

Minimally invasive plate osteosynthesis (MIPO) in the treatment of the femoral shaft fracture where intramedullary nailing is not indicated

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Abstract The aim of this study was to examine the results of minimally invasive plate osteosynthesis (MIPO) of the femoral shaft fracture in patients where intramedullary nailing is contraindicated and evaluate the proper number of the screws for stable fixation. This was a retrospective study of 36 closed femoral shaft fractures which underwent MIPO using a conventional 4.5 broad dynamic compression plate (DCP) with 14–18 holes fixed with three or four screws in the proximal and distal fragments. Thirty-three fractures had bony union in 21.0 weeks (range, 12–28 weeks), two had delayed union that required bone graft and union at 28 and 32 weeks. Malalignment occurred in five cases. Sixty-two fragments were fixed with three screws—40 in cluster and 22 in separated positions. Ten fragments were fixed with four screws—eight in cluster and two separated. Broken screws were found in three cases; all were in the group with three screws fixed in cluster group. MIPO of the femoral shaft fracture is an alternative treatment in the patient where intramedullary nailing is contraindicated. Malalignment is the common complication that must be carefully evaluated intraoperatively. We recommend using at least three separated screws in each fragment to reduce the risk of screw breakage.

Résumé L'objectif de cette étude est d'étudier les résultats de la technique MIPO pour les fractures de la diaphyse fémorale chez les patients pour lesquels l'enclouage centro-médullaire est impossible ou contre indiqué. Le but de l'étude est d'évaluer le nombre de vis permettant d'avoir une fixation stable. Matériel et méthode: une étude rétrospective a été réalisée sur 36 fractures diaphysaires

fémorales fermées en utilisant une plaque DCP, avec vis de 4,5, une plaque de 14 à 18 trous fixée par 3 ou 4 vis dans le fragment proximal et 3 ou 4 vis dans le fragment distal. Résultats: 3 fractures ont consolidé en moyenne à 21 semaines (12 à 28 semaines). 2 ont présenté un retard de consolidation nécessitant une greffe avec une consolidation de 28 à 32 semaines. Un cal vicieux est survenu dans 5 cas. 62 fragments ont été fixés par 3 vis, 40 bien groupés et 22 dans une position différente plus étalés. 10 fragments ont été fixés par 4 vis, 8 en position groupée, 2 en position différente. Nous avons constaté une fracture de vis dans 3 cas, toutes les vis cassées se sont retrouvées dans le groupe des vis fixées de façon convergente bien groupée. En conclusion: la technique MIPO est une alternative au traitement des fractures diaphysaires fémorales chez les patients pour lesquels l'enclouage est contre-indiqué. Un cal vicieux est une complication relativement fréquente et doit être prévenue opératoirement. Nous recommandons d'avoir au moins 3 vis dans des directions différentes pour chaque fragment afin de réduire le risque de fracture de vis.

Introduction

Closed intramedullary nailing of the femur is now considered to be a standard treatment for a femoral shaft fracture [22]. Over the past decade there has been an evolution in the techniques used for plating of long bone fractures [5, 9, 17]. Plate osteosynthesis is particularly advantageous in certain situations where an intramedullary nail may be contraindicated or technically not feasible. These may include the polytrauma patient, ipsilateral femoral neck and shaft fractures [16], fracture in the proximal or distal shaft [9, 13], paediatric femoral shaft fracture, or an excessively narrow intramedullary canal [7, 18].

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As a result of technical advancement, minimally invasive plate osteosynthesis (MIPO) has gained popularity in recent years and has achieved satisfactory clinical outcomes [1, 6, 7, 12, 21]. The plate is inserted by a percutaneous approach with separate proximal and distal incisions. This method requires less soft tissue dissection and preserves the fracture haematoma, and blood supply to the bone fragments which results in undisturbed rapid callus bone healing.

This article reports results and complications and evaluates the proper number of screws for the treatment of closed femoral shaft fractures treated with the MIPO technique in patients for which intramedullary nailing is not indicated.

Patients and methods

A retrospective review was performed on all femoral shaft fracture patients treated with the MIPO technique at Chiang Mai University Hospital between January 2000 and December 2004. The indications for plating and inclusion are patients with multiple injuries, small or obliterated medullary canal, and open growth plate. All were closed fractures and were classified according to AO classification [15] as AO 32A,B,C. Operations were performed by both authors. The operative time, fluoroscopy time, intraoperative complications, plate length, number and position of screws used both in proximal and distal fragments, postoperative complications, and secondary procedures were recorded (Table 1).

The fracture follow-up data included time to full weight bearing and time to complete healing with bridging callus on three of four cortices in both AP and lateral views. The presence of change in fracture alignment, failure of plate or screws, complications such as infection, delayed union, malunion, and any unplanned operation were evaluated.

Surgical technique

The patient was placed in a supine position on the radio-lucent operating table. A supporting pad was placed under the knee in 30 degrees of flexion with the patella pointed upward. The limb was draped free from the iliac crest to the foot to allow intraoperative assessment of length and rotation. In segmental multifragmentary fractures or long spiral fractures, the opposite uninjured limb was also prepared to allow intraoperative comparison with the fracture side. The image intensifier was positioned on the opposite site of the operating table. The 4.5-mm broad dynamic compression plate (DCP) was used for all cases. The plates chosen were long, from 14–18 holes, depending on the fracture location and configuration. As a general rule, the plate should be long enough to allow the insertion of at least three screws each into the proximal and distal main fragments.

Small (4–5 cm) proximal and distal incisions are made over the lateral aspect of the femur with deep dissection down through the ilio-tibial tract and vastus lateralis muscle in line with their fibres to the plane between the periosteum and the vastus lateralis muscle. The lateral cortex of the femur was exposed using two Hohmann retractors—one ventral and one dorsal on both incisions. A tunnelling instrument was then tunnelled from the proximal incision toward the distal incision between both Hohmann retractors to create a submuscular, extraperiosteal tunnel. One end of the plate was tied to the hole at the tip of the tunnelling instrument by means of a suture. The tunnelling instrument was then withdrawn, pulling the attached plate along the prepared tunnel.

Once the plate was fully advanced into the tunnel, the image intensifier was used to check the correct position of the plate. The proximal end of the plate was positioned on the centre of the lateral cortex of the proximal femur and fixed with the first bicortical screw in the most proximal hole to reduce space between the bone and the plate. Longitudinal traction was applied to restore the length and rotation alignment of the femur. The alignment was checked with the image intensifier in both anteroposterior (AP) and lateral views. The second proximal screw was inserted in the third proximal hole. With the lateral cortex of the distal fragment exposed between two Hohmann retractors, the distal end of the plate was centred on the lateral cortex and fixed with a screw through the last plate hole. The length and angulation are rechecked. If reduction is satisfactory, the second distal screw was inserted into the second or third distal hole for more stability. At this step, the hip rotation test [10] was done by flexion of the hip and knee to 90 degrees, and internal and external rotation of the hip is performed. If alignment was achieved, the fixation was completed using at least three bicortical screws on each main fragment. Screw placement was done by two different techniques depending on surgeon preference. The first author prefers three or four separated screws in order to obtain more stable fixation but this approach requires longer or separate incisions for percutaneous screw insertion. The second author prefers three or four adjacent screws that can be inserted through the incisions.

Patients without associated injury were allowed to perform hip and knee motion as tolerated. Partial weight-bearing (10–15 kg) with crutches was started on the second or third postoperative day. The progressive weight-bearing was gradually increased as fracture union progresses. Radiographic evaluation was performed every six weeks until complete healing.

Results

Thirty-four patients with 36 closed femoral shaft fractures were treated with MIPO. There were 29 males and five females, with an average age of 31.4 years (range, 13–

Table 1 Patient characteristics

Case	Gender/ age	AO class	Indication for plating	Type of injury	Full weight bearing(wk)	Fracture healing(wk)	Follow- up (mo)	Complications	Secondary procedure	Plate holes	Proximal screws/ configuration*	Distal screws/ configuration*
1	M/17	32C2	Associated open Fx tibia	RTA	16	16	6	None	None	18	4C	3C
2	M/20	32B2	Chest injury	RTA	12	20	8	None	None	16	4S	4C
3	M/36	32C3	Vascular injury	RTA	32	40	12	None	None	18	3S	3S
4	M/21	32B3	Pelvic Fx	Fall	12	20	12	One broken screw	None	16	3C	3C
5	M/19	32C3	Acetabular Fx	RTA	20	32	18	Delayed union	Bone graft	16	3C	3C
6	M/33	32B2	Small canal	RTA	12	22	12	None	None	16	3S	3S
7	F/18	32A3	Small canal	RTA	10	20	8	None	None	14	3C	3C
8	F/40	32A2	Knee dislocation	RTA	12	20	6	None	None	16	4C	4C
9	M/38	32C2	Small canal	RTA	16	24	10	AP angulation 15°	None	16	3S	3S
10	F/31	32C2	Small canal	RTA	16	24	10	LLD 1.2 cm	None	18	3C	3C
11	M/45	32A2	Open Fx distal tibia	RTA	12	20	8	Malrotation 20°	Early correction	16	3S	4C
12	M/28	32C1	Abdominal, pelvic injury	RTA	16	24	12	AP angulation 10°	None	16	3S	3S
13	F/29	32C2	Acetabular, Interochanteric Fx	RTA	12	20	12	None	None	18	4C	3C
14	F/32	32C2	Small canal	RTA	12	20	12	Varus 10°	None	18	3S	3S
15	M/17	32C3	Small canal	RTA	13	20	12	None	None	16	3C	3C
16	M/33	32A3	Interochanteric Fx	Fall	12	22	18	None	None	14	3C	3C
17	M/22	32C1	Abdominal injury	RTA	12	20	10	None	None	18	4S	4C
18	M/47	32A2	Tibia plateau Fx	RTA	16	22	14	None	None	18	3S	3C
19	M/22	32C3	PCL, LCL injury	RTA	14	20	12	None	None	14	3S	3C
20	M/31	32C1	Small canal	RTA	20	28	24	Delayed union	Bone graft	18	3C	3S
21	M/18	32A2	Small canal	RTA	12	18	6	None	None	18	3C	3C
22	M/21	32A2	Small canal	RTA	12	18	10	None	None	18	3C	3C
23	M/13	32A2	Open growth plate	RTA	10	16	10	None	None	14	3C	3C
24	M/28	32B2	Small canal	RTA	12	20	8	None	None	18	3S	3C
25	M/18	32B2	Small canal	RTA	14	20	6	None	None	14	3C	3C

Table 1 (continued)

Case	Gender/ age	AO class	Indication for plating	Type of injury	Full weight bearing(wk)	Fracture healing(wk)	Follow- up (mo)	Complications	Secondary procedure	Plate holes	Proximal screws/ configuration*	Distal screws/ configuration*
26	M/35	32B3	Femoral neck Fx	RTA	16	20	8	None	None	14	3C	3C
27	M/46	32C3	T-L spine Fx	Fall	24	24	12	None	None	18	3C	3C
28	M/19	32B2	Small canal, pelvic Fx	RTA	16	20	10	None	None	14	3S	3S
29	M/50	32B2	Proximal tibia Fx	RTA	16	20	8	None	None	14	3C	3C
30	M/72	32A1	Periprosthetic	Fall	20	20	12	None	None	14	4C	3C
31	M/36	32B2	Abdominal, pelvic injury	RTA	20	24	8	None	None	18	3C	3C
32	M/32	32C2	Chest injury	RTA	20	20	8	LLD 1.5 cm	None	18	3S	3S
33	M/19	32B3	Femoral neck Fx	RTA	24	28	16	Two broken screws	Revised screws	14	3C	3C
	Bilateral Fx	32B2	Humerus Fx		20	20	8	None	None	18	3C	3S
34	M/40	32C2	Abdominal injury	RTA	26	20	12	None	None	18	3C	3S
	Bilateral Fx	32B2	Acetabular Fx		20	20	12	One broken screw	None	16	3C	3S

Fx fracture, RTA road traffic accident, PCL posterior cruciate ligament, LCL lateral collateral ligament, AP anteroposterior, LLD limb length discrepancy

* Number of screws used and configuration where C is cluster and S is separated

72 years). All fractures were followed-up at least until fracture union. Average follow-up was 10.8 months (range, 5–18 months). Thirty of these injuries were caused by road traffic accident and four from fall from height. The indications for MIPO included 20 cases (59%) of multiple injuries, 12 cases (35%) of small medullary canal, one open growth plate, and one periprosthetic femoral shaft fracture.

According to AO classification, there were nine (24%) type A (simple) fracture patterns, 13 (35%) type B (wedge) fracture patterns, and 15 (41%) type C (complex) fracture patterns. The 4.5-mm broad DCP with 14 holes was used in ten fractures, with 16 holes in ten fractures, and with 18 holes in 16 fractures. Three cluster screws were fixed in 40 fragments and three separated screws were fixed in 22

fragments. Four cluster screws were fixed in eight fragments and four separated screws in two fragments.

The average operative time was 94 minutes (range, 60–162 minutes), and average C-arm time was 112 seconds (range, 72–180 seconds). There was no varus or valgus malalignment greater than 10 degrees. There were two patients with 12 and 14 degrees of recurvatum without any long-term morbidity. There was one internal malrotation of 20 degrees that required revision. This patient had associated open segmental tibial fracture treated with an external fixator, and during the MIPO procedure the leg and the external fixator was covered with a towel; the hip rotation test was difficult to evaluate. Two patients had shortening of 1.4 and 1.7 cm respectively.



Fig. 1 **a** Case 27. A 46-year-old man sustained a motorcycle accident with femoral shaft fracture AO 32C. **b** The fracture was stabilised with 18 holes broad DCP using three cluster screws to bridge the fracture

zone. **c** Radiograph showing the fracture after six months with complete callus bridging the fracture. **d** The incisions and full functional range of motion after six months

There were no wound healing complications or infections. Thirty-three fractures (91.8%) healed without complication (Fig. 1a–d). The average time until three of four cortices had stable bridging callus was 21.0 weeks (range, 12–28 weeks). The average time to full weight bearing was 16.1 weeks (range, 10–32 weeks). Two cases had delayed union that required bone graft—one with gross displacement of bone fragment and large bone gap without callus at 12 weeks and the other with fracture distraction of 5 mm. There were three cases of broken screws—one case had two broken screws with plate loosening that needed revision and two cases had one broken screw with the fractures healed (Fig. 2). All broken screw cases were in the three-cluster screws group. There was no plate failure. One case had alignment change with plate bending of ten degrees varus.

Discussion

Closed intramedullary nailing is the standard treatment for femoral shaft fracture [22]. However, in certain situations intramedullary nailing may not be ideal. In our series, there were 12 cases of small medullary canal that measured 7 or 8 mm. Excessive reaming may caused thermal necrosis and severe osteomyelitis [8]. One patient had previous hip prosthesis such that nailing was not possible. The other cases were multiple injuries or associated fractures for which intramedullary nailing is contraindicated.

Fig. 2 Case 4 with one broken screw. The femoral shaft fracture fixed with 16 hole broad DCP with three clusters on each side of the fracture. The uppermost screw in the distal fragment was broken but at 20 weeks the fracture healed



Biological plating is the concept that is particularly useful in comminuted articular or metaphyseal fractures that cannot be nailed. This technique described by Mast et al. [14] uses “indirect reduction”, which minimises direct exposure and muscle stripping, reducing the fracture by distraction using either a distractor, tension device, or lamina spreader. In 1997, Wenda [21] and Krettek [12] introduced a percutaneous plating technique called “minimally invasive plate osteosynthesis (MIPO)”. MIPO has gained popularity and has continued to evolve in the last decade. Farouk et al. [2] studied the vascular supply to the femur in the cadaver and compared the effects of two surgical plating techniques, the conventional lateral plate osteosynthesis and MIPO, on femoral vascularity. The results showed that MIPO maintained the integrity of the perforators and nutrient arteries and was associated with superior periosteal and medullary perfusion.

There are few reports of MIPO of the femoral shaft in young adults because femoral shaft fractures which can be fixed by plate are better stabilised with interlocking nails. Kanlic et al. [7] reported 51 cases of paediatric femur fractures treated with submuscular bridge plate with excellent healing in all cases and early functional recovery. There were four patients (8%) who had leg-length discrepancy, one patient with a broken plate, and one refracture of a pathological fracture after early plate removal. Sink et al. [18] described the percutaneous submuscular bridge plating in the treatment of 27 unstable paediatric femoral fractures with early stable bony union in 11.7 weeks without significant complications. These two reports describe paediatric femoral shaft fractures in which the healing is faster than in adults. There was a report describing the MIPO of the femoral shaft in adults using the condylar blade or condylar screw. Wenda et al. [21] reported 17 cases of comminuted femoral fractures treated with the MIPO technique, where 13 cases had excellent healing and three needed bone grafting. There were no infections nor bleeding from perforator vessel injury.

In our study the femoral shaft fractures were treated with MIPO using broad DCP. The healing rate was 91.6%, and bone graft was performed in two cases. The union rate was acceptable compared to intramedullary nailing [22]. MIPO does not make bone graft unnecessary but reduces the rate significantly compared to conventional plating in complex fractures [21]. In the past, primary bone grafting in femoral plating in cases of no medial buttress of the bone was recommend to prevent fatigue failure of the plate [16, 19]. Geissler et al. [4] reported plating of 71 femoral fractures, 69% of which were bone grafted which can significantly reduce the complication rate of compression plating. The MIPO technique allows biological fracture healing by preserving the vascularity of all bone fragments, thus serving as a living bone graft. Therefore, primary bone

graft is not necessary. However, we recommend bone grafting in cases with no signs of callus on the radiographs at three months or cases with extreme destruction of vascularity by trauma, open fracture, or bone loss where healing takes more time. In our series delayed bone graft was performed in two cases of wedge fracture with 5 mm fracture distraction and in another with large bone gap from fracture displacement; both fractures had uneventful healing after 32 weeks.

The previous AO/ASIF guidelines for a specific number of screws or cortices in each fragment should no longer be used in MIPO as the only information concerning anchoring a plate in the main fragments to achieve good fixation stability. Field et al. [3] found that the omission of 40% of the total screw from a plate–bone construction did not have a deleterious effect on structural stiffness. Tornkvist et al. [20] also reported that the wider spacing of bone screws increased the bending strength of screw–plate fixation and can be more effective than increasing the number of screws. The modern trend toward using fewer screws should be done by optimally rather than maximally using screws to minimise damage to the bone. In this study each main fragment was fixed with three screws in 62 fragments and four screws in ten fragments. Sixty-nine fragments gave adequate stability of fixation until the bone healed, but three fragments had broken screws, all in the three-cluster group. There were no reports regarding the number of screws for the conventional plate in MIPO. From our data, we recommend that three cluster screws in each major fragment has a risk of screw breakage; therefore, at least three separated screws are preferable. However, the maximum age of the patients in our series was 72 years but the average age was 31.4 years. Most of the patients had good bone quality. We therefore cannot deduce whether the screw fixation in this manner would be effective in osteoporotic bone.

Since the fracture is usually reduced by closed reduction through the soft tissue window away from the fracture site, malalignment is a more common complication compared to conventional open reduction. To prevent malalignment, Krettek et al. [10] recommended various techniques to assess the correct limb length, axial alignment, and rotation. Rotational deformity was one of the complications in MIPO. Krettek et al. [12] reported the rotational deformity of 14 distal and proximal femoral fractures treated with MIPO—two had malrotation more than ten degrees and four had malrotation of nine degrees. In eight complex distal femoral fractures treated with transarticular MIPO [11], two had malrotation of 15 degrees. We found one case had 20 degrees of internal rotation deformity due to the technical error of draping. The tibia had an open fracture treated by an external fixator and the tibia was covered during the surgery; rotational assessment was difficult.

Limb length discrepancy (LLD) occurred in 8% of 51 paediatric femoral shaft fractures treated with submuscular plating [7]. Of 14 proximal and distal femoral fractures using MIPO described by Krettek [12], there were three cases of 1.5 cm LLD and three cases of LLD more than 2 cm. In our study we found two cases of shortening more than 1 cm (1.4 and 1.7 cm). Both of these had segmental comminution since there was no cortical contact between the distal and proximal fragments for determining the correct length. In such cases, preparation of both lower limbs to compare the lengths or using the meterstick technique is recommend.

In the frontal plane malalignment, there were no initial malreductions greater than five degrees because the screw reduced the plate and the bone closed together. There was one case of late angulation of the plate of ten degrees at four-months follow-up. In the sagittal plane, there were two patients with 12 and 14 degrees of recurvatum. However, these deformities posed no clinical morbidity with follow-up.

Our results in this study of MIPO treated with conventional plates are comparable to the results of the femoral shaft fractures treated with intramedullary nailing. The technique can be used for all femoral shaft fractures. Although the biomechanics of the plate fixation are less stable compared to the intramedullary nail, the mechanical stability is stable enough for bone healing. Healing was rapid, and postoperative care was simplified. The two major complications were malalignment and screw breakage. We recommend using at least three separated screws in each fragment to prevent stress on the screw and screw breakage. Intraoperative limb length, axial alignment, and rotation must be carefully assessed to prevent malalignment. The limitations of our study include lack of a comparison group, retrospective data collection, and no randomisation in outcome evaluation.

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