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TRAUMA SURGERY

Percutaneous cerclage wiring followed by intramedullary nailing for subtrochanteric femoral fractures: a technical note with clinical results

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Abstract
Background Although intramedullary nailing is an ideal treatment for subtrochanteric femoral fractures, it is technically challenging in fractures extending into the nail entry area and/or involving the lesser trochanter. Although the application of circumferential wire may facilitate reduction in these situations, its use remains controversial due to possible blood supply disturbances to underlying bone. In the present study, we evaluated complex subtrochanteric fractures treated by percutaneous cerclage wiring followed by intramedullary (IM) nailing for anatomical fracture reduction and union.
Methods Twelve patients (mean age 48.3 years) with an unstable subtrochanteric fracture were prospectively treated. Indications of percutaneous cerclage wiring followed by IM nailing were a fracture extending proximally into the nail entry area deemed difficult to treat by anatomical reconstruction by IM nailing or a fracture with long oblique or spiral component. One or two cerclage wires were percutaneously applied for the temporary reduction of main fragments, and then, a cephalo-medullary or a reconstruction nail was fixed. We assessed radiologic results (union time, alignment), functional results, and complications.
Results All 12 cases healed, without a bone graft, at an average of 19.1 weeks after surgery (range 16–24). In 11 cases, acceptable alignment was achieved (mean, valgus 0.3° extension 0.6°) with minimal leg-length discrepancy; the other exhibited 1 cm of shortening. All patients were able to return to pre-injury activity levels, and median Merle d'Aubigne score was 16.9 (15–18). No infection or implant-related complication was encountered to latest follow-up (minimum 12 months postoperatively).
Conclusion Temporary reduction by percutaneous wiring offers a means of satisfactory nailing in difficult subtrochanteric femoral fractures, and affords anatomical reconstruction and favorable bony union.

Keywords Subtrochanteric femoral fractures · Percutaneous wiring · Intramedullary nailing

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Introduction

Subtrochanteric fractures have been treated by open reduction and osteosynthesis using fixed-angle blade plates and condylar screw/plate systems to achieve anatomic reduction and rigid fixation. However, this technique can result in a large amount of periosteal stripping and devascularization of fragments, which are often followed by nonunion and implant failure. To overcome these complications, intramedullary (IM) nailing was advocated for the fixation of subtrochanteric fractures. This technique offers the advantages of reduced implant to hip joint distance, reduced bending moment, and a percutaneous, soft tissue sparing insertion technique. However, due to a short proximal fragment with a fixed flexion, abduction and external rotation deformity, IM nailing commonly results in varus malalignment and iatrogenic displacement of fractures

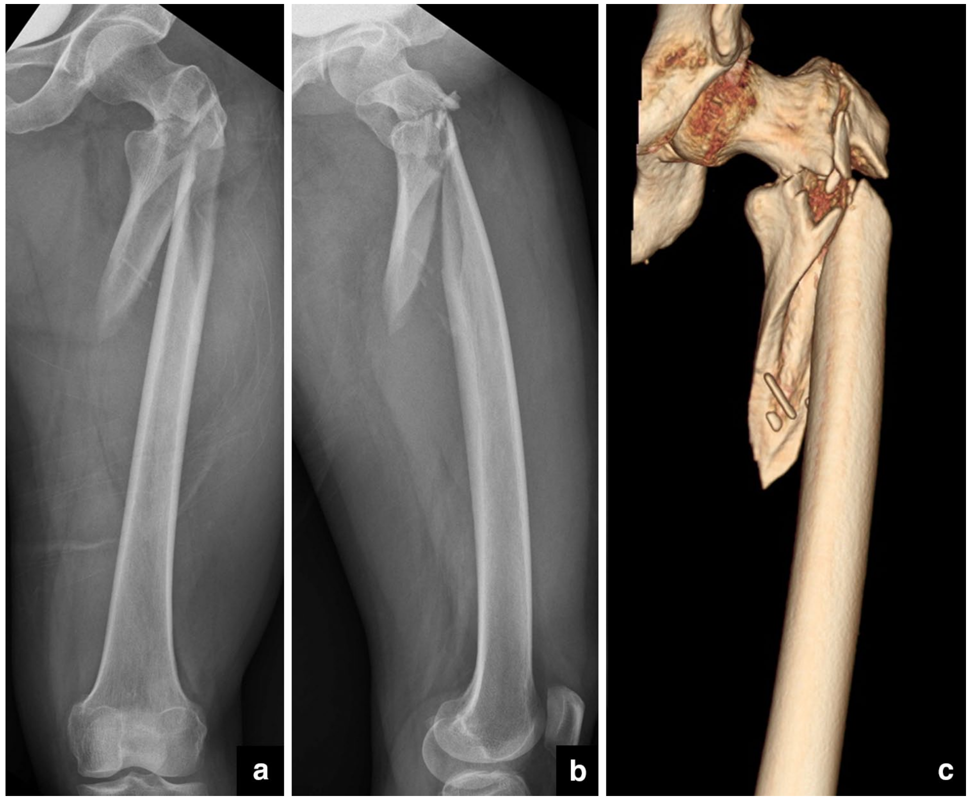

Fig. 1 A 44-year-old woman sustained a comminuted subtrochanteric femoral fracture (**a**, **b**). The CT scan showed a fracture line extending into the greater trochanter and loss of continuity of the lesser trochanter (Russell-Taylor type IIB) (**c**)

involving the nail entry. In particular, when associated with fracture extension into the entry site, a nail may be displaced posteriorly through the fracture site [1].

Clamps through a small lateral incision may reduce fractures anatomically while nailing, but re-displacement often occurs after clamp release [2]. Circumferential wires have been used for a long time for reduction as well as maintenance [3, 4], but open wiring and the extensive surgical dissection required may devitalize bone fragments, which may be followed by non-union and/or implant failure. To avoid these difficulties, we used a percutaneous cerclage passer system to reduce and maintain the main fragments of complex subtrochanteric fractures, and followed this with intramedullary nailing.

Patients and methods

Fourteen subtrochanteric femoral fractures treated between March 2009 and April 2012 were enrolled in this study. All underwent closed IM nailing after percutaneous cerclage wiring. Surgical treatments and clinical follow-up visits were conducted at two university teaching hospitals. Indications for this study were fractures for which IM nailing was viewed to be difficult in terms of accurate reconstruction, and subtrochanteric fractures extending to the greater trochanter or piriformis fossa. Long oblique or spiral fractures, whether or not comminuted, were indicated for this method. We excluded patients with a transverse or short oblique subtrochanteric hip fracture and those who had a segmental fracture elsewhere in the ipsilateral femur (AO/OTA type 32-C2.1). For obvious reasons, any fracture reduced anatomically by closed reduction before percutaneous wiring was also excluded. Type III open fractures, pathologic fractures, and patients that refused to consent to the technique were also excluded. After applying these exclusion criteria, 14 of the 48 patients with a subtrochanteric fracture treated between March 2009 and April 2012 met our inclusion criteria. However, one of the 14 patients with unsatisfactory reduction in the operating room was directly revised using an open procedure, and another was not followed because of a move to another region. Finally, 12 patients were followed for over 12 months (range 13–39 months).

Operative technique with case demonstration

Case 1

A 44-year-old woman sustained a comminuted subtrochanteric femoral fracture after pedestrian traffic accident. Radiographs demonstrated a fracture line extending into the greater trochanter and loss of continuity of the lesser trochanter (Russell-Taylor type IIB) (Fig. 1a–c).

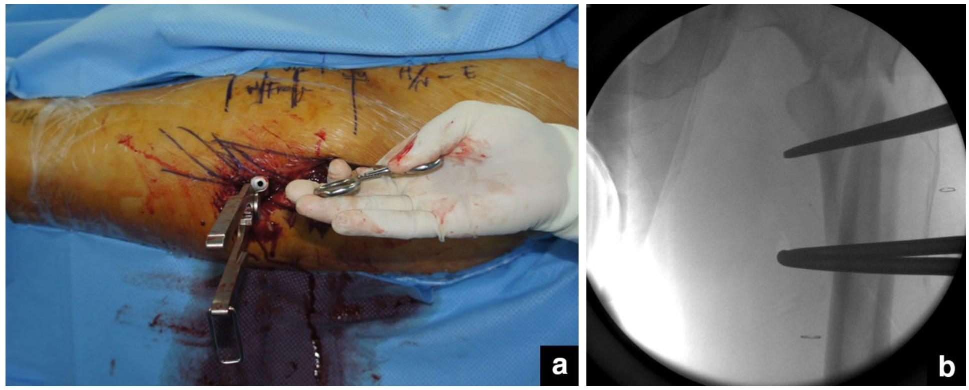

Fig. 2 After correction of flexion and external rotation deformities of the proximal fragment with hemostatic forceps, the cerclage passer was inserted through a small incision and passed dorsally and ventrally around the major displaced area, and connected each other (**a**, **b**)

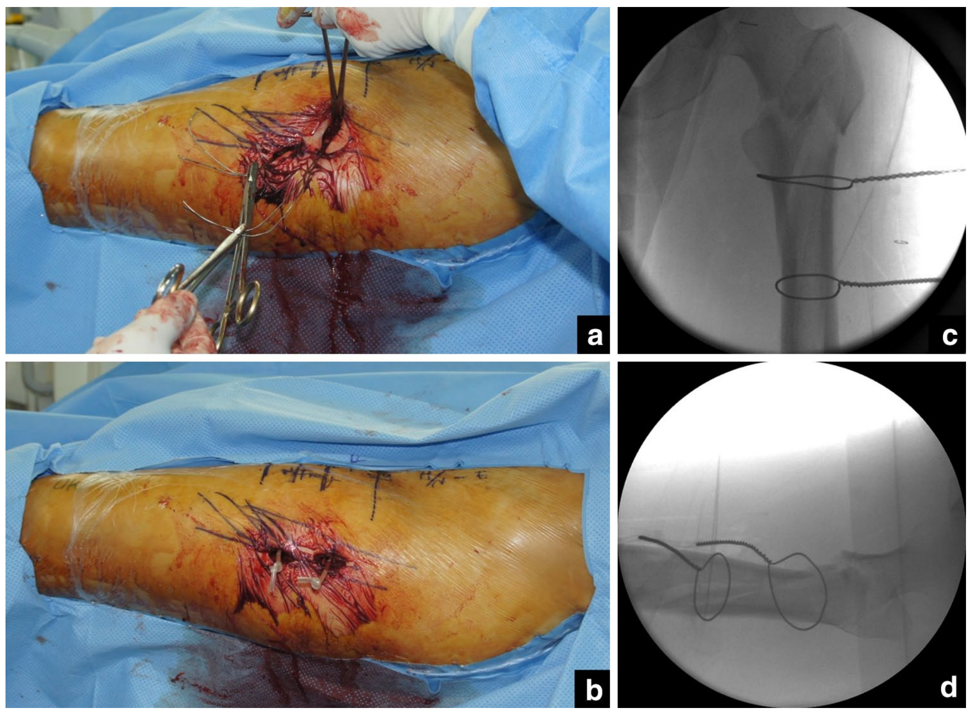

Fig. 3 A wire was inserted through the tube of the passer, which was then disconnected and removed (**a**). After closed reduction of the fracture, the wire loop was tightened. Another cerclage wiring was performed in the same manner (**b**) and intraoperative fluoroscopic image showing the reduction of the fracture (**c**, **d**)

Patient was placed supine on a traction table. The contralateral limb was abducted, flexed, and externally rotated to facilitate passage of the image intensifier. The preliminary reduction was then achieved by longitudinal traction, and a 2 to 3-cm incision was made over the lateral aspect of the femur to locate the major displaced area. A direct deep dissection to the lateral aspect of the femur was accomplished by longitudinally splitting the iliotibial tract and vastus lateralis. A tunneling device was then used to make a tunnel for a percutaneous cerclage passer, and was inserted both dorsally and ventrally around the femur. Each half of the cerclage wire passer was then carefully inserted, and after confirming the correct closed position over the fracture with image intensification, the halves were connected and closed (Fig. 2a, b). Then, a wire of sufficient length was inserted through the tube of the passer, which was then disconnected and removed (Fig. 3a). Another wire loop was made using the same technique (Fig. 3b). Closed reduction of the fracture was done under the image intensifier by combining manual traction with different degrees of internal and external rotation of the leg until closure of the fracture gap was achieved. During closed reduction, the wire loops were sequentially tightened to maintain reduction of major spiral fractures (Fig. 3c, d). Tightened wire was cut to leave a 1-cm tail, which was bent to the side of femur. Definitive stabilization with an IM nail was performed in the standard manner (Fig. 4a–e). Fracture union was achieved within 6 months (Fig. 5a, b) with an excellent functional outcome (Fig. 5c, d).

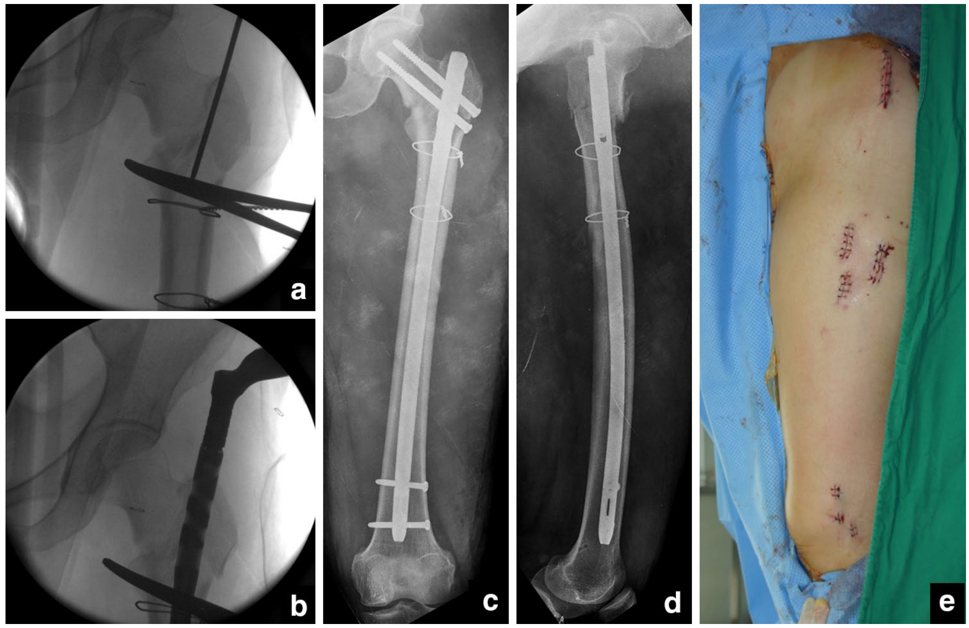

Fig. 4 Definitive stabilization of fracture with an intramedullary nail was performed in the standard fashion while the reduction was maintained by the cerclage loops (**a**, **b**). Satisfactory alignment was achieved postoperatively (**c**, **d**) with minimal scar (**e**)

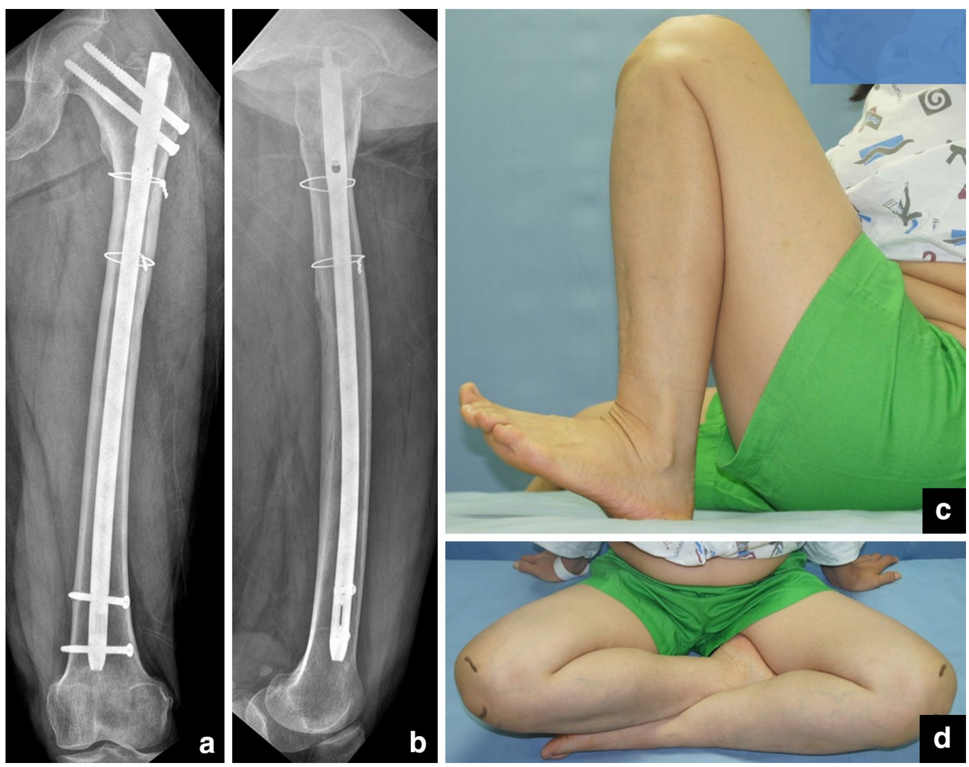

Fig. 5 The radiograph after 6 months demonstrated healing of the fracture (**a**, **b**) with an excellent function (**c**, **d**)

Case 2

A 49-year-old woman suffered from a comminuted subtrochanteric femoral fracture after falling from a height. Radiographs showed a fracture line extending into the greater trochanter and neck (Russell-Taylor type IIB) (Fig. 6a–c).

The patient was placed with supine position on a traction table. After preliminary reduction of the fracture by longitudinal traction, a tunneling device was used to prepare the tunnel for the cerclage passer (Fig. 7a). Then, one half of the cerclage passer was inserted ventrally through the prepared tunnel (Fig. 7b, c), and the other half was inserted dorsally and connected to each other (Fig. 7d, e).

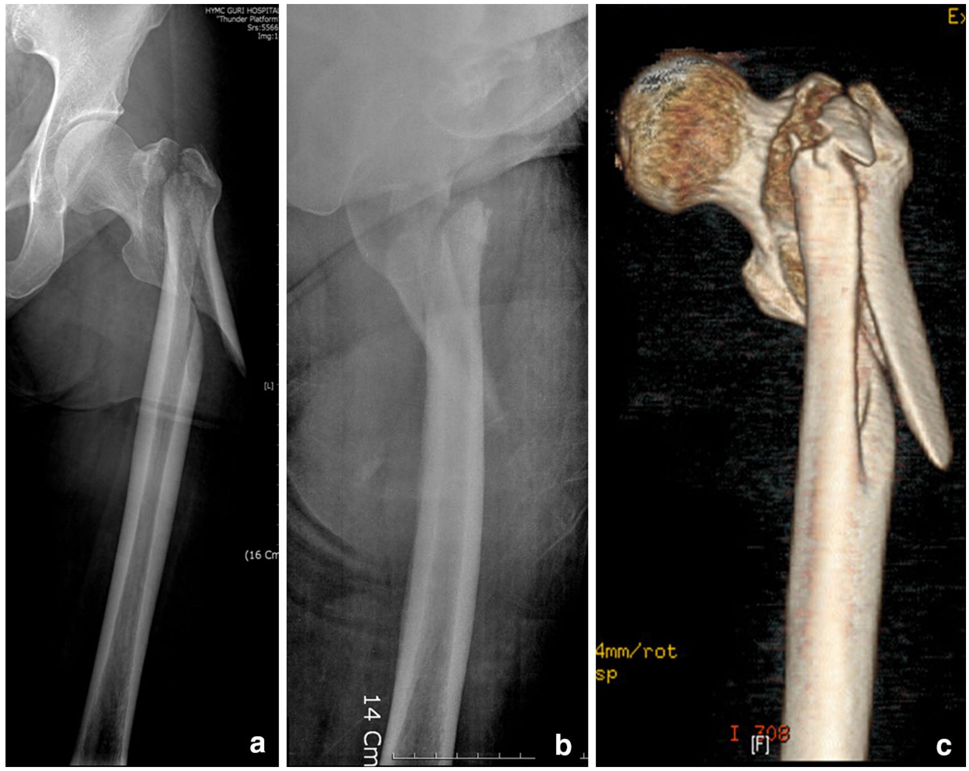

Fig. 6 A 49-year-old woman suffered from a comminuted subtrochanteric femoral fracture with a fracture line extending into the greater trochanter and neck (**a**–**c**)

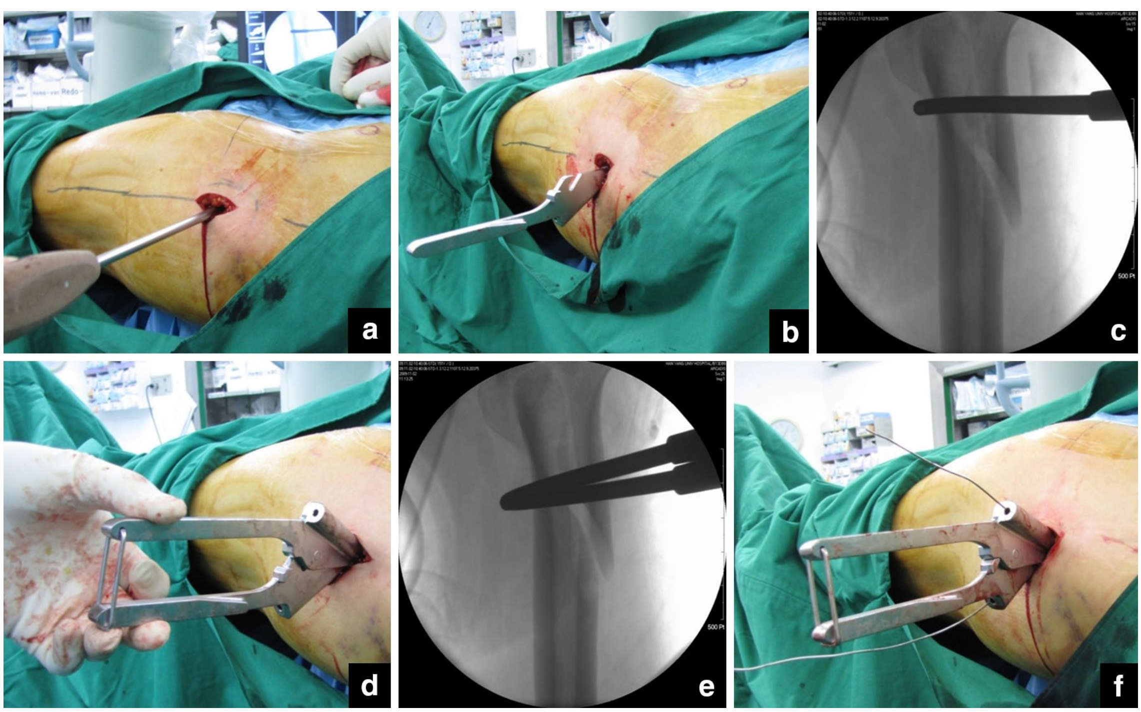

Fig. 7 After preparing the tunnel for the cerclage passer (**a**), one half of the cerclage passer was inserted ventrally through the prepared tunnel (**b**, **c**). The other half was inserted dorsally and connected each other (**d**, **e**). Then, a wire of desired length was inserted through the cerclage passer (**f**)

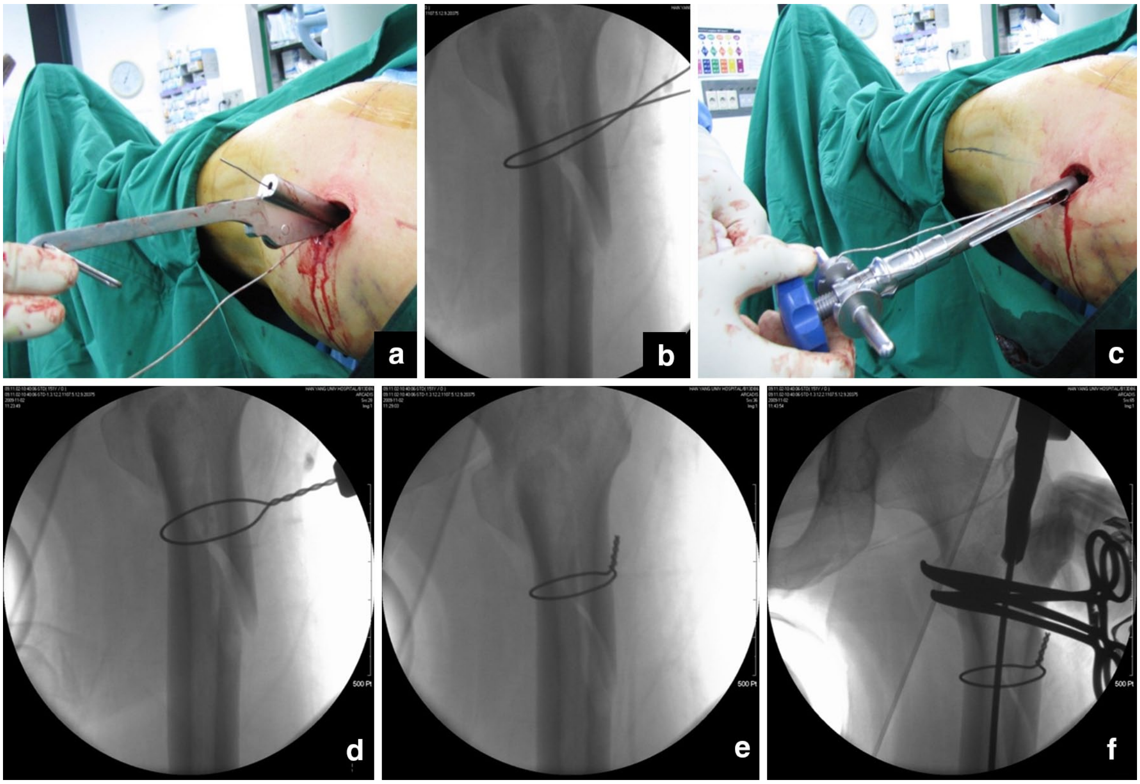

Fig. 8 The cerclage passer was disconnected and removed (**a**, **b**). Then the wire loop was tightened to reduce the fracture (**c**, **d**). Intraoperative fluoroscopic image shows the reduction of the fracture (**e**). Then the fracture was stabilized with a long proximal femoral nail using standard technique (**f**)

Thereafter, a wire of desired length was inserted through the cerclage passer (Fig. 7f), which was then disconnected and removed (Fig. 8a, b). The wire loop was sequentially tightened (Fig. 8c, d) and the spiral fracture was reduced and maintained with the wire loop (Fig. 8e). Then the fracture was stabilized with a long proximal femoral nail in the standard fashion (Fig. 8f). Satisfactory alignment was achieved postoperatively (Fig. 9a). At 7 months follow-up, the fracture was completely healed (Fig. 9b) with a satisfactory clinical outcome (Fig. 9c).

Post-operative management and assessment

Patients were mobilized on the first postoperative day, and partial weight-bearing was allowed as soon as pain was tolerable. Follow-up was scheduled every 4–6 weeks until fracture union and at 1 year postoperatively. If radiographs taken at first visit showed maintenance of the screw position and no loss of reduction, patients were allowed to increase weight-bearing progressively as tolerated.

Alignments in the frontal and sagittal planes were assessed on anteroposterior and lateral plain radiographs obtained immediately after surgery and at latest follow-up visits. Callus formation on 3/4 cortices and fading of fracture lines on radiographs were considered signs of fracture union. During last visits, a long-standing film was used to determine leg-length discrepancies between injured and uninjured femurs. Hip and knee ranges of motion and limb rotations and alignments were checked at all follow-up visits. Final clinical outcomes were evaluated using the modified Merle d'Aubigne scoring system (excellent 18, good 15–17, fair 12–14, poor <12), which is based on pain, walking, and range of motion assessments.

Results

Of the 12 patients included in this study, 10 were men, and age at operation for all study subjects ranged between 30 and 71 years (average 48.3 years). Causes of injuries were traffic accidents (7 patients) and falls (5 patients). Six patients suffered multiple fractures, which included spine fractures, pelvic ring injuries, ipsilateral acetabular fractures, humerus fractures, tibial fractures, and foot fractures. Four patients sustained various chest traumas, such as, flail chest, pneumo-/hemo-thorax, and multiple rib fractures. No patient had a major neurovascular injury, and there was no open fracture. Numbers of fracture types (according to

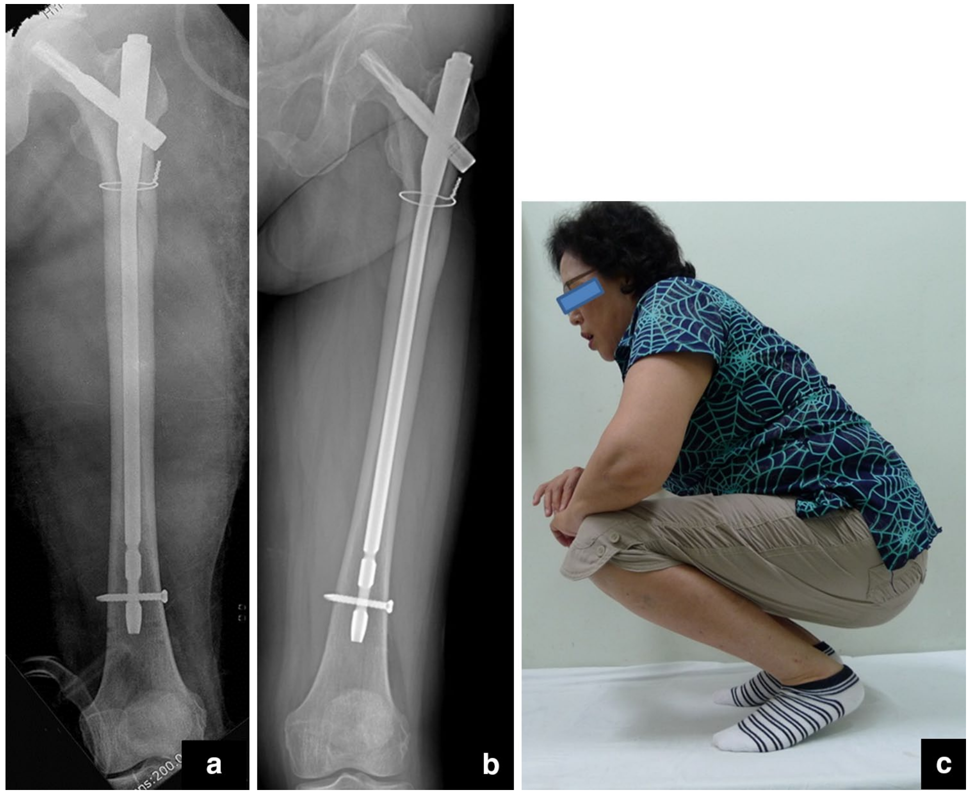

Fig. 9 Satisfactory alignment was achieved postoperatively (**a**) and follow-up radiograph after 7 months showed solid union of the fracture (**b**) with a satisfactory function (**c**)

the AO/OTA classification) were: two of 32-A1.1, six of 32-B1.1, and four of 32-C1.1. According to the Russell-Taylor classification, there were two type IIA and ten cases in type IIB fractures. All fractures had a spiral component in the subtrochanteric region.

Average operation length was 118.5 min (range 85–180 min), and average intraoperative radiation exposure time was 141 s (range 36–351 s). Blood loss averaged 240 ml (range 100–370 ml). A single wire or two wires were used, prior to IM nail insertion, in six patients each. A cephalomedullary nail (long PFN or PFNA, Synthes®, Oberdorf, Switzerland) or a second-generation reconstruction nail (A2FN, Synthes®, Oberdorf, Switzerland) were used in six patients each. Nail lengths ranged between 340 and 380 mm, and diameters between 9 and 11 mm.

All 12 patients were adjudged radiographically to have been healed at 24 weeks (mean 19.1 weeks, range 16–24 weeks). No major complication, such as, non-union, implant failure, or infection, was encountered. In one patient, re-operation for malrotation (removal and re-fixation of distal interlocking screws after correction) was performed at 1 week after the index operation.

At final follow-up visits, average femoral neck–shaft angle was 135.4° (range 132°–138°), and the average difference of contralateral femoral neck–shaft angle in extension was 0.6° (range 3° in extension to 2° in flexion). No patient complained of a foot progression angle difference with respect to rotational alignment. In seven patients who underwent a CT scan postoperatively, the anteversion difference was 2.4° (range −2° to 3°). One patient with a comminuted fracture experienced femoral shortening of 10 mm, whereas the other 11 showed <5 mm of shortening (mean −1.8 mm, range −10 to 0 mm).

All patients achieved a good or excellent functional result with a median Merle d'Aubigne score of 16.9 (range 15–18), and all could squat without difficulty (Table 1). In terms of range of hip motion, all patients achieved pre-injury levels, although two patients experienced mild discomfort in the area of proximal screw insertion.

Discussion

Anatomical reconstruction after closed IM nailing is an ideal goal for the treatment of subtrochanteric fractures, as is the case for other diaphyseal fractures of lower extremities. However, mal-union and non-union are common complications after IM nailing of a subtrochanteric fracture, due to a fixed flexion, abduction and external rotation deformity of a short proximal fragment [5–7]. When the fracture extends to the nail entry, IM nailing is not recommended because of the risk of secondary malreduction on nail passage. In addition, when a fracture is of the long oblique or spiral variety, IM nailing may result in little bone-to-bone

Table 1 Background information on the patients enrolled in the study

Case no.	Age	Associated injury	AO/OTA class	Russel-Taylor class	Nail	Wire no.	Operation time (min)	Union time (weeks)	LLD (mm)	Coronal alignment	Sagittal alignment	Function[a]
1	51	O	32-C1.1	IIB	Recon	2	130	22	−10	Neutral	2° flexion	18
2	43	O	32-C1.1	IIB	Recon	2	100	20	−3	3° varus	Neutral	18
3	54	O	32-B1.1	IIA	C-M	2	105	18	0	2° varus	2° flexion	15
4	49	O	32-A1.1	IIB	C-M	2	85	20	−2	3° varus	2° flexion	16
5	30	×	32-B1.1	IIB	Recon	1	140	16	0	Neutral	Neutral	16
6	40	×	32-B1.1	IIB	Recon	2	90	18	0	Neutral	2° flexion	18
7	44	×	32-B1.1	IIB	Recon	2	90	20	0	Neutral	1° flexion	18
8	71	×	32-A1.1	IIA	C-M	1	100	18	−2	2° valgus	Neutral	16
9	49	O	32-B1.1	IIB	C-M	1	160	16	0	1° varus	2° extension	17
10	54	O	32-B1.1	IIB	C-M	1	180	24	0	Neutral	1° flexion	17
11	55	×	32-C1.1	IIB	Recon	1	135	22	−5	2° valgus	2° flexion	16
12	40	×	32-C1.1	IIB	C-M	1	110	18	0	Neutral	3° extension	18
Mean	48.3						118.5	19.1	−1.8			16.9

Recon Reconstruction nail, *C-M* cephalo-medullary nail, *LLD* leg-length discrepancy

[a] Assessed by Merle d'Aubigne score

contact area, malalignment, and disturb or prolong bone healing. Under such conditions, extra-medullary fixed-angle devices may be a safe option. Several studies have shown anatomical reconstruction with excellent fracture healing after minimally invasive plating with locking plates [8, 9]. However, limited mechanical performance has been reported [10, 11]. Apivatthakakul and Phornphutkul [12] reported that percutaneous cerclage wiring followed by IM nailing is a surgical technique of fracture reduction, in one of the largest series conducted on complex subtrochanteric fractures. Our results showed that anatomic or close to anatomic reduction was achieved in all cases of Russell-Taylor type II fractures (for which extra-medullary implants are recommended) [13]. We presume that provisional reduction with percutaneous cerclage wire may also ensure the nail starting point and prevent further displacements of intertrochanteric fragments by the nail.

The use of cerclage wire to overcome malalignment after IM nailing is not new [3, 4], although there has been frequent argument about its strangulation of bone blood supply and resultant non-union. However, the circumferential wire appears to be non-harmful, because the periosteal vascular supply is circumferential, rather than longitudinal, and multiple vessels nourish the periosteal layer [14–17]. Therefore, non-union after the open cerclage wiring technique is considered the result of wide dissection of surrounding periosteum and soft tissue near the fracture. The newest technique of percutaneous cerclage wiring reduces this risk substantially, according to an experimental study [18]. Due to the use of a small incision, our technique may preserve perforator vessels and their anastomoses, and this seemed to aid undisturbed fracture healing. We were unable to find any detrimental effect of our technique, as all 12 patients achieved uneventful fracture healing without implant failure. Although a recent series on open cerclage wiring did not show a higher complication rate [3, 4], the longer operation time and incision, a larger bleeding and more soft tissue damage are expected than our technique.

Müller et al. [19] in an experimental study showed that additional wire cerclage can significantly decrease osteosynthesis mechanical failure after the IM nailing of subtrochanteric fractures, and Lenz et al. [16, 17] found that cerclage cable, which has multiple fine metal fibers, may strengthen this benefit. However, this advantage of medial buttress seems not confident as seen in this series, as the blind knotting method can introduce asymmetric twist and/or insufficient wire tension in percutaneous cerclage wiring [15]. The purpose of our technique is temporary reduction and the maintenance of difficult subtrochanteric fractures during IM nailing. Because we did not experience any postoperative/final follow-up alignment changes, we consider the IM nails used have sufficient stiffness without small cerclage wire, and thus, we do not believe that multiple wires or strong wire is needed to enhance the stabilization of subtrochanteric fractures.

Our study has several limitations. In addition to its small cohort size and non-comparative design, two types of IM nails were used. However, Starr et al. [6] compared the outcomes of the Russell-Taylor Recon Nail (Smith-Nephew®, Memphis, Tennessee, USA), which employs a piriformis fossa entry portal, or a Long Gamma Nail, version 2 (Howmedica®, Rutherford, New Jersey, USA), which employs a trochanteric entry portal and found no appreciable differences, which concurs with our observations. The risk of vascular injury is a disadvantage of cerclage wire. For example, Aleto et al. [20] reported injury of the superficial femoral artery (SFA) in the proximal femur during revision total hip arthroplasty. On the other hand, Apivatthakakul et al. [18] reported that the SFA is further away from the bone in the proximal femur, and we did not experience this complication in the present series.

Conclusions

The present study demonstrates the efficacy and safety of the use of percutaneous cerclage wiring to facilitate satisfactory IM nailing in patients with a complex subtrochanteric fracture. Although additional prospective comparative studies are needed to explore the role of this method more fully, the described technique appears to achieve anatomical reconstruction with IM nailing.

Conflict of interest All authors have certified that they have no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with this article.

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