

Percutaneous cerclage wiring and minimally invasive plate osteosynthesis (MIPO): a percutaneous reduction technique in the treatment of Vancouver type B1 periprosthetic femoral shaft fractures

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Abstract

Background Periprosthetic femoral fractures (PPFs) associated at or near a well-fixed femoral prostheses (Vancouver type-B1) present a clinical challenge due to the quality of the bone stock and instability of the fracture.

Objectives The purpose of this study was to present a novel reduction technique and analyze clinical and radiographic outcome in patients with Vancouver type-B1 fractures treated with percutaneous cerclage wiring for fracture reduction and maintenance of reduction with minimally invasive plate osteosynthesis (MIPO) utilizing a locking compression plate (LCP).

Methods Between March 2007 and December 2008, ten consecutive patients with spiral, oblique or wedge Vancouver type-B1 were treated with closed percutaneous cerclage wiring using a new cerclage passer instrument (Synthes®) through small 2–3 cm incisions for reduction and maintenance of reduction. Internal fixation with MIPO was obtained utilizing a long LCP Synthes® bridging the fracture. The reduction time, fixation time and operative time were recorded. The rehabilitation protocol consisted of partial weight bearing as tolerated. Clinical and radiographic outcomes included evidence of union, return to pre-injury mobility, and surgical complications were recorded.

Results There were three men and seven women with an average age of 74 years (range 47–84 years) at the time the

fracture occurred. The average follow-up was 13.2 months. One patient died 2 months after surgery due to cardiovascular problems and was excluded. The average reduction time with percutaneous cerclage wiring was 24.4 min (range 7–45 min). The average fixation time was 79 min (range 53–100 min). The average operative time was 103 min (range 75–140 min). Blood loss was minimal and only two patients needed a blood transfusion. All fractures healed with a mean time to union of 18 weeks (range 16–20 weeks). There was one implant which bent 10° in the post-operative period but went on to heal uneventfully within 16 weeks. There was no evidence of loosening of any implants. Seven patients returned to their previous level of mobility. Two patients required a walker. There were no implant failures, wound complications or infections.

Conclusions Percutaneous reduction of spiral, oblique or wedge-type B1 PPFs with percutaneous cerclage wiring combined with minimally invasive locking plate osteosynthesis provided satisfactory reduction, adequate stability and healing in nine patients. Our early results suggest that this reduction technique and fixation may be a useful solution for this growing challenge in orthopaedics. The authors caution that this technique must be done carefully to avoid serious complications, e.g., vascular injury.

Keywords Periprosthetic femoral fracture · Vancouver type B1 · Treatment · Percutaneous cerclage wiring · Minimally invasive plate osteosynthesis (MIPO)

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Introduction

The treatment of periprosthetic femoral fracture (PPF) is challenging and associated with a complication rate as high as 48% [1]. Complex fracture patterns and co-morbidities

common in this patient population such as osteoporosis, previous surgery, and frailty, demand a surgeon with both trauma surgery and revision arthroplasty skills [2]. The Vancouver classification has become widely accepted as it considers the fracture location, quality of bone stock and stability of the implant [3]. The type B1 femoral fracture is defined as a fracture around the stem or just below it with a stable prosthesis. Since the prosthesis is stable, fracture fixation should be the treatment of choice to achieve the aim of early fracture healing and early mobilization without disturbing the femoral prosthesis.

Open cerclage wiring technique is a well-known procedure for treating PPF. Cerclage wires and internal fixation for the treatment of PPF have been used either alone or combined with long stem implants since 1975 [4]. More recently, modifications to this procedure have been explored. Khan and O'Driscoll [5] treated three short oblique PPFs with simple encircling wiring and had excellent results. In 1981, Johansson et al. [6] reported 37 PPFs. Twenty-five were treated with cerclage wiring, dynamic compression plates, and lag screws with or without revision to a long-stem prosthesis. With a follow up of 3.9 years and using the Harris hip score, the unsatisfactory results were 56%. With unstable PPF, a combination of long stem prosthesis and cerclage wiring could provide additional stability [7]. All previous reports treating the PPFs with wiring were done by the open reduction technique.

Percutaneous cerclage wiring using Gotzes method and interlocking nailing of the tibial fracture was described by Habernek [8]. Percutaneous wiring preserves the periosteal blood supply without extensive exposure. Ease of percutaneous passage of wire around the tibia is attributable to its medial subcutaneous surface and absence of muscle. The femur, however, has a robust muscular envelope over the metaphysis and diaphysis which may obstruct the passage of wire through a small incision. As a result, most of the cerclage wiring in this region has been performed by open techniques.

Open reduction and internal fixation for the treatment of PPF with conventional plates with or without a combination of cerclage wiring, cable or allograft has demonstrated unsatisfactory outcomes because of the unstable proximal fixation and extensive soft tissue dissection which leads to a delayed fracture union [9]. The concept of biological plating by Mast et al. [10] presented the indirect reduction technique and bridged the fracture zone without disturbing the fracture fragment's blood supply, thus potentially reducing the risk of a delayed union, nonunion, and infection. The introduction of minimally invasive plate osteosynthesis (MIPO) in the treatment of femoral fractures has led to more biologic technique of plate osteosynthesis. In addition to accepted clinical outcomes, there is evidence that this technique preserves the periosteal blood supply by utilizing

incisions that are remote from the fracture [11, 12]. During the same period of MIPO, the locking compression plate (LCP) has been introduced to treat the periprosthetic fractures. The principle of angular stable screw has the advantage of unicortical screw fixation in the proximal part with limited bone stock for securing the proximal fixation [13–16]. The combination of MIPO and locking plate fixation for PPFs was reported by Fulkerson [16] and Chakravarthy [15]. The results were satisfying with good healing and less complications. Xue et al. [2] reported the results of the locking compress plate with mini open reduction technique with cerclage band and LCP fixation for type B1 PPFs in 12 cases. There was one delayed union, but no loss of reduction, plate breakage or wound complications. There were no previous reports combining the state of the art of minimally invasive reduction with percutaneous cerclage wiring and MIPO for the treatment of PPFs.

The purpose of this study was to present this novel minimally invasive reduction technique, as well as analyze the clinical and radiographic outcomes of patients with Vancouver type-B1 PPF's treated with percutaneous cerclage wiring for fracture reduction, and internal fixation with LCP.

Materials and methods

Between January 2007 and December 2008, ten consecutive patients with a spiral, oblique or wedge Vancouver type-B1 were treated with percutaneous cerclage wiring using a new cerclage passer instrument (Synthes®) (Fig. 1a, b) through the small 2–3 cm incisions for reduction and maintenance of reduction and fixation with MIPO technique. There were three men and seven women with an average age of 74 years (range 47–84 years) at the time of fracture. The mean interval between initial arthroplasty and the time of fracture was 4.4 years. Nine fractures occurred in patients with primary hip arthroplasty and one fracture in a patient with a revision implant. The reduction of the fracture was done by closed means with the percutaneous cerclage wiring using percutaneous cerclage passer instruments. The number of wire loops used for the reduction of the fracture depended on the fracture configuration. For oblique fracture a single wire loop was used to secure between the fragments. Two wire loops were used in a spiral fracture, one at the proximal and one at the distal part of the fracture. In a comminuted wedge or spiral wedge fracture, 2–3 wire loops were needed. After passing the cerclage, the fracture reduction was done by manual traction and sequential tightening of the wires using a wire holding forceps or the plier. Internal fixation was obtained with a long LCP Synthes® bridging the fracture bypassing the fracture zone. The LCP distal femur was used for the fracture

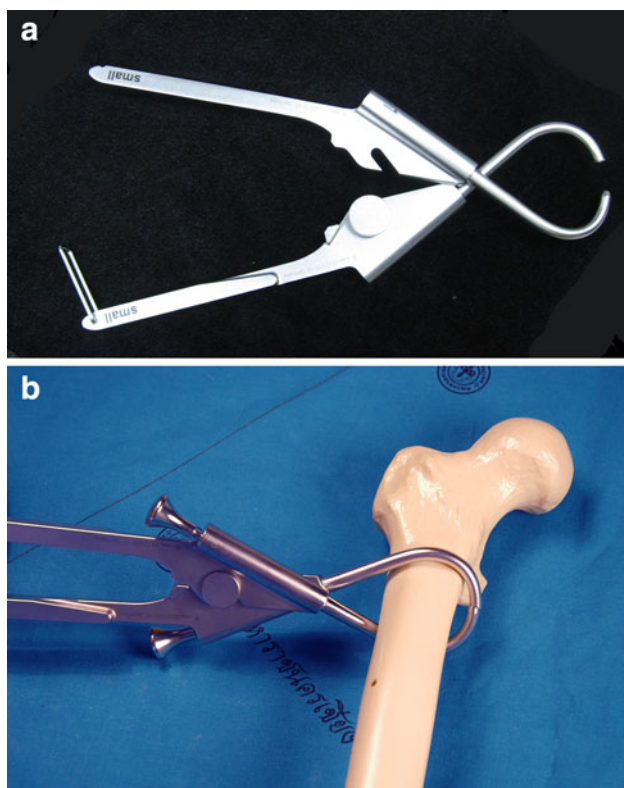


Fig. 1 **a** The percutaneous cerclage passer consists of two dividable forceps which are connected in the middle flat part. When closing the forceps, the tips will meet together. **b** The cerclage passer connecting over the proximal femur

which extended into the distal shaft. The curved broad 4.5 LCP was used for the fractures that did not need fixation at the femoral condyle. Proximal contouring of the plate was performed when there was a need due to the fracture pattern. All the surgical steps were recorded by digital camera. The reduction time, fixation time, and total operative time were recorded using the recorded time from the digital camera. The reduction time was defined as the duration from first incision at the fracture to the time that the fracture was completely reduced and temporarily maintained by the cerclage wire. The fixation time started from complete reduction to skin closure. The rehabilitation protocol consisted of partial weight bearing of 10–15 kg in the first week. Patients were followed-up at weeks 6, 12, 20, 32 and 52 until the fracture healed clinically and radiographically. The fracture was considered clinically healed when the patient had no pain on weight bearing and with movement of the hip and knee. Radiographic union was documented when at least three cortices showed bridging callus.

Surgical technique

A 74-year-old man sustained a PPF 15 years after a THR (Fig. 2a). The operation was carried out with the patient in

a supine position on a normal radiolucent operating table. The limb was draped free from the iliac crest to the foot to allow intraoperative assessment of length and rotation. The image intensifier was positioned on the opposite side of the operating table.

Preliminary reduction of the fracture by manual traction is needed. A 2 cm longitudinal incision was made through the skin, subcutaneous tissue and fascia at the proximal part of the fracture fragment using the image intensifier. Deep dissection was performed directly to the lateral aspect of the femur. A tunneling device was used to facilitate the insertion of the cerclage passer through the intermuscular septum and the muscle envelope surrounding the femoral shaft both dorsally and ventrally. A trocar was placed in each tube of the cerclage passer to prevent the soft tissue from entering the cannulated tubes. The cerclage passer was inserted gently into the prepared tunnel dorsally around the femoral shaft, then the other half of the forceps was inserted ventrally.

The flat middle parts of the forceps were connected and forceps handles were then brought together and secured by locking the bracket on the end of the device. Of note, the correct position of the tip of the wire passer should be controlled by the image intensifier (Fig. 2b).

The trocars were removed from both branches of the forceps and a cerclage wire diameter of 1.25 mm was passed through the cerclage passer until the wire passed through the opposite side. The forceps was unlocked and the two branches of the forceps were disconnected and removed. The first wire loop was loosely tightened (Fig. 2c) and the same technique was applied to the second wire loop (Fig. 2d). Indirect reduction of the fracture was done under the image intensifier by manual traction, internally or externally rotating the leg to close the fracture gap. The wire loops were tightened to allow circumferential force moving the fracture fragments into their place (Fig. 2e). The length and the rotation were checked by observing the cortex of the fracture which should have no overlapping or gap at the fracture site. Fracture reduction was maintained by the wires.

The proximal and distal incision for the plate were marked on the skin according to the lengths of the plate. The length of the plate should extend proximally to allow fixation with at least four locking screws and distally to allow at least three spreading locking screws (Fig. 3a). Deep dissection was performed to the lateral cortex of the femur without detaching the periosteum. The tunneling instrument was inserted to prepare the tunnel for the plate. The plate was inserted following the prepared tunnel and aligned with the lateral cortex. The position of the plate was checked by the image intensifier in both AP and lateral views (Fig. 3b, c). The locking screws were inserted through the stab incisions.

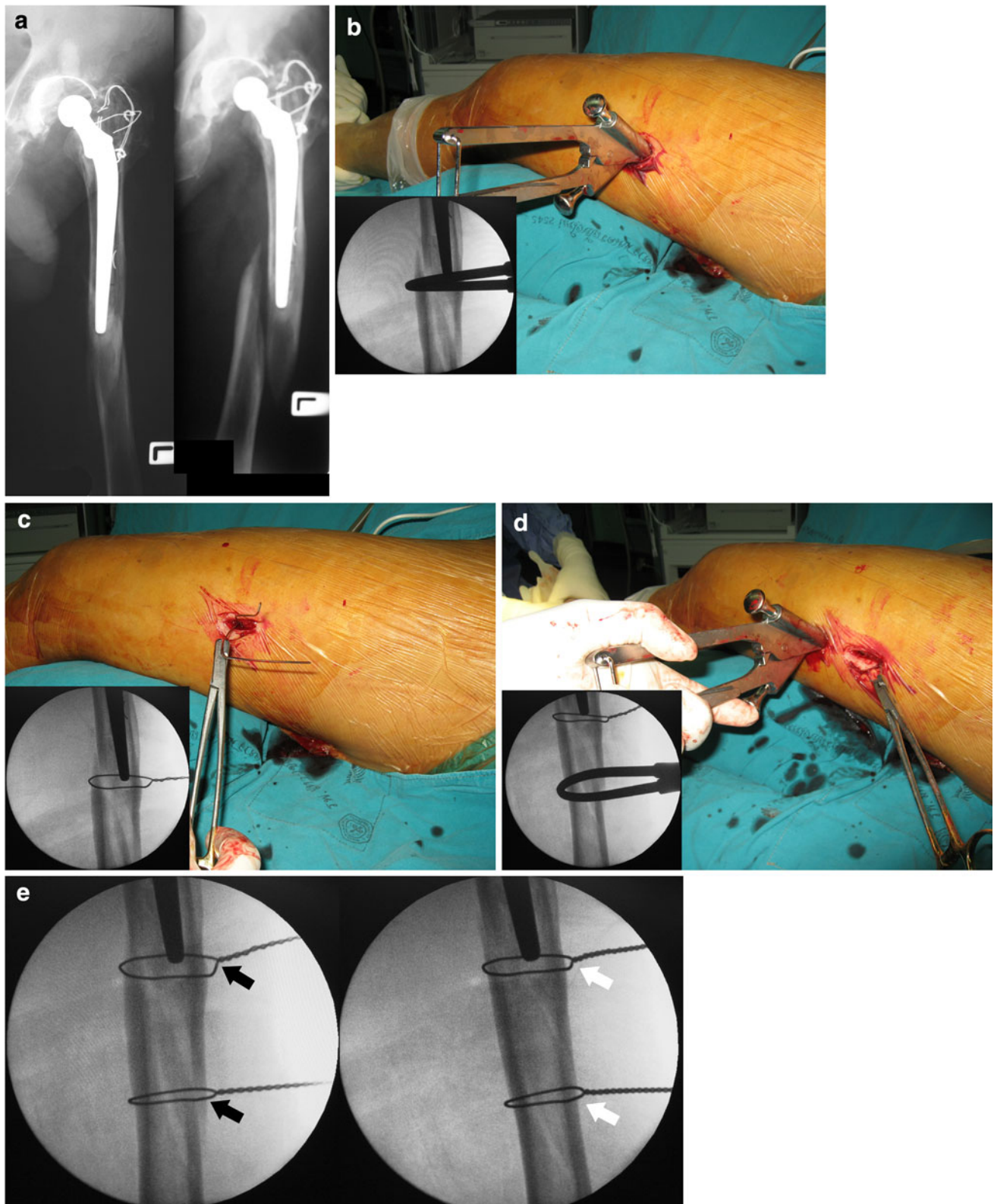


Fig. 2 **a** A 74-year-old man sustained a periprosthetic femoral fracture, he could walk without pain prior to this injury. **b** The cerclage passer being inserted through the small incision, the X-ray showing the tip of the passer meeting together over the fracture. **c** After passing the wire and remove the cerclage passer, the first wire loop was loosely

tightened. **d** The cerclage passer being inserted through the second incision. **e** Tightening the wire loop to reduce the fracture. The X-rays showing the wires not completely tightened (*black arrow*), wires completely tightened (*white arrow*) and the fracture was reduced

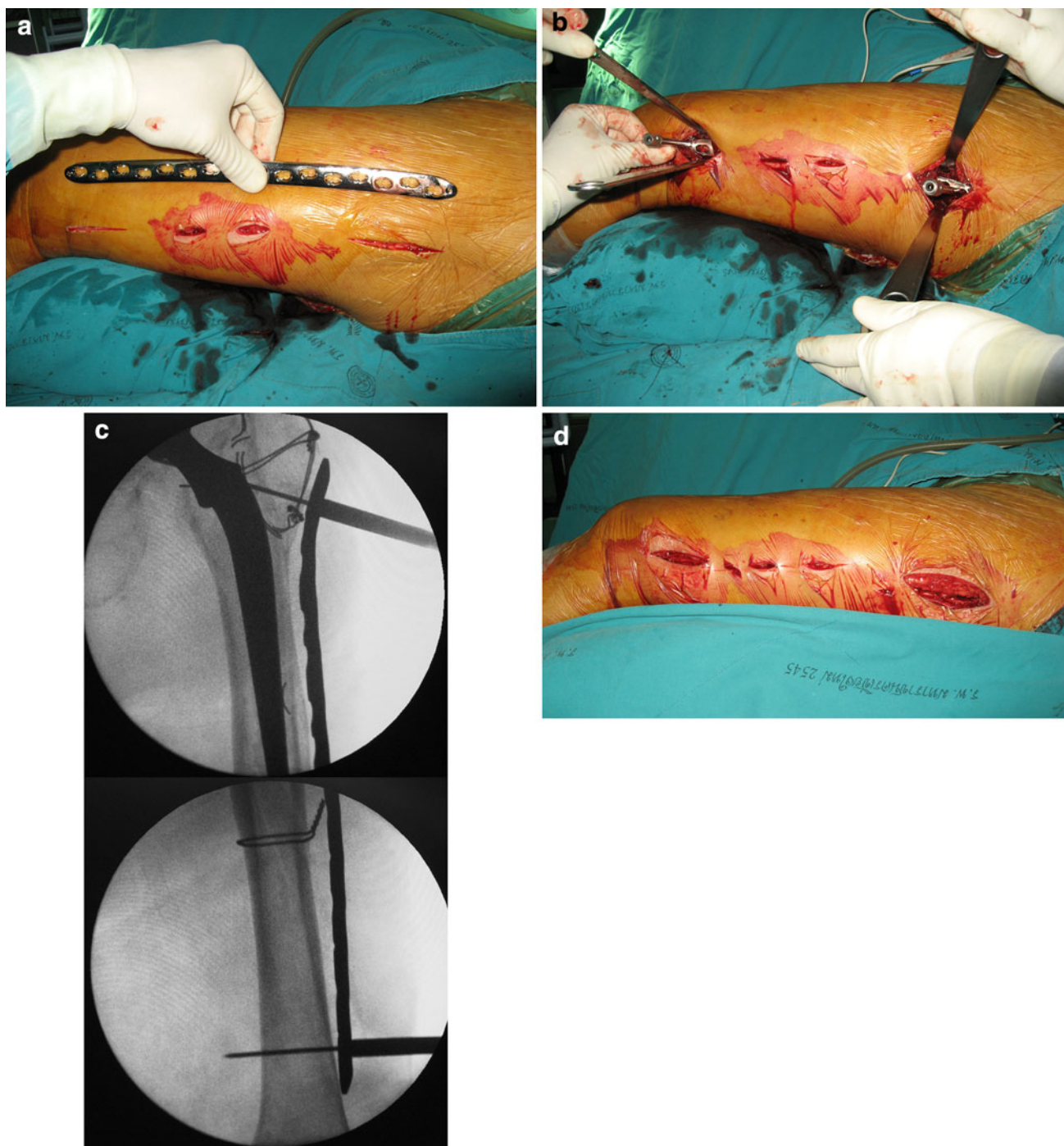


Fig. 3 **a** Determination of the plate length and marking the skin incisions. **b** Inserting the plate into the prepared tunnel and adjust the plate position. **c** The X-rays showing the position of the plate temporarily

fixed with K wires. **d** The incisions after percutaneous wiring and MIPO

Periprosthetic screws were preferred in the proximal fragment to avoid damaging the cement mantle and to accommodate more thread in the bone (Fig. 3d). The suction drain was used as an option.

The patient was encouraged to move the hip and knee on second post-operative day. Partial weight bearing and

assisted ambulation with 10–20 kg limits was allowed for 6 weeks, more progressive weight bearing was allowed during 6–12 weeks and full weight bearing start after 3 months. The patients were followed-up at weeks 6, 12, 20, 32, and 52 until the fracture healed clinically and radiologically (Fig. 4a, b).



Fig. 4 **a** Post-operative AP and lateral X rays. **b** 20 weeks post-operative AP and lateral X rays, good healing with callus bridging the fracture

Results

Clinical and radiological follow-up were possible for nine of the ten patients. One patient died 2 months post-op as a result of cardiovascular problems. This patient was excluded resulting in nine cases that were followed-up for at least 12 months. The average follow-up time was 13.2 months (range 12–18 months). Implants used for fixation of the fractures included one LCP distal femur and eight curved broad 4.5 locking plates (Synthes®). The fracture pattern was spiral in four patients, oblique in three patients, and wedged in two patients. The average reduction time, as defined in “Materials and methods”, was 24.4 min (range 7–45 min). Closed reduction was successful in all but one case. The average fixation time was 79 min (range 53–100 min). Difficulty contouring the plate resulted in a fixation time of 100 min in one patient and was a result of a previous revision hip prosthesis with strut graft and wiring (case 1). The average operative time was 103 min (range 75–140 min). Intraoperative contouring of the LCP distal femur was needed two times to match the anatomy of the proximal femur. Blood loss was <100 cc and only two patients needed blood transfusions post-operatively. All fractures healed with a mean time to union of 18 weeks (range 16–20 weeks). There was one implant which bent post-operatively by 10°. This did not progress and the fracture went on to heal uneventfully in 16 weeks. No screw

breakage, implant loosening or failure was observed. Seven patients returned to their previous level of mobility. One patient developed pain around the knee from osteoarthritis and remained dependent on a walker. One patient remained mobile with a walker due to hemiparesis from stroke (Table 1). There were no vascular or nerve injuries, no wound complications or infections. One patient had minimal pain in the mid-thigh from prominence of the wire tip.

Discussion

Periprosthetic femoral fracture is one potential complication of total hip arthroplasty. As PPFs around the total hip arthroplasties are encountered with greater frequency, precise diagnosis and accurate classification is an important step in treatment decisions. The Vancouver classification has become widely accepted as it considers the fracture location, quality of bone stock and stability of the implant. [3] A fracture about the well-fixed femoral stem is described as Vancouver B1 fracture. Accurately distinguishing fractures associated with well-fixed stems (B1) from those associated with loose stem (B2, B3) is critical in the planning of fracture management. Failure to identify a loose stem is likely to lead to treatment failure if an osteosynthesis technique rather than complex revision hip arthroplasty is performed. Various surgical treatment

Table 1 Patient demographic, fracture type, number of wire loop, reduction time, fixation time, operating time, healing time and complications

Case	Sex/age	Fracture type	Pre-op (years)	No. of wire loop	Reduction time (min)	Fixation time (min)	Time for surgery (min)	Fracture healing (weeks)	Fu (months)	Complication
1	F/84	Spiral	THR 15, Rev 7	2	30	100	130	16	15	None
2	M/74	Spiral	THR 12	2	26	79	105	20	12	None
3	M/47	Wedge	THR 2	3	45	95	140	20	18	None
4	F/76	Oblique	Hemi 4	1	7	78	85	16	12	Angulation 10°
5	F/80	Spiral	THR 6	2	27	73	100	18	12	None
6	F/74	Oblique	Hemi 5	2	24	66	90	16	14	None
7	F/79	Wedge	THR 7	2	22	53	75	20	12	None
8	F/80	Spiral	THR 4	2	34	76	110	–	–	Died 2 months after the operation
9	M/68	Oblique	Hemi 4	1	15	80	95	18	12	None
10	F/76	Spiral	THR 7	2	24	82	106	18	12	None

THR total hip replacement, Hemi hemiarthroplasty, Rev revision prosthesis

options have been described for Vancouver B1 fractures [17]. Open reduction and internal fixation with compression plate has been a standard method of B1 periprosthetic fracture. Sen et al. [18] treated 12 patients with B1 periprosthetic fracture with ORIF using a low contact dynamic compression plate. Ten fractures united in an average period of 7 months with the mean Harris hip score average of 85. Haddad et al. [19] reported 98% healing rate of the forty PPFs treated with cortical struts alone or in conjunction with a plate, the strut allografts serving both a mechanical function and a biological function led to high rate of union. However, ORIF with or without strut allografts required large surgical exposure with soft tissue dissection and disturb the blood supply at the fractures.

According to the biological plating concepts, Ricci et al. [14, 20] report the open indirect reduction technique and dynamic compression plate fixation without bone grafting in 41 patients with B1 periprosthetic fractures. All fractures healed in satisfactory alignment at an average of 12 weeks. One patient had one fractured cable and two others had one broken screw, but all of the fractures healed without evidence of implant loosening or malalignment. They suggested that the use of indirect open reduction and internal fixation with a single extraperiosteal lateral plate, without the use of allograft struts improved fracture healing and reduced the need for bone-grafting. The success of this technique results from the preservation of the fracture hematoma and sufficient plate length for providing relative stability to allow bridging of the fracture with callus.

Minimally invasive plate osteosynthesis (MIPO) has become widely practiced in the treatment of periarticular fracture, metaphyseal fractures or in certain diaphyseal fracture where intramedullary nailing may not be ideal, including in B1 PPFs [12, 21]. This technique requires less soft tissue dissection and preserves the fracture hematoma

and blood supply to the bone fragments resulting in undisturbed rapid callus bone healing [11]. These advantages combined with the application of a locking plate system can be used for unicortical screw fixation in the proximal fragment and also in osteoporotic bone [22]. The preliminary report of MIPO in seven PPFs was described by Abhaykumar and Elliot [23]. There were five type B fractures and two type C fractures. They used the dynamic compression inserted percutaneously with the aim of fixing at least eight cortices in each fragment. All fractures healed in 5 months, six had regained independent mobility and one had suffered a pre-fracture cerebrovascular accident and mobilized poorly.

Modern osteosynthesis techniques are increasing in the treatment of these Vancouver B1 fractures and appear to be effective with satisfactory healing and less complications [20]. Locking plate technology offers increased angular stability and, theoretically, better fixation in osteoporotic bone. Buttaro et al. [24] treated 14 patients with a Vancouver type-B1 treated with open reduction and internal fixation with use of a LCP. Cortical strut allografts were used to stabilize five fractures. Eight fractures healed uneventfully at an average of 5.4 months. Three treatment constructs failed with fracture of the plate within 12 months after surgery. An additional three constructs also failed because of plate pullout. All failures except one occurred in constructs in which a cortical strut allograft had not been utilized. The authors suggested that supplementation with strut allografts should be used routinely if the LCP is selected to treat these fractures. In our opinion, from the biological concept of fracture treatment, the cause of these failures may not only come from the stability of fixation but also the devascularized fracture fragments leading to delayed union or nonunion which cause implant failure.

Historically there was a great amount of controversies regarding the application of cerclages in fracture treatment because it was suggested that this technique led to a strangulation of periosteal vascularization, resulting in bone necrosis and nonunion [25–27]. Actually from a biological view point, it was the surgical dissection and stripping to expose and reduce the fracture that caused the bone necrosis and other complications. Kirby et al. [28] reported an experimental study to evaluate the effect of a cerclage band on the vascularity of intact bone in six dogs by microangiography and correlated histology. They found no evidence of complete cortical devascularization under any size or type of cerclage appliance at any time interval. Numerous examples of vessels traversing the cortex directly beneath all the cerclage appliances were observed. They concluded that cerclage devices, even when flat and wide, do not restrict cortical vascularity when applied to intact bones. From their study, the correct wiring technique with minimal soft tissue stripping has minimal effects upon the cortical blood supply. However, this study was on intact bone that may not be the same as in a fracture situation.

Farouk et al. [29] studied the topography of the perforating vessels of the deep femoral artery and found that the second and third perforating vessels passed near to the lateral surface of the femur and had a risk of injury during conventional lateral approach, the division or ligation of the perforating arteries and their anastomosis is inevitable [30].

Percutaneous cerclage wiring for the femoral shaft fractures using cerclage passer is not described in the literature. The newly developed percutaneous cerclage passer offer percutaneous passing of the wire over the fracture with a 2–3 cm small incision. This technique allows fracture reduction and maintenance of the reduction without obstructing the plate insertion prior to definite fixation with the locking plate. The small incisions preserve the soft tissue envelope, muscle, periosteum around the fracture zone with less destruction of the blood supply around the femur than open wiring technique.

This new technique can preserve the perforator vessels and their anastomosis leading to better bone healing and a decreased need for bone grafting. The disturbed area of that blood supply was minimal only at the area of wire that surrounds the bone. We believe that most of the segmental anastomosis of the perforating vessels still can be preserved as supported by Kirby et al. [28]. In oblique fracture, the fracture can be reduced by single wire loop in the middle part of the fracture. The long oblique or spiral fracture need two wire loops to control the fracture at the proximal and distal end. Preservation of the vascular anastomosis between both wire loops is possible. The cerclage functions in two different applications. First, as a fracture reduction tools during surgery by the centripetal action. Second, cerclage function as implants which may be used alone or with

a protective splint. The mechanical strength of the cerclage in this study is insufficient to allow functional aftercare, the cerclages improve initial fixation and approximation of the fragments. Internal splint using locked plate provides adequate stability between proximal and distal fragment [27]. Cerclage cable provide more tension and resistant than the twist wire to reduce the bone or holding the plate. However, the cables cannot be used at this period of time because the cable crimping instrument cannot pass through the small incision.

Closed reduction of the femoral shaft fracture is challenging. Various techniques have been described using extramedullary or intramedullary instruments. Cerclage wiring is an extramedullary instrument that provides circumferential force across the fracture surfaces when tension is applied. The limitation of the cerclage is that it can be used in only the most long oblique fracture, spiral fracture and some wedge fractures. Transverse or short oblique fractures should be avoided. Multifragmented comminuted fractures are difficult to reduce by the cerclage. One wedge fracture could not be reduced by percutaneous means due to delayed fracture treatment for 16 days. In this case a mini-approach open reduction at the fracture was performed.

The percutaneous cerclage instrument must be used with caution since the cerclage passer is inserted without direct visualization of the fracture and it may potentially catch vital structures when surrounding the femoral shaft. The cerclage tunneler and cerclage passer have to pass closely to the bone to avoid entrapment of the superficial femoral artery and vein injury on the medial side [31]. After passing the cerclage wire around the fracture, reduction of the fracture was easily done by longitudinal traction with both slightly internal and external rotation of the leg along with a gradual twisting of the wire loops to close the bone gap. The reduction and alignment was checked by the image intensifier. Eight of nine fractures were reduced anatomically; one case had the gap of 3 mm at the fracture due to the cement mantle blocking the reduction. However, with the concept of a bridging plate with relative stability and a minimally invasive approach, the fracture healed well with callus formation (Fig. 4a, b).

With percutaneous wiring, the fracture is well reduced and maintained the operative time and fluoroscopy time should be less than other closed reduction technique and MIPO. The average closed reduction time in our study was 24.4 min which is acceptable compared to other techniques of the femoral shaft fracture reduction [32]. The advantage of the described techniques is the ability to achieve an almost anatomic reduction of simple short oblique and spiral fractures and to maintain this reduction, without obstruction of the definite plate fixation. The average operative time was 103 min which is comparable to open biological plating and MIPO reported by Erhardt et al. [33] and

less than the 125 min of mini-open reduction and MIPO reported by Kumar et al. [34]. The clinical results were satisfactory in terms of fracture healing with few complications. Our results show no nonunion, delayed union or infection which appears to be less than the complication rate seen with conventional open reduction and internal fixation. The average time to union, at 18 weeks, was comparable to other method of indirect reduction or mini-open reduction and fixation for such difficult fractures [2, 35, 36]. The outcome of this technique is comparable to the other techniques with potential biological advantages.

The limitation of this series includes its retrospective nature, the small number of patients, and its missing control group. The follow-up time is insufficient to evaluate the survival of the prosthesis. Percutaneous cerclage of the fracture still has no experimental study to validate the effect of the wire on cortical vascularity and surrounding muscle in vivo. Further study in animal experiment is needed.

In conclusion, percutaneous reduction of spiral, oblique or wedge-type B1 PPFs with percutaneous cerclage wiring combined with MIPO provided satisfactory reduction, adequate stability, and healing. Our early results encourage us to propose that this minimally invasive reduction and fixation technique will have a role to play in the future treatment of PPFs that need internal fixation.

Conflict of interest No conflict of interest is present.

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