step-off between the articular fragments, which were covered and connected by the capsule-periosteal coverage. Any step-off between the articular fragments was reduced under direct visualization and stabilized using either mini-screws or fine K-wires (Fig. 2b, c). The posterior wall fragments were reduced back into their anatomical position using a ball spike pusher. Reduction was primarily assessed by reading the fracture lines between the posterior wall fragment and the intact posterior column. Most of the time, the initial reduction achieved using the ball spike pusher was not sufficient to compress the fracture site. This preliminary reduction was provisionally held by K-wires, which were introduced from near the labral margin of the posterior wall fragment to the posterior column. Fine tuning and further compression were frequently needed to achieve anatomical reduction. A collinear clamp or pointed reduction clamp was used for this purpose. The hook of the collinear clamp was introduced through the greater sciatic notch and anchored against the quadrilateral surface, and the spike with the button was positioned over the posterior wall fragment. Compression and final reduction were

**Fig. 2 a** After surgical exposure with Kocher Langenbeck approach, the fracture window can be developed between capsuloperiosteal attached posterior wall fragments (yellow arrows) and remnant retroacetabular surface. Through this fracture window, any impacted articular surface can be assessed (black arrows). Axial image of CT can reveal the relationship between impacted articular surface (black arrow) and posterior wall fracture fragment (yellow arrow). A schematic image demonstrates the fracture window (green curved arrow). **b** The impacted articular surface was elevated and supported with allograft cancellous chip bones. Anatomical reduction was assessed using the femoral head as a template (white arrows). **c** Step-off between the articular fragments which were covered and connected by the capsule-periosteal coverage was evaluated. Any step-off between the articular fragments was reduced under direct visualization and stabilized with fine K-wires (yellow arrow)



achieved by clamping. The initial provisional K-wires were repositioned as needed during or after final reduction. We attempted to place K-wires on each major articular fragment starting from the lateral margin of the wall fragment to the posterior column (Fig. 3).

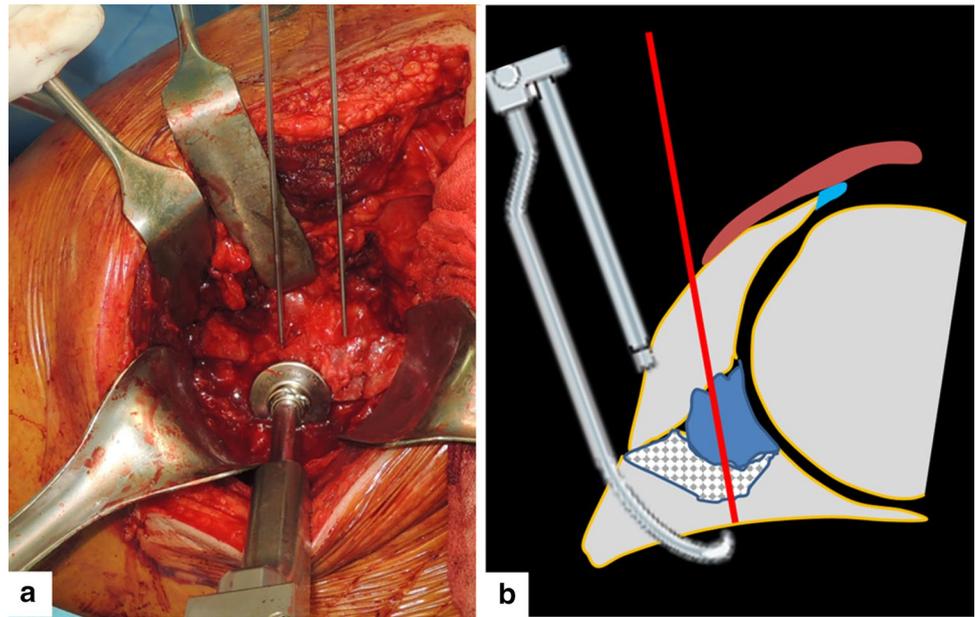
The final quality of reduction was assessed using intraoperative fluoroscopy (AP, oblique, and lateral view of the hip joint). The position of the provisional K-wires was also evaluated carefully to ensure that they did not penetrate articular surfaces as they were mostly replaced with

positioning screws after buttress plating of each posterior wall fragment.

### Choice of implant

The senior author of this study initially attempted to use the fragment-specific buttress plating technique using 2.4-mm LCPs. This choice of implant depended on the size of the wall fragments. As we were encouraged by the favorable results in the first case, we expanded our indications

**Fig. 3** **a** Inverted posterior wall fracture fragments were reduced and fixed with K-wires provisionally. A collinear clamp was used for compression and final reduction. **b** Schematic image demonstrated the location of both arms of collinear clamp



for this technique to all posterior wall fractures. Thereafter, the clover leaf or 2-hole T-shaped 2.7-mm VA LCPs from the VA foot set (DePuy Synthes, USA) surfaced as the primary choice for the following reasons. First, 2.7-mm screws were more feasible to be placed on the right side through the posterior wall fragments than 3.5-mm cortical screws. Second, the core diameter of 2.7-mm locking screws is 2.3 mm, which is 0.1 mm thinner than that of 3.5-mm cortical screws. Third, the stiffness of 2.7-mm locking screws does not decrease as much as the decrease in the outer diameter of the screws compared with that of 3.5-mm cortical screws. The elasticity of the plates was not only feasible for easy contouring but also strong enough for buttressing with proper underbending. The VA locking screw holes provide a versatility to accommodate locking screws in and around the posterior wall fragment.

### Plate contouring

The plate was contoured using 2.4-mm/2.7-mm VA bending pliers to avoid deforming the VA holes. Typically, the plates were contoured using the following methods. Initially, the plates were underbent at the shaft to buttress the wall fragment by cortical screw placement. We noticed that the plate head often tended to lift apart from the wall fragment where we wanted to perform a compression. We started to overbend the plate slightly at the neck to maximize the compression. This overbending at the neck also helped direct the trajectory of the plate head screws further away from the joint. Typically, the appearance of the contoured plate assumed a lazy S shape from the side view (Fig. 4a).

### Plate orientation

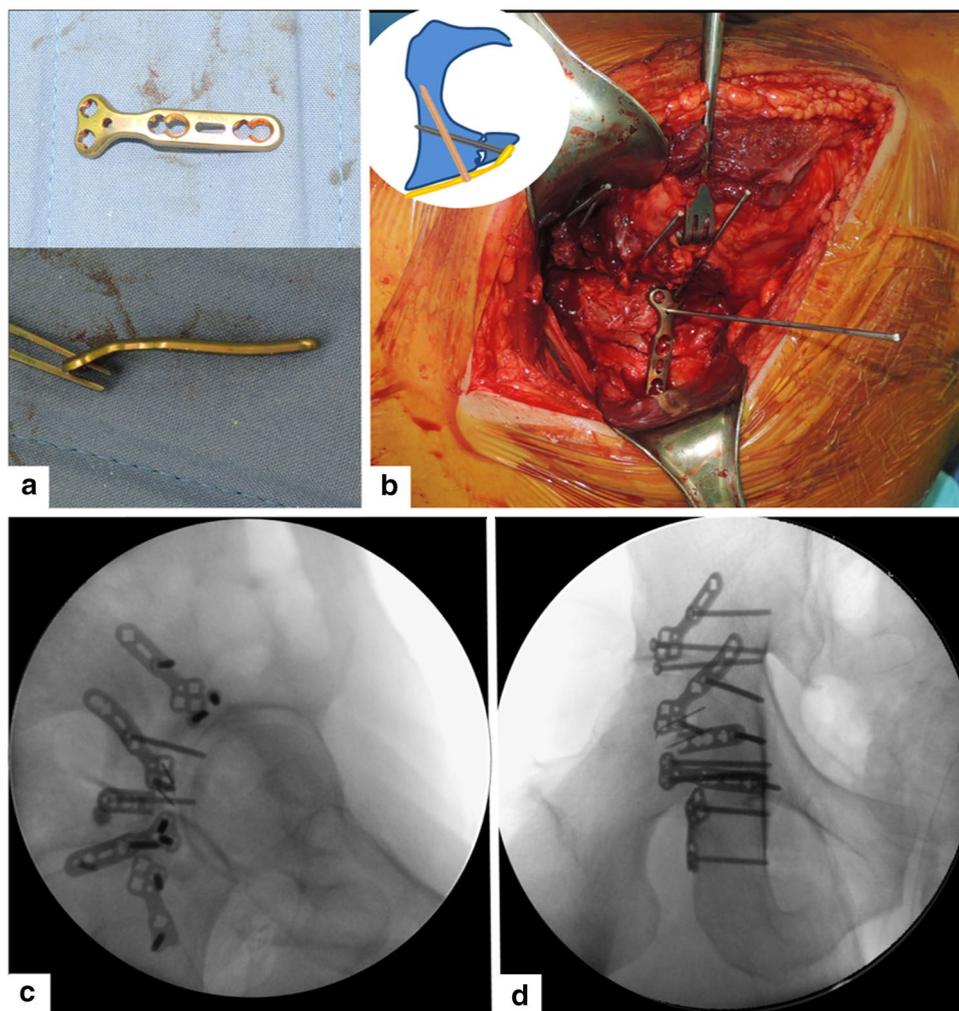
The basic orientation of the plates was roughly radial to the articular margins of the given wall fragments if the intact part of the retroacetabular surface was wide enough to accommodate a minimum of two screws through the shaft part of the plate. If the intact part of the retroacetabular surface was not wide enough to accommodate two screws either owing to the large size of the wall fragment or additional wedge behind the wall fragment, plates were oriented obliquely. Owing to the radial orientation of the plates around the acetabulum, plate positioning and screw placement were easier than the classical plating, even at the weight bearing dome area (Fig. 4b).

Initially, we attempted to position the plate as closely as possible to the articular margin of the wall fragment so that we could place screws into the screw holes right through the posterior wall fragment. As we attempted to use this tactic with 2.7-mm VA LCPs, we found that it was not feasible to place screws without penetrating the joint. A combination of one or two positioning screws near the joint and buttress plating separately and slightly away from the articular margin on each wall fragment became the standard fixation construct (Fig. 4c).

### Sequence of fixation

A cortical screw was placed at the underbent part of the plate. In rare occasions, where purchasing was not good enough to compress the plate, we compressed the plate using Collinear clamps, and locking screws were placed. The provisional K-wires, which were placed near the joint,

**Fig. 4** **a** 2.7 mm Two hole variable angle locking plate was overbent like a lazy S shape for the compression of fracture fragment. **b** The plate was positioned radial to the articular margin of the wall fragments according to intact part of the retroacetabular surface. A cortical screw was inserted initially at the nearest hole in the shaft of plate to compress the fracture site, then followed locking screws to fragments (white round image). **c, d** Additional plating and lag screw fixation was completed according to the fracture fragment. The accurate reduction and stable fixation were achieved by fragment specific fixation technique



were mostly replaced by positioning screws upon completion of plating.

The final quality of reduction and the fixation construct were carefully assessed once again using fluoroscopy (Fig. 4d). All screw positions in the posterior wall fragment were confirmed under fluoroscopic guidance. The short external rotator muscles were sutured back. The gluteus maximus muscle was repaired using interrupted sutures. Subcutaneous and skin closure was performed over the suction drain.

### Postoperative management and follow-up

Most of the patients were encouraged to begin muscle-strengthening exercises and continuous passive hip ranges of motion 2–3 days after surgery. The patients were instructed to begin partial weight bearing, with 30% of their full weight at 6-weeks post-surgery, increasing to 50%, and full weight by 12 weeks, according to patient tolerance [20].

### Result (Table 1)

Among the 68 patients which have posterior wall fracture element in acetabulum, 23 with comminuted posterior wall fractures with  $\geq 3$  fragments in the CT scan and no column involvement with a minimum follow-up duration of 12 months were enrolled in final cohort.

All patients (Nineteen men and four women) sustained high-energy injuries (motorbike TA in four patients, car TA in sixteen patients, and falls in three patients). The mean patient age was 48 years (range 23–69 years). Twelve patients had associated injuries in their major extremities. The mean BMI was  $25.0 \text{ kg/m}^2$  (range  $19.8\text{--}33.4 \text{ kg/m}^2$ ). The average duration of follow-up was 26.8 months (range 12–45 months) (Table 1).

The number of fracture fragments was 3.4 (range 3–5). Marginal impaction was combined in ten patients. The free posterior wall fragment was incarcerated in the hip joint in seven patients. Superior dome involvement was identified in eight patients.

**Table 1** Demographics, fracture characteristics, surgical details, follow up outcomes

<b>Demographics</b>	
Age, years, average (range)	48 (23–69)
Sex (M:F)	19:4
Laterality (Rt.:Lt.)	9:14
BMI, average (range)	25.0 (19.8–33.4)
Injury mechanism	
In car TA	16
Motorbike TA	4
Fall	3
Hip Dislocation, <i>n</i> (%)	16 (69.5%)
Associated injury	
Isolated PW fracture (none, minor fracture)	11
Multiple fracture	12
Polytrauma with unstable vital sign	3
Ligament injury of knee joint	2
<b>PW fracture characteristic</b>	
Number of fracture fragment, average, (range)	3.4 (3–5)
Marginal impaction, <i>n</i> (%)	10 (43%)
Incarcerated fragment	7 (30%)
Superior acetabular dome involvement	8 (35%)
<b>Surgical details</b>	
Approaches	
Trochanteric osteotomy, <i>n</i>	4
	2 cases—femoral head fracture
	2 cases—superior dome involvement
Number of plates, average, (range)	3.5 (2–5)
Position of plates	
Transverse (radial)	15
Oblique	2
Combined	6
Operation time, min, average (range)	200 (141–280)
Quality of reduction	
Anatomical (0–1 mm displacement)	18
Imperfect (2–3 mm displacement)	5
Poor (>3 mm displacement)	0
<b>Follow up outcomes</b>	
Follow up duration, month, average (range)	26.8 (12–45)
Bony union (%) and union time (weeks)	22 (96%), 12 weeks
Complications	
Acute postoperative infection	1: THRA conversion after infection control
AVN, heterotopic ossification loss of reduction, sciatic nerve palsy	0
Functional outcome	
Excellent, <i>n</i> (%)	6 (27%)
Very good, <i>n</i> (%)	14 (64%)
Good, <i>n</i> (%)	2 (9%)
Fair, <i>n</i> (%)	0 (0%)
Poor, <i>n</i> (%)	0 (0%)

All patients underwent the procedures using the K-L approach in the lateral position. Trochanteric flip osteotomy was performed in two of the eight patients who had

superior dome involvement. The average number of 2.7-mm plates used was 3.5 (range 2–5). The plate was positioned transversely (radially) in fifteen patients, obliquely in two

patients, and both transversely and obliquely in six patients. The mean operation time was 200 min (range 141–280 min).

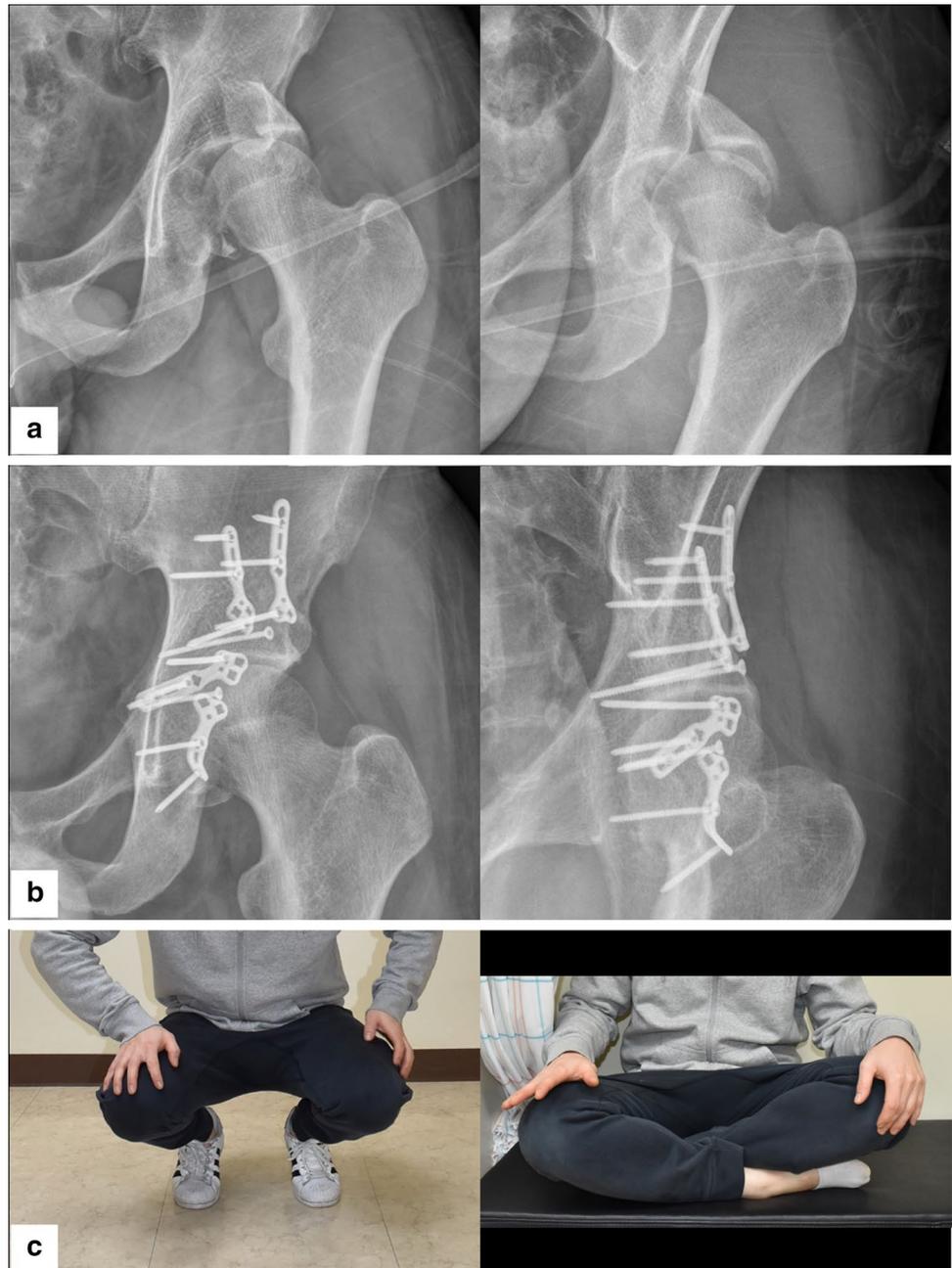
The quality of reduction was measured on postoperative radiographs and CT scan, which were described by Moed et al. [6]. Anatomical reduction was achieved in eighteen patients. Imperfect reduction was achieved in five patients.

Among the 23 patients, 22 achieved fracture union without any revision surgery. The average time to union was 12 weeks (range 10–15 weeks). One patient who had diabetes mellitus received a revision surgery for THRA due to acute postoperative infection. There were

no complications, including loss of reduction, fixative failures, sciatic nerve palsy, heterotopic ossification, and early posttraumatic arthritis during follow-up, in the other patients.

The functional outcome was evaluated by a trained orthopedic surgeon using the modified clinical grading system developed by D' Aubigne and Postel [19], adopted by Letournel and Judet [2] and modified by Matta [21]. The average functional score was 17 (range 15–18). Functional outcomes in 6 patients were graded as 'excellent'; those in 14 patients were graded as 'very good'; those in the other two patients were graded as 'good' (Fig. 5).

**Fig. 5** **a** 34 year old male patient sustained comminuted posterior wall acetabular fracture after 4 m fall. **b** A year after fragment specific fixation, there is no complications. **c** Range of motion was fully recovered and function score was graded as excellent



## Discussion

The traditional fixation method for comminuted posterior wall fractures involves lag screw fixation or spring plate application with main buttressing plating using 3.5-mm longitudinal reconstruction plates [12–15]. Although many variables reported as risk factors for poor outcomes, including delay of reduction of hip dislocation, age, intraarticular comminution, and avascular necrosis, can affect the clinical results [22, 23] anatomical reduction and stable internal fixation, which can be controlled by surgeons, can guarantee favorable clinical outcomes [9, 24, 25]. However, the outcomes of the traditional fixation method have not always been satisfactory [10, 21, 26].

Currently, several alternatives for comminuted posterior acetabular wall fractures have been introduced in surgical fixation using locking compression pilon plates, T plates, and cervical vertebral plates, which yielded favorable results [27–29]. Although these techniques improved the contact surface with comminuted fragments and plates compared with the original one-third tubular plate, these still have problems with contouring of the longitudinal plate and limited peripheral screw fixation as in spring plates. A standard overlying longitudinal 3.5-mm reconstruction plate can reinforce the buttressing effect on spring plates applied or lag screw-fixed posterior wall fracture fragment [15, 30]. However, this longitudinal plating needs extended soft tissue dissection for plate positioning and technical demands on contouring of the plate along the complex-shaped retroacetabular surface [31, 32]. Furthermore, when the fracture extends to the superior dome of the acetabulum, it is highly impossible to buttress the fragment effectively by a longitudinal plate itself without any supplementary fixation because the plate goes along the pillar of the posterior column [11]. Even with bending procedures for directing longitudinal plates peripherally as seen in our previous case, it is questionable whether proper buttressing was achieved. To overcome this problem, a three-dimensional printer-assisted plate precontouring technique was introduced to aid in plate positioning and fixation [32–34]. However, this novel technique is not always available in every surgical field.

These technical difficulties could be associated with weak fixation construct and postoperative complications, including heterotopic ossification, deep wound infection, and sciatic nerve palsy. Although our fragment-specific fixation technique had been used to overcome the technical difficulty of applying longitudinal plating, our plating construct could not only make an efficient buttressing effect without supplementary longitudinal plating, but also improve the complications that occur in longitudinal plating. Owing to the radial orientation of these small

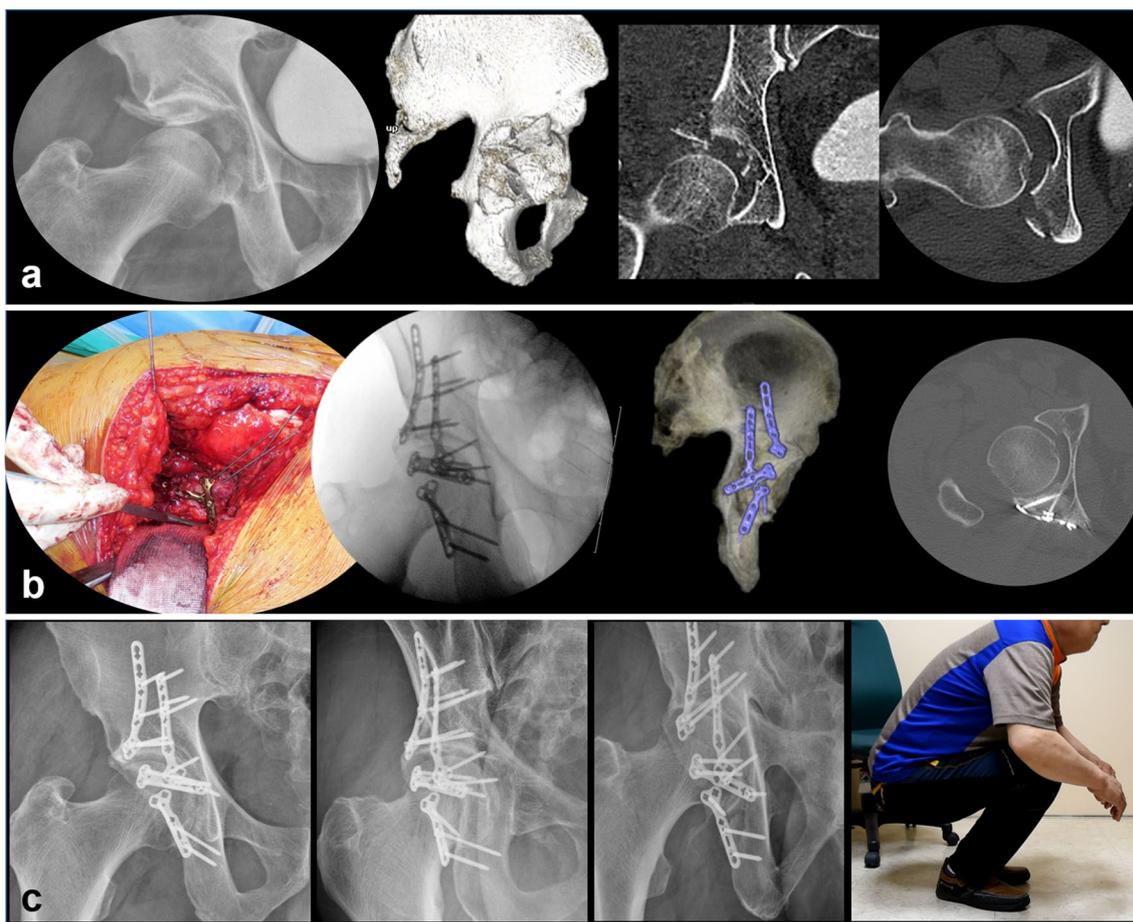
plates around the joint, the plates even in dome fractures could be positioned radially to the hip joint for resisting the dislocation force of the femoral head [21]. In addition, angular stable fixation for each fragment could be achieved with locking screw fixation through the VA locking plate holes that allow for a more stable fixation of comminuted fracture fragments than spring plates. It seems that it can reduce the risk of secondary reduction loss without longitudinal reconstruction plating during follow-up. Its orientation of plate position and low profile feature can yield less surgical exposures than those of traditional longitudinal plating. It could reduce soft tissue dissection to provide a space for plate positioning and consequently reduce other problems. Such findings could be supported by those of our case series. Among the eight patients with superior dome involvement, we achieved reduction and fixation without trochanteric osteotomy in two patients. There were no heterotopic ossification and sciatic nerve palsy in all patients (Fig. 6).

Nevertheless, our fixation strategy still needs technical or implant-related improvements for screw fixation. Screw fixation in peripheral fractures has a risk of screw penetration into the joint space. Screw confirmation must be followed up after each screw fixation [35], making surgeons more radiologically exposed. In addition, additional lag screw fixations out of plates have to be considered when two-screw fixations may not be achieved using the plate. VA screw fixation should not exceed a 30° difference to prevent joint penetration of screws, and additional lag screw fixations must be considered when plates are positioned extremely peripherally.

The limitation of this study includes its lack of biomechanical analysis. In comminuted fractures, longitudinal reconstruction plates with accessory spring plates have a higher load to failure than reconstruction plates alone, which was proven in a fresh human cadaveric biomechanical study [30]. However, any biomechanical study with fragment specific fixation has not been performed yet. Nevertheless, our clinical series could prove that our fixation method is clinically sufficient to achieve bone union without any fixation loss.

## Conclusion

The fragment-specific fixation technique using 2.7-mm VA LCPs can be a possible alternative to the classical 3.5-mm lag fixation or spring plate fixation augmented with 3.5-mm reconstruction plate fixation, especially for superior dome involvements or multifragmentary posterior wall fractures.



**Fig. 6** **a** Plain radiograph and CT scan of the 56-year old male patient demonstrated that comminuted posterior wall fracture of the right hip. The fracture was involved in a superior dome area (coronal image) and associated with marginal impaction (axial image). **b** Fragment specific fixation was performed without trochanteric osteotomy. A

postoperative CT scan confirmed that reduced fracture fragments were buttressed with four 2.7 mm VA LCPs and captured with VA screws. **c** A year after-radiographs show no signs of reduction loss, fixative failure, heterotopic ossification, and early-stage osteoarthritis. The function of the hip joint was recovered well

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institution or practice at which the studies were conducted.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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