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Original Article

Minimally Invasive Surgery for Unstable Pelvic Ring Fractures: Transiliac Rod and Screw Fixation

Kazukiyo Toda[a]*, Yukihisa Yagata[b], Takeshi Kikuchi[a], Tomoyuki Takigawa[a,c], and Yasuo Ito[a]

[a]*Department of Orthopaedic Surgery, Kobe Red Cross Hospital, Kobe City, Hyogo 651-0073, Japan,*
[b]*Department of Orthopaedic Surgery, Hyogo Emergency Medical Center, Kobe 651-0073, Japan,*
[c]*Department of Orthopaedic Surgery, Okayama University Hospital, Okayama 700-8558, Japan*

Pelvic fractures occur with high-energy trauma, and the patient's clinical status is unstable. Although a number of surgical methods for unstable pelvic fractures are available, none can achieve strong fixation with minimal invasiveness. We describe a surgical transiliac rod and screw fixation (TIF) procedure that provides minimally invasive fixation using a spinal implant for unstable pelvic ring fractures, and we retrospectively analyzed the procedure's outcomes in 27 patients with type B or C1 fractures (based on the AO/ATO classification system). Small skin incisions are made above the posterior superior iliac spines on both sides. The ilium is partially resected, and two iliac screws are inserted on each side. The spinous process of the sacral spine is then shaved, and the iliac screws are connected to 2 rods, one placed caudal to the other. Corrective manipulation is performed at the fracture site, and the rods are connected with connectors. Favorable fracture reduction, defined as a rating of 'excellent' or 'good,' was achieved in 77.8% of the patients. Transiliac rod and screw fixation (TIF) will be a useful therapeutic option for unstable pelvic ring fractures.

Key words: pelvic ring fractures, sacral fracture, transiliac rod and screw fixation, spinal fixation system, minimally invasive surgery

Pelvic ring fractures are often associated with high-energy trauma and complicated by injuries in multiple organs. An unstable pelvic ring fracture might lead to continuous hemorrhage and worsening clinical status. It is thus desirable to stabilize unstable pelvic ring fractures as soon as possible in a minimally invasive manner. A number of posterior fixation methods have been reported for pelvic ring fractures, including external fixation, iliosacral (IS) screw fixation, plate fixation, and spinopelvic fixation. External fixation is less invasive and relatively simple to perform, but it results in insufficient fixation and is therefore essentially a temporary emergency treatment. IS screw fixation is minimally invasive, but reduction cannot be performed and the fixation is not secure, which limits the use of this method. Transiliac plate fixation, which connects the left and right ilia with plates, is invasive to soft tissues posterior to the pelvis, and reduction at the fracture site is limited. The most secure fixation for pelvic ring injuries accompanied by a sacral fracture is spinopelvic fixation. However, this procedure is highly invasive, involves a large operative area, and compromises movement of the intact lower lumbar vertebrae.

We developed a minimally invasive transiliac rod and screw fixation (TIF) procedure that involves using a spinal implant for the treatment of unstable pelvic ring fractures that are type B and C1 based on the classifica-

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*Corresponding author. Phone: +81-78-231-6006; Fax: +81-78-241-7053
E-mail: kz-toda@kobe.jrc.or.jp (K. Toda)

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tion by the *Arbeitsgemeinschaft für Osteosynthesefragen*/American Orthopaedic Trauma Association (AO/OTA) [1,2]. Herein we describe the operative procedure and associated outcomes of the TIF procedure.

Materials and Methods

Patients. We retrospectively analyzed the cases of the patients treated with the TIF procedure at our hospital during the years from 2005 to 2016. The background characteristics of the patients are summarized in Table 1. The cases of 27 patients with a mean age of 42.2 years (range 16-76 years) were included. All patients sustained high-energy trauma caused by a fall or traffic accident. The mean injury severity score [3] was 25.7 (range, 4-75). According to the AO/OTA classification system, pelvic ring fractures were classified as B1 in 5 patients, B2 in 19 patients, B3 in 2 patients, and C1 in one patient. The accompanying sacral fractures were classified based on the Denis classification system [4] as type I in 11 patients and type II in the other 16 patients. Bilateral pubic fractures were observed in 10 patients, ipsilateral pubic fractures in 12 patients, and contralateral pubic fractures in 3 patients.

Table 1 Patient demographic data

Age (years)*	42.2 (16–76)
Gender (male/female)	17/10
Mechanism of injury	
Fall from height	12
Traffic injury	10
Crush	5
Injury severity score*	25.7 (4–75)
Pelvic fracture type (AO/OTA)	
B1	5
B2	19
B3	2
C1	1
Sacral fracture type (Denis)	
I	11
II	16
III	0
Pubic fracture	
Ipsilateral	12
Bilateral	10
Contralateral	3
Symphysis	1
None	1
Time from injury to surgery (days)*	6.4 (1–15)
Follow-up (months)*	14.6 (1–56)

*Data are presented as means (ranges).
AO/OTA, *Arbeitsgemeinschaft für Osteosynthesefragen*/American Orthopaedic Trauma Association.

The fracture and its reduction are evaluated by a CT examination performed before and after the operation, according to the modified classification system of Tornetta and Matta [5,6]. The maximal displacement of the fracture site is measured, and its reduction is graded on the 3 standard views of the pelvis. The displacement criteria were: excellent, ≤4 mm; good, 5-10 mm; fair, 10-20 mm; and poor, >20 mm. The screw and rod locations were also confirmed by CT examination.

For the treatment of continuous pelvic bleeding, transcatheter arterial embolization (TAE) was performed in 10 patients, and laparotomy was performed for hemostasis in one patient. On average, these 27 patients underwent the TIF procedure at 6.4 days (range 1-15 days) after the injury. The mean follow-up duration was 14.6 months (range 1-67 months). This retrospective study was conducted with the prior approval of the institutional review board of our hospital, and the requirement for patient informed consent was waived.

Technical note. The TIF procedure was performed as follows, with the patient under general anesthesia in the prone position on a radiolucent table. When the fracture is the lateral-compression type, fracture reduction is applied by positioning and pushing the sacrum. Approximately 6-cm-long incisions are made slightly medial to the posterior superior iliac spine on both sides (Fig. 1A). The soft tissue is dissected, and a 2-cm-deep, 3-cm-long portion of the iliac crest is resected bilaterally (Fig. 1B,C). This osteotomy is important for preventing skin problems such as pain and bedsores caused by the protrusion of the screws against the skin.

With the use of a pedicle probe, holes are made in the bone to insert screws at the site of resection in the posterior iliac crest, bilaterally (Fig. 1D). After confirming that cortical bone is not ruptured by using a sounder, screws are inserted (Fig. 1E). This procedure is repeated to insert 2 screws on each side (Fig. 1F). Caudal screws are inserted towards the anterior inferior iliac spine in a lateroinferior direction. Cranial screws are inserted slightly tilted cranially and laterally, away from the horizontal direction. Screws with dimensions that do not allow for penetration of cortical bone are selected: the most commonly used sizes are 6.5-9.5 mm in diameter and 40-90 mm in length. A preoperative

computed tomography (CT) scan is useful for deciding the screw size and the direction of screw insertion.

Next, the base of the sacral spinous process is resected with a chisel to make space for the rods (Fig. 2A, B). The distance between the screws on the left and right sides is measured, and rods are cut into an appropriate length based on the distance. Since the sacrum bulges dorsally and the iliac screws on both sides are inserted laterally, bending the rods into a W-shape makes it easier to place them under the muscle layer (Fig. 2C). By connecting 2 rods to the upper and lower pairs of screws on both sides, the left and right ilia are connected (Fig. 3A). At this point, the displacement of the pelvic fracture can be corrected using a compression device (Fig. 3B). After the set of screws are tightened, transverse connectors are placed between the upper and lower rods: one each on the left and right sides (Fig. 3C, D).

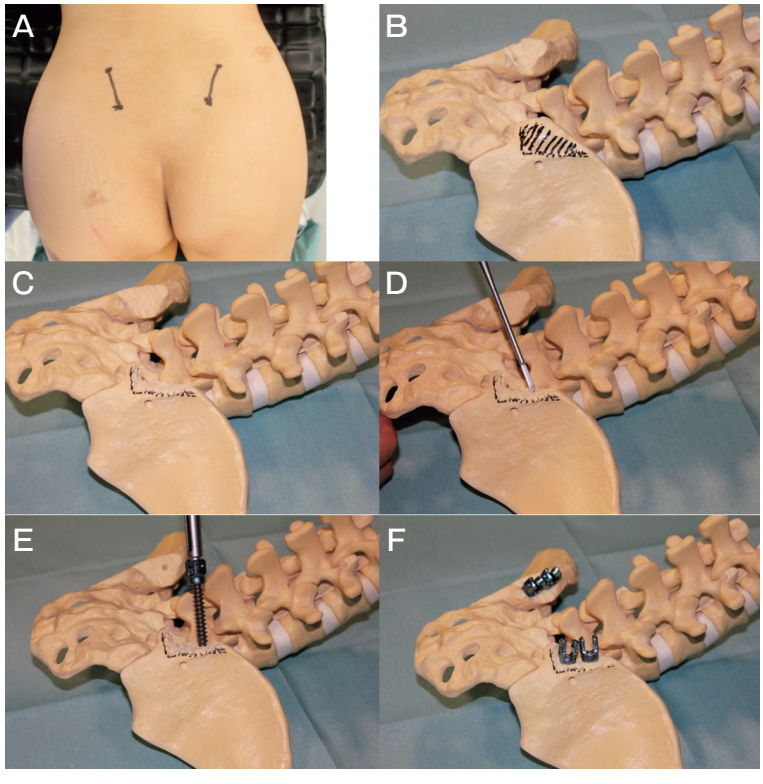

Fig. 1 **A**, Location of the skin incisions; **B**, Area of resection in the posterior superior iliac spine. The area should be wide enough to fit 2 screw-heads easily; **C**, View after the resection of the posterior superior iliac spine. Trabecular bone where the screws are to be inserted should be exposed sufficiently; **D**, Preparation of holes in the bone using a pedicle probe. Normally, excessive force is not needed as the pedicle probe goes into the trabecular bone; **E**, Insertion of the screws. The direction and depth of the holes are confirmed in advance, using a sounder; **F**, View after the insertion of 2 iliac screws on each side.

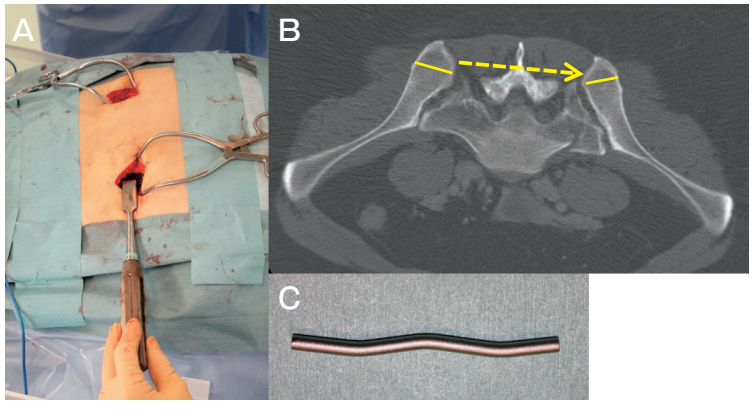

Fig. 2 **A**, The spinous process of the spine is shaved off using a chisel; **B**, Shaving off the spinous process simplifies the placement of the rods connecting the screws; **C**, Rods are bent into a W-shape before placement.

When the bone union is confirmed by CT radiograph and examination at >6 months after the surgery, implant-removal surgery is suggested to the patient.

Results

The results of the 27 patients' surgeries with the TIF procedure are summarized in Table 2. The mean blood loss was 223 mL (range 100-500 mL), and the mean operative time was 129 min (range 60-163 min).

The mean preoperative displacement of the fracture in the pelvis was 10.7 mm (range 1-32 mm). The mean postoperative displacement was reduced to 6.9 mm (range 1-18 mm). According to the modified classification system of Tornetta and Matta [5,6], fracture reduction was 'excellent' in 8 patients, 'good' in 13 patients, 'fair' in 6 patients, and 'poor' in no patients. There was no malposition, including screw perforation into the pelvis or an intervertebral foramen.

Table 2 Surgical results

Blood loss (mL)*	223 (100–500)
Operative time (min)*	129 (60–163)
Fracture reduction[1]	
Excellent	8
Good	13
Fair	6
Poor	0
Complication	
Infection	0
Neurological deficit	0
Deep vein thrombosis	0

*Data are presented as means (ranges).
[1]Modified from the classification system of Tornetta and Matta (Tornetta P and Matta JM, Outcome of operatively treated unstable posterior pelvic ring disruptions. Clin Orthop Relat Res 329, 186–193, 1996).

Perioperative complications such as wound infection, nerve injury, and deep vein thrombosis were not observed. Complete bone union was achieved in all 15 patients who were followed for ≥6 months. The screws and rods were removed in 11 of these 15 patients. Detailed bone union was not evaluated in other 12 patients, as they were transferred and followed at different hospitals. No unexpected surgeries were applied in all 27 cases.

Case presentation. A 36-year-old woman sustained fractures in a traffic accident, including a B2 pelvic fracture based on the AO/OTA classification system and a type II right sacral fracture based on the Denis classification system. Right ischium and pubis fractures were also observed (Fig. 4A-E). Her other injuries included multiple rib fractures and hemopneumothorax. No neurological abnormalities were noted. TIF was performed at 7 days after the patient's injury. *In situ* fixation was performed without corrective manipulation (Fig. 4F, J).

Before the surgery, the patient experienced severe pain in her right hip and right leg with movement, which resolved immediately after the TIF procedure. No perioperative complications were noted. Complete

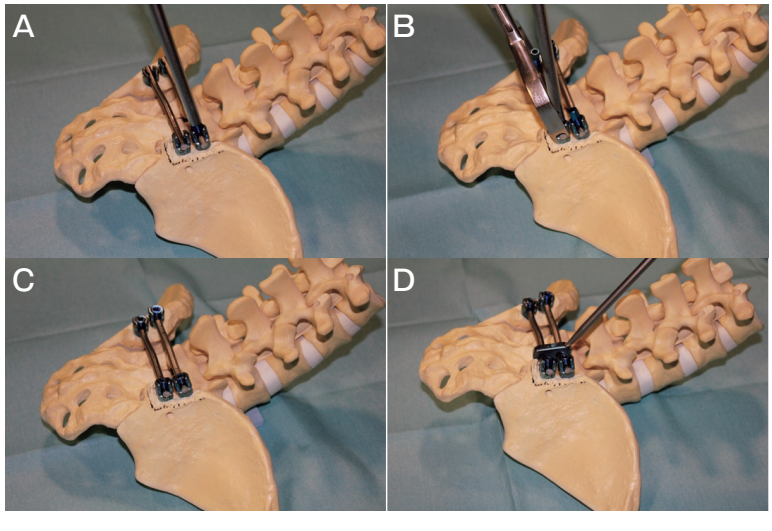

Fig. 3 **A**, Two rods, upper and lower, are connected to the iliac screws on each side; **B**, The space between the left and right ilia can be narrowed by using a compressor; **C**, Once in position, the screws are tightened; **D**, One transverse connector is placed on each side.

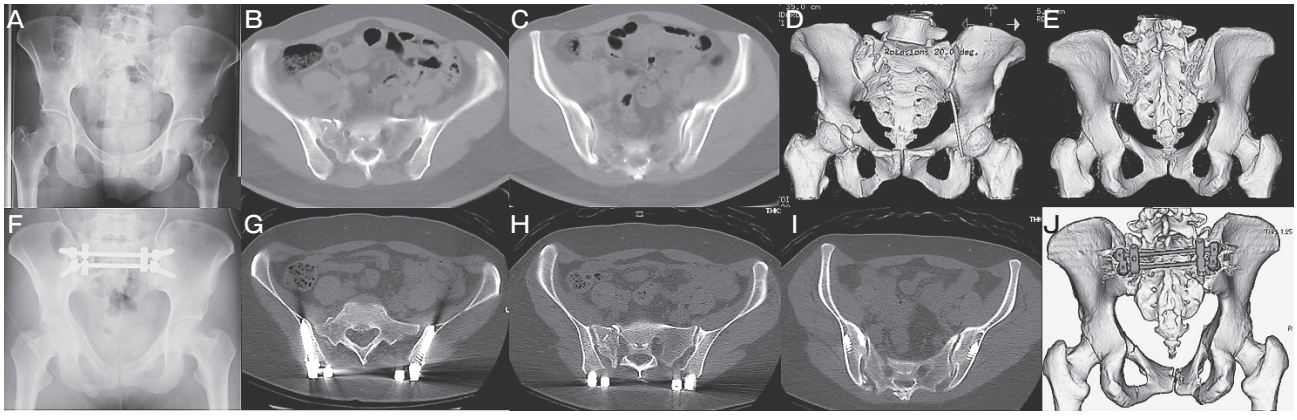

Fig. 4 This patient was a 36-year-old woman who sustained fractures in a traffic accident. The preoperative radiograph (**A**), axial CT images (**B**, **C**), and three-dimensional CT images (**D**, **E**) show the right sacral, ischium, and pubis fractures. She was diagnosed with a type B2 pelvic fracture according to the AO/OTA classification system. TIF was performed in a minimally invasive manner 7 days after the injury. The postoperative radiograph (**F**), postoperative axial CT images (**G**–**I**), and a postoperative three-dimensional CT image (**J**) demonstrate the secure fixation of the left and right ilia across the fracture site.

bone union was achieved 6 months after surgery. At the last follow-up 15 months after surgery, there were no complaints related to the hip, and the patient returned to pre-injury activity levels.

Discussion

The TIF procedure would be indicated for AO/OTA type B1, B2, B3, and C1 pelvic fractures. It would not be indicated for type C2 and C3 fractures with complete disruption of the pelvic ring or type C1 fractures with severe vertical displacement. For these fracture types, spinopelvic fixation, which can provide secure fixation, would be desirable [7]. IS screw fixation is minimally invasive, but it is associated with serious potential complications including the misplacement of screws and nerve root injury [8]. For patients without severe displacement of the fracture, posterior plate fixation can be used [9].

Internal fixation with plates is minimally invasive and useful, although making adjustments between the plate and ilium is difficult in some cases. In addition, due to the properties of the plate, reduction at the fracture site is extremely limited. In the TIF procedure, the use of a spinal implant allows the surgeon to have more control at every stage of the procedure, including the placement of iliac screws that serve as anchors, the selection and connection of rods, corrective manipulation, and the placement of transverse connectors. Lateral compressive force to reduce the displacement can be easily applied by using a compression device along with checking the displacement. As a result, fixation can be achieved relatively easily with minimum invasiveness and small incisions above the left and right ilia. Spinal instrumentation has been reported to provide more secure fixation than posterior plates [10].

In this series of 27 patients treated with TIF, favorable postoperative fracture reduction rated as excellent or good was achieved in 77.8% of the patients. Although corrective manipulation is easier with TIF than with plate fixation, TIF has weaker corrective capability than spinopelvic fixation or open manipulation. Thus, TIF is not indicated for patients with severe displacement requiring massive correction. Many of our patients had accompanying injuries and, therefore, an unstable clinical status; however, the fracture sites were stabilized with a relatively low level of invasiveness as indicated by the mean blood loss of 223 mL and the mean operative time of 129 min. Moreover, no infection or other local wound problems occurred in any patients, including the 10 patients who underwent TAE before TIF and one patient who underwent a laparotomy for hemostasis. We thus believe that secure fixation in a less invasive manner is desirable not only for the treatment of fractures, but also as a means to stabilize the patient's clinical condition.

The Luque-Galvestone technique has been developed as a strong anchoring method for the ilium [11] and has been applied for scoliosis and deformity followed by trauma [12]. Although iliac screws are now

widely used as distal anchors for spino-pelvic fixation, to the best of our knowledge, a minimally invasive application of bilateral iliac screws for pelvic fracture has not been reported. No differences in torque during the insertion of iliac screws toward the anterior inferior iliac spine and the supraacetabular area of the ilium were observed [13]. There is a wide range of acceptable trajectories when inserting screws. Clinically, the greater trochanter serves as a landmark to determine the direction of the insertion.

Excellent clinical outcomes have been reported for minimally invasive surgeries using iliac screws and rods, which are used in TIF. Wang *et al.* used one screw on each side and one rod between them for their procedure. We believe that fixation using 2 iliac screws on each side provides more secure fixation of the ilium [14]. There are 2 methods for using 2 iliac screws. In one method, one screw is inserted in the cranial direction and the other is inserted in the caudal direction. In the other method, both screws are inserted in the caudal direction. The latter method provides more longitudinal compressive stiffness, but no significant difference has been shown between the 2 methods in terms of torsion stiffness [15]. In our TIF method, we try to insert the cranial screws in the cranial direction as much as possible in order to anchor the ilium widely and increase the stability of the construct.

In TIF, the contralateral ilium is used as an anchor, which requires fixation of the intact contralateral sacroiliac joint. Consequently, we think that it is better to remove the implant when bone union of the fracture site is achieved in young patients, because implant removal might lower the probability of future problems at the screw insertion site and the contralateral sacroiliac joint.

The present study was a short-term retrospective clinical investigation involving a small number of cases at a single institution. Future detailed evaluations of long-term clinical outcomes of the TIF procedure are needed.

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