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ORIGINAL STUDY

Minimally invasive plate osteosynthesis without floating segment fixation for segmental fracture of femur

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Segmental fractures of the femur are technically difficult to manage by intramedullary nailing, the gold standard treatment. We specifically describe minimally invasive plate osteosynthesis (MIPO) without floating segment fixation for this particular fracture pattern. Twenty patients with segmental fractures of the femur were operated on by the MIPO technique. Data were collected on operative time, postoperative complications, union times, and clinical outcomes. The mean operative time was 63.5 minutes (range 50-90). There were no peri-operative complications. All fractures were united with a mean union time of 16.1 weeks (range 12-20). Regarding postoperative malalignment, limb shortening was demonstrated in 4 patients, valgus angulation in 2 and varus angulation in 3. One patient had a bent plate with 7°varus angulation. According to the Thoresen score, 13 were determined to be excellent values, 6 to be good and 1 to be fair. MIPO without floating segment fixation is a safe and effective alternative for segmental fractures of the femur especially in circumstances that are unsuitable or unfeasible for intramedullary nailing.

Keywords : MIPO; segmental fractures of the femur; floating segment fixation.

INTRODUCTION

Femoral fractures are usually from high-energy trauma that results in substantial injuries to bone and soft tissue. Closed intramedullary nailing is considered the gold standard treatment for femoral fractures and provides optimal mechanical properties and biological preservation as well as favorable outcomes *(1)*. Nevertheless, among various fracture patterns of the femur, a segmental fracture which is particularized by 1 or more completely-circumferential floating segments between the proximal and distal fragments is inherently challenging to be managed by closed nailing. This is due to the difficulty of fracture reduction by an indirect technique, difficulty in the reaming process, and nail passage, as well as the reported occurrence of delayed union and nonunion *(2-4)*.

MIPO provides relative stability without interference with the biological environment for bone healing *(5,6)* This technique is proposed for overcoming the adverse consequences of conventional open plating and as an alternative when

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intramedullary nailing is unsuitable and unfeasible. Even though several published reports demonstrated the high union rates and satisfactory results of femoral fractures treated by the MIPO technique *(7-9)*, to date there are still no clinical series specifically on MIPO of segmental fractures of the femur.

MIPO was postulated to be a safe and effective option for segmental fractures of the femur. Thus, we report a case series of patients with segmental fractures of the femur who received this minimally invasive procedure. We report the outcomes focusing on fracture union, postoperative complications including fracture malalignments, as well as radiologic and clinical outcomes.

MATERIALS AND METHODS

A retrospective case series of MIPO was performed on segmental fractures of the femur in 20 consecutively recruited patients at a trauma unit in a tertiary center between January 2016 and March 2019. No eligible patients declined to participate. The inclusion criteria were closed extra-articular segmental fractures of the femur which were categorized as 32C2 by AO/OTA classification and age $\geq$ 18 years. The exclusion criteria were open fractures, pathological fractures, concomitant femoral neck or intertrochanteric fractures, combined subtrochanteric and supracondylar fractures, and age <18 years. The demographic data, cause of injury, associated injury, level of fractures, and time-to-operate were recorded. This study has been approved by the ethical committees of Buddhachinaraj Hospital in accordance with the Declaration of Helsinki.

The operations were carried out as soon as the patient's hemodynamic status had been stabilized. Proximal tibia skeletal traction was applied if the operation needed to be delayed more than 24 hours after injury. All of the operations were performed under general anesthesia. The patient was positioned supine on a radiolucent table. Both affected and uninjured limbs were prepared and draped free to facilitate the measurement of length and rotation. The longitudinal distraction force was steadily maintained during the operation by a surgical assistant. The lateral approach to the proximal and distal fragments of the femur was used via 2 separate incisions. The lateral parapatellar approach was selected if the implant needed to be placed distally on the femoral condyle. The submuscular tunnel connecting the proximal and distal windows was created and then the chosen plate was applied through the tunnel passing over the floating segment and positioned properly on the proximal and distal fragments under image intensifier guidance. An attempt to re-approximate the floating segment to the main fragments was not carried out. After two screws were inserted into both proximal and distal fragments, the distraction force was released. Residual coronal and sagittal angulations were confirmed by the image intensifier. Passive rotation of both hips was compared to affirm correct axial rotation. Residual shortening was measured by comparing the length with the uninjured limb. Once all of the required alignments were obtained, the remaining screws were inserted for complete fixation. The wounds were closed under a vacuum drain. The type of plates and operative time defined as the time from skin incision to complete wound closure were recorded. The drain was removed at 2 days after surgery, and then physical therapy was started for restoring motion of hip and knee joints as well as ambulation with non-weight bearing. Partial weight-bearing was allowed at postoperative 6 weeks and full weight-bearing at 12 weeks or presentation of bridging callus. Weight-bearing was delayed for 3 months for 1 patient (patient no.11) who had bilateral femoral fractures. Radiographic assessment of fracture alignment and fracture union was performed during the immediate postoperative period and every 6-8 weeks. Fracture union was determined as the presentation of a bridging callus at 3 of 4 cortex in anterior-posterior and lateral views. Orthoroentgenogram was taken at postoperative 1 year. Clinical assessment including postoperative complications, and Thoresen score which designated the results to be excellent, good, fair, or poor regarding fracture alignment, degree of pain and swelling, and range of motion (ROM) of the affected knee were recorded *(10)*.

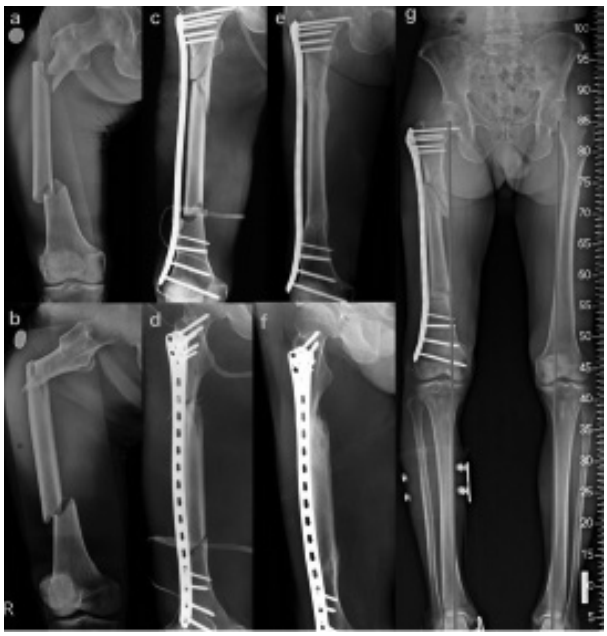

Fig. 1. — (a,b) Subtrochanteric and distal shaft fractures of right femur. (c,d) Immediate post-operative radiographic images of MIPO with reversed DF-LCP fixation. (e-g) Radiographic images at post-operative 9 months.

Fig. 2. — (a,b) Combined proximal shaft, distal shaft and supracondylar fractures of left femur. (c-g) At post-operative 1 year of MIPO with DF-LCP fixation, the fractures were united and the injured limb was fully functional.

RESULTS

The present series of 20 cases included 17 males and 3 females with a mean age of 45.9 years (range 22-66). All of the patients were injured by motor vehicle accidents. Regarding the level of fractures of each femur, 6 were subtrochanteric-shaft (Fig. 1), 9 were shaft-shaft , 4 were shaft-supracondylar, and 1 was shaft-shaft-supracondylar (Fig. 2). The mean time-to-operate was 68.2 hours (range 8-168) (Table 1).

There were no immediate postoperative complications. The mean follow-up time was 17.2 months (range 12-36). According to types of plate, 4.5/5.0 broad locking compression plates (LCP) were used in 2 patients, distal femur LCP (DF-LCP) in 10, and reversed DF-LCP in 8. The mean operative time was 63.5 minutes (range 50-90). All fractures were united in a mean duration of 16.1 weeks (range 12-20). Regarding postoperative malalignments, 4 patients had limb shortening of 10, 10, 10, and 5 mm, 2 patients had valgus angulation of 4° and 5°, and 3 patients had varus angulation of 7°, 7°, and 5°. No apparent rotational deformities were observed in any patients. One patient had a bent plate with 7°varus angulation and the fractures were uneventfully united with excellent clinical outcomes. According to the Thoresen score, 13 were determined to be excellent values, 6 to be good and 1 (patient no.14), who suffered from a concomitant severe head injury, to be fair (Table 2).

DISCUSSION

Segmental fractures of the femur are technical tasks in orthopedic trauma. The utility and reliability of MIPO for these particular fractures remain currently still undetermined. In the present study, all fractures were united and good-to-excellent clinical outcomes were achieved in all except 1 case of MIPO for segmental femoral fractures.

Intramedullary nailing for treating segmental femoral fractures is technically difficult due to obstacles in several steps during the operation in-cluding fracture reduction, guide insertion, reaming, and nail passage especially when the

Table l. — Demographic and clinical characteristics

Patient No.	Sex	Age	Side	Cause of injuries	Level of fractures	Associated injuries	Time to operate (hour)
1	F	66	L	MVA	Sub-MS	Rt. distal radius fracture	96
2	M	24	L	MVA	MS-MS	None	8
3	M	22	L	MVA	MS-Sup	Pelvic fracture, bladder injury	120
4	M	45	R	MVA	MS-MS	None	168
5	M	27	R	MVA	MS-Sup	Rt. floating elbow	10
6	M	66	R	MVA	Sub-MS	None	12
7	M	64	R	MVA	MS-Sup	None	8
8	M	24	R	MVA	MS-MS	None	72
9 (Fig. 1)	M	58	R	MVA	Sub-MS	None	120
10	M	65	L	MVA	Sub-DS	Lt. patellar fracture	9
11	M	40	R	MVA	Sub-MS	Contralateral femoral fracture, multiple rib fractures, kidney injury	120
12	M	27	R	MVA	MS-MS	Lt. tibial shaft fracture	96
13	M	63	L	MVA	PS-DS	None	12
14	M	50	R	MVA	MS-DS	Intra-cranial hemorrhage	9
15	M	49	L	MVA	Sub-DS	None	120
16	F	29	L	MVA	PS-MS	Lt. distal radius fracture	12
17	M	54	L	MVA	PS-Sup	None	144
18	M	70	L	MVA	PS-DS	None	72
19 (Fig. 2)	F	34	L	MVA	PS-DS-Sup	Lt. distal radius fracture	12
20	M	40	L	MVA	PS-DS	Lt. tibial plateau fracture	144

MVA, motor vehicle accident; Sub, subtrochanteric; PS, proximal shaft; MS, midshaft; DS, distal shaft; Sup, supracondylar

Table ll. — Radiographic and clinical outcomes

Patient No.	Operative time (minute)	Type of plate	Time to union (wk)	Thoresen score	Complication	Follow-up time (month)
1	75	Reversed DF-LCP	12	excellent	Shortening 10mm	12
2	65	Broad LCP	16	excellent	None	16
3	50	DF-LCP	20	good	Shortening 10mm, valgus 4°	24
4	55	DF-LCP	20	good	Shortening 10mm, varus 7°	12
5	60	DF-LCP	16	excellent	None	12
6	70	Reversed DF-LCP	16	excellent	None	12
7	60	DF-LCP	12	excellent	None	15
8	55	Broad LCP	20	excellent	Bent plate with varus 7°	18
9 (Fig. 1)	70	Reversed DF-LCP	12	good	None	36
10	50	Reversed DF-LCP	16	good	None	24
11	90	Reversed DF-LCP	18	good	None	18
12	60	DF-LCP	16	excellent	None	15
13	70	Reversed DF-LCP	20	excellent	None	15
14	70	DF-LCP	16	fair	Shortening 5mm, valgus 5°	18
15	50	Reversed DF-LCP	16	excellent	None	18
16	55	Reversed DF-LCP	16	excellent	None	17
17	75	DF-LCP	12	excellent	None	15
18	50	DF-LCP	12	excellent	Varus 5°	15
19 (Fig. 2)	65	DF-LCP	16	excellent	None	20
20	75	DF-LCP	20	good	None	12

LCP, locking compression plate; DF-LCP, distal femur locking compression plate.

floating segment is less than 10 cm in length. Various surgical techniques have been purposed to assist in the reduction and reaming process of the unstable floating segment including reduction finger, clamp assisted reduction, 4 pin assisted reduction, and miniopen plating augmentation *(3,11-13)*. In the literature, the incidence of nonunion after closed intramedullary nailing of segmental femoral fractures is 0-22% *(2,3)*. Babalola et al described open nailing in a resource-restricted setting for 8 segmental fractures of the femur and all were united *(14)*.

MIPO technique is comprised of indirect reduction to restore length, alignment, and rotation along with vascular preservation of the fracture zone and providing relative stability by plate fixation to promote secondary bone healing *(5)*. The remarkable advantage of MIPO for femoral fractures is in the situations unfeasible for nailing such as deformed or narrow canals, very distal fractures with intra-articular extension, or femoral fractures in children *(8,15)*. In the particular circumstance of unsuitability to use a fracture table as polytrauma with an unstable pelvic fracture or concomitant perineal injury, MIPO would be an indispensable option.

Another virtue of MIPO is in the setting of multiple injuries. Stannard et al. described 10 open fractures with severe soft tissue injuries treated by MIPO instead of external fixation and only one of them developed a superficial infection *(16)*. In the present study, the average operative time was 63.5 minutes and no operation spanned more than 90 minutes. Because of less-equipped requirements, short operative time and less invasive technique, MIPO is especially useful in damage control surgery for polytrauma patients who are classified in borderline or unstable groups.

Ipsilateral neck or intertrochanteric fractures were not enrolled in this study because combined implants such as multiple screws and plates or multiple screws and retrograde nailing are generally recommended *(17)*. Another excluded group was combined subtrochanteric and supracondylar fractures due to no feasible precontoured single plate to stabilize these dual fractures.

Cortical apposition between the floating segment and main fragments is inevitably necessary for nail insertion. Additionally, the degree of displacement and size of the third fragments influenced bone healing of femoral fractures treated by intramedullary nailing *(18,19)*. Nevertheless, there have been no published reports delineating the impact of cortical apposition and displacement of the floating segment on the bony union of femoral fractures operated on by the MIPO technique. In the present study, an effort to manipulate the floating segment was not performed to avoid further dissection and further blood loss. However, all of the fractures were ordinarily united whether spontaneous cortical apposition occurred or not (Fig. 2).

Apivatthakakul et al. reported MIPO of femoral fracture in 34 cases. Seven of them were segmental fractures which coded as 32C2 and all fractures were united without any secondary procedures *(8)*. In a systematic review of 19 studies of femoral biologic plate fixation by Papakostidis et al., the union rate was 98.4% of 697 femoral fractures *(9)*. A prospective series of Angelini et al. demonstrated a 95% union rate of 57 simple femoral fractures operated by MIPO *(7)*. Consistent with formal studies, all segmental fractures in the present study were united affirming the high reliability of MIPO for femoral fractures with this particular fracture pattern.

Postoperative malalignment and subsequent malunion are major concerns of MIPO for femoral fractures. In a series of Apivattakakul et al., 4 of 7 MIPO of segmental femoral fractures had malalignment including shortening in 2 patients, varus angulation in 1, and AP angulation in 1 *(8)*. The analysis of Papakostidis et al. demonstrated a 0-29% malunion rate after femoral biologic plating and 74% of malunion was coronal and sagittal angulation *(9)*. Lill et al. used MRI to measure postoperative rotational malalignment and described a significant difference in the average malrotation between MIPO (14.3 degrees) and conventional open reduction (5.2 degrees) *(20)*. In the present series, by plain radiographic images and clinical presentation, 6 of 20 patients demonstrated some degree of residual angulation and shortening but without obvious deformities and symptomatic disability.

There were some limitations to the present study. It was an uncontrolled retrospective case series and the number of the enrolled patients was small, thus some aspects such as the need of establishing cortical apposition cannot be conclusive. Comparing the MIPO technique for these particular fractures with closed intramedullary nailing could provide more relevant scientific data. Despite no apparent or symptomatic rotational malalignment demonstrated in this series, objective measurements such as CT scan or MRI could assess more accurate degrees of deformities which may affect late posttraumatic arthritis of the knee joint.

CONCLUSION

Concerning utility, simplicity, and reliability, MIPO without floating segment fixation can be a noteworthy alternative for segmental fractures of the femur especially in the situations where the gold standard treatment as intramedullary nailing is unfeasible or unsuitable.

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