

# Open Biological Reduction and a Locking Compression Plate for Distal Femoral Fractures: A Review of 40 Cases

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**Objective:** To determine the clinical results of patients with comminuted fractures of the distal femur treated by open biological reduction using an indirect reduction technique and locking compression plate (LCP) without primary bone grafting.

**Material and Method:** Prospective observation was conducted with 40 patients (24 males and 16 females), average age 48.7 years (range 20-81), with distal femoral fractures AO/OTA types A2 (5), A3 (17), C2 (8) and C3 (10) who were treated using an open indirect reduction technique and fixation with LCP between May 2010 and December 2013. Among the 40 patients, 28 were closed fractures and 12 were open fractures. Clinical results were evaluated using the Neer score six months after surgery. Follow-up periods ranged from 12 to 36 months (average 18.35).

**Results:** Thirty eight (95%) of the fractures healed completely without a secondary procedure. The average time to union was 14.45 weeks (range 12-24). The average knee range of motion was 2° (0-5) to 110° (20-140). Two patients had an implant failure which required revision and secondary iliac bone grafting. There were no varus or valgus deformities, no limb shortening and no deep infections. Neer scores were excellent in 18 cases (45%), good in 14 (35%), fair in 6 (15%) and poor in 2 (5%). The mean Neer score was 83.60 (range 50-100).

**Conclusion:** The indirect reduction technique for the treatment of comminuted distal femoral fractures provides satisfactory results when combined with LCP fixation.

**Keywords:** Distal femoral fracture, Indirect reduction technique, Comminuted fracture, Locking compression plate

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Distal femoral fractures typically require operative fixation to achieve a good functional outcome. Challenges in treating these fractures include comminuted articular fragments, bone loss and osteoporosis leading to implant failure (screw and/or plate breakage) or construct deformity (nail or plate bending).

Evolution of surgical techniques in recent decades has included changing the principle of treatment to increase emphasis on the biology and preservation of the blood supply including using the less invasive stabilization system (LISS) and locking plates<sup>(1,2)</sup>, the minimally invasive plate osteosynthesis (MIPO technique)<sup>(3)</sup>, the indirect reduction and submuscular technique<sup>(4,5)</sup>, and retrograde nailing<sup>(6)</sup>. All these methods have yielded effective treatment outcomes, high union rates, low rates of implant failure and low rates of secondary procedures for bone grafting.

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The concept of indirect reduction as introduced by Mast and Ganz<sup>(7)</sup> combines minimal destruction of soft tissue with a technique that uses reduction tools to avoid unnecessary intraoperative soft tissue stripping as a method of preserving blood supply, promoting bone healing and avoiding the need for anatomical reduction of the metaphysis and diaphysis. The surgical technique of indirect reduction damages the blood supply to the bone less than traditional open reduction; additionally, the management of alignment is easier than with MIPO. Results of using the indirect reduction technique of treating distal femoral fractures with the condylar blade plate and condylar buttress plate reported by Bolhofner et al<sup>(7)</sup> were good to excellent in 84% of cases and results of treatment with the condylar blade plate reported by Kolb et al<sup>(8)</sup> were good to excellent in 82% of cases. Disadvantages of the condylar buttress plate include poor fixation in osteoporotic bone and varus collapse in medial comminution fractures, while the condylar blade plate is unable to control coronal plane fractures which results in poor fixation in osteoporotic bone<sup>(9)</sup>. A locking compression plate provides angular stability between screw and plate which prevents secondary

varus malalignment and also offers the advantage in osteoporotic bone of increasing the pullout resistance of the locking head screw<sup>(10,11)</sup>.

Previous studies of the treatment of distal femoral fractures using the biological indirect reduction technique and LCP fixation usually were combined with "MIPO and LISS"<sup>(12)</sup>. Vallier et al<sup>(13)</sup> reported on LCP fixation for distal femoral fractures (33-C3) using the indirect reduction technique, in some cases with primary bone grafting as well. The present study is similar to the study of Vallier et al, but without primary bone grafting.

### Objective

To determine the clinical results of patients with comminuted fractures of the distal femur treated by open biological reduction using the indirect reduction technique and LCP without primary bone grafting.

### Material and Method

The present study was approved by the Ethics Committee of Sawanpracharak Hospital. Forty patients with distal femoral fractures (AO/OTA types A2, A3, C2, C3) were treated with open reduction and internal fixation by two surgeons between May 2010 and December 2013. The exclusion criteria were growth plate fracture, periprosthetic fracture, metabolic bone disease and pathological fracture. The operations were performed using the standard lateral approach for the distal femur and the parapatellar approach for articular fractures. Surgical technique followed indirect reduction concepts, including the use of an external fixator or femoral distractor for reduction of metaphyseal or metadiaphyseal fractures without exposing the fracture site (Fig. 1) as well as the use of a Kirschner wire joystick and a large periarticular cramp aid for reduction of articular fractures with

minimal destruction of posterior and medial soft tissue. Medial exposure was not performed and no primary bone grafting was done. Intraoperative fluoroscopy was used to assess alignment and joint congruity. A minimum of four locked screws were placed distally and a minimum of eight cortices were placed proximally<sup>(13)</sup>. Open fractures and polytraumatized patients were treated using a staged procedure. Rehabilitation protocol consisted of passive and active movement of the knee and toe-touch weight bearing in patients who could use walking aids. Progressive weight bearing was allowed depending on the callus formation until fracture healing. Patients were followed-up to determine clinical outcomes for pain, knee motion, walking capacity using radiography four weeks postoperatively, with subsequent assessment every four weeks until the fracture healed. Neer scores were used for overall outcome evaluation at the sixth month after surgery.

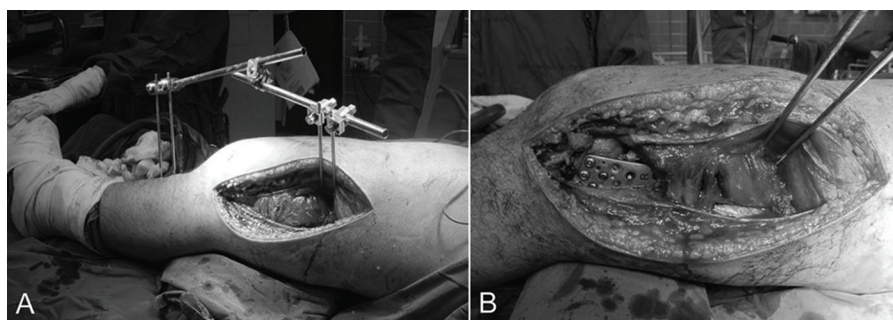
### Statistical analysis

Results are expressed as mean, standard deviation (SD) and range for quantitative data. Other variables are presented as percentages to show proportions.

### Results

At the beginning of the present study, 44 patients with 45 distal femoral fractures were included; however, four patients with five fractures were lost to follow-up, leaving 40 patients with 40 fractures, 24 males and 16 females, average age of 48.7 years (range 20-81). There were 28 closed fractures and 12 open fractures. Demographic data, fractures classification, mechanism of injury, associated injuries including organ injuries are summarized in Table 1.

Patients started full weighted bearing when callus was apparent in follow-up radiographs, at a mean



**Fig. 1** Open reduction of fracture distal femur using lateral approach combined with external fixator. The muscle on the lateral side was not completely detached. The plate insertion was done beneath the vastus lateralis.

**Table 1.** Patient demographic and injury characteristics

Age	Sex	Mechanism of injury	Open/closed	OTA classification	Associated injury					
Mean age	Male	24	Car accident	5	Open fracture	12	A2	5	Isolated fracture	28
48.7±13.31 years (range 20-81)	Female	16	Motorcycle accident	30	Closed fracture	28	A3	17	Multiple injury	8
			Fall	5			C2	8	Fx distal radius	3
							C3	10	Fx clavicle	1
									Fx pelvis	1
									Fx radius and ulnar	1
									Fx patellar	3
									Fx tibial plateau	1
									Fx shaft tibia	2
									Rupture quadriceps tendon	1
									Rupture ACL	1
									Polytrauma	4
									Head injury	2
									Pneumothorax	1
									Rupture liver	1
Total				40						

ACL = anterior cruciate ligament

of 9.5 weeks post op (range 8-16). The average time to radiological union was 14.45 weeks (range 12-24), and follow-up periods were from 12 to 36 months, averaging 18.35 months. Two patients had implant failures at three months postoperatively which required revision osteosynthesis and secondary iliac bone grafting. There were no varus or valgus deformities, no limb shortening and no deep infections in any of the patients. The results of treatment are shown in Table 2.

Thirty eight patients (95%) had completely healed fractures (Fig. 2-4). The average range of motion of the knee joint was 2° (0-5) to 110° (20-140). Functional outcomes according to the Neer score were excellent in 18 of cases (45%), good in 14 (35%), fair in 6 (15%) and poor in 2 (5%). The mean Neer score was 83.60 (50-100).

### Discussion

Fracture of the distal femur has two distinct patterns: those in young patients resulting from high-energy trauma and those in elderly patients from low-energy injuries. The report by Weight and Collinge showed that the outcomes of treatment of those two groups can be analyzed together<sup>(14)</sup>. Reported complications with open anatomical reduction and rigid internal fixation with traditional plate include delayed or nonunion (29% to 38%) and infection (7% to 20%)<sup>(15)</sup>. Using indirect reduction and internal fixation improved the results of treatment. The advantage of instability after biological internal fixation by bridging plate is the production of early bridging callus even with no bone grafting<sup>(16)</sup>. The disadvantage

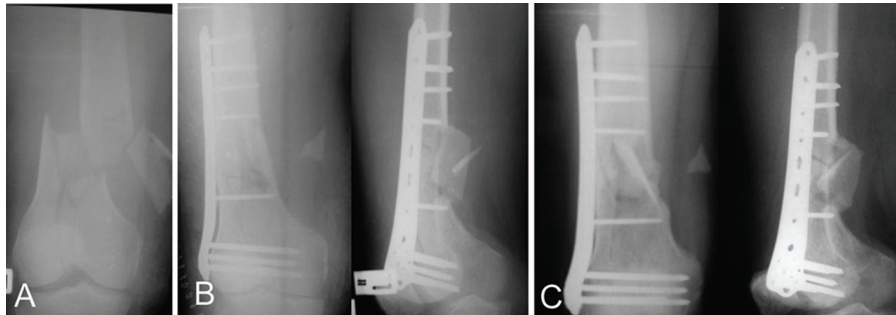
**Table 2.** Results of treatment

Mean follow-up (months)	18.35±2.80 (range 12-36)
Time to radiological union (weeks)	14.45±2.65 (range 12-24)
Knee ROM (degrees)	2±1.85 (range 0-5) to 110±26.31 (range 120-140)
Implant failures	2 (5%)
Infections	0
Secondary procedures	2 (5%)
Neer scoring system	83.60±14.06 (range 50-100)
Excellent	18 (45%)
Good	14 (35%)
Fair	6 (15%)
Poor	2 (5%)

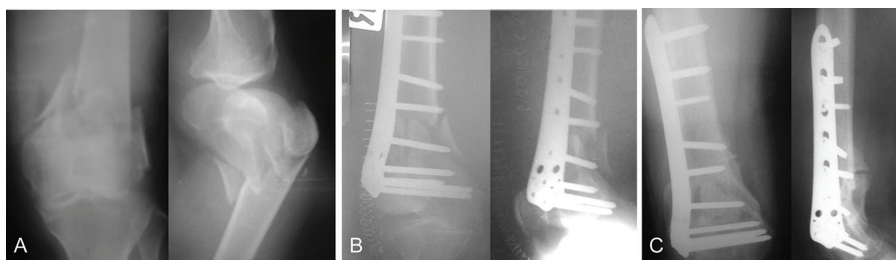
ROM = range of motion

of this technique is that it is technically demanding. The authors found that the management of alignment is easier than manual manipulation when applied with a femoral distractor or with external fixation especially in a comminution fracture or a floating knee injury. Both devices have the advantage of maintaining alignment during attachment of the plate to the bone. Augmentation with a hinged knee brace or a long leg cast in cases with severe osteoporosis, with external fixation in cases of severe comminution, for a short period of three to four weeks is recommended. Slow appearance of callus formation after three to six months may be an indication of the need for bone grafting<sup>(13)</sup>.

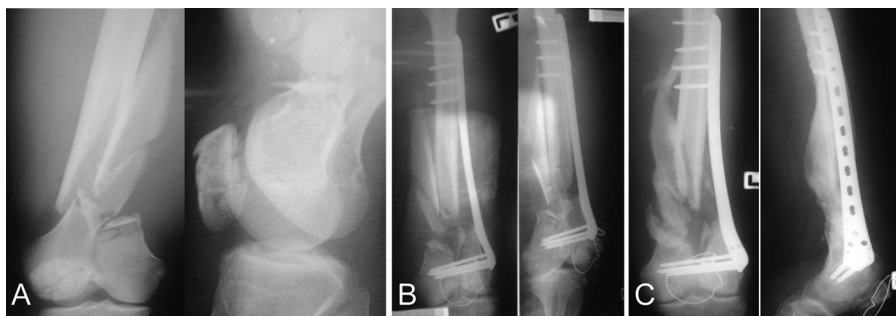
Ostrum and Geel<sup>(4)</sup> and Bolhofner et al<sup>(7)</sup> reported early union in 93% to 100% of fractures and infection rates of 0% to 2% of cases. On the other hand, a recent report by Henderson et al<sup>(17)</sup> reported a 19%



**Fig. 2** Distalfemoral fracture (A3, AO classification): (A) Initial injury, (B) Postoperative reduction, (C) Follow-up at 10 months.



**Fig. 3** Distal femoral fracture (C2, AO classification): (A) Initial injury, (B) Postoperative reduction, (C) Follow-up at 20 months.



**Fig. 4** Distal femoral fracture (C3, AO classification): (A) Initial injury, (B) Postoperative plain radiograph, (C) Follow-up at 12 months.

nonunion rate, a 15% delayed union rate, a 20% implant failure rate and a 32% rate of needing a second procedure. Implant failure occurring early (less than 3 months post op) was most often the result of mechanical instability secondary to either the surgical technique or the implant design, while implant failure occurring late (more than 3 months post op) was most often due to fatigue failure (nonunion or delayed union)<sup>(17)</sup>. Sixty percent of failures occurred in the proximal fragment. Independent predictors of implant failure included diabetes, an OTA A3 fracture pattern, a high body mass index, the use of a stainless steel plate, the use of a shorter plate length<sup>(18)</sup> and improper coronal plane alignment. These are the most crucial factors

affecting overall outcome<sup>(9)</sup>. In our practice, bicortical fixation of at least eight cortices was performed using proximal fixation. We found that six patients had screw breakage at the screw-plate interface, but that the fracture had already united. Two patients had screws loosen and implant failure more than three months post op (delayed union). One was a type C2 closed fracture, and the other was type C2 open fracture. The patients were treated with an anatomical dynamic compression plate and an iliac crest bone graft.

Thirty-eight patients (95%) had successful results with a median union time of 14.45 weeks (range 12-24). This result was similar to previous comparative studies<sup>(7,8,13)</sup> (Table 3). Open biological

Study	No. of patients	Fracture type (AO system)	Closed/open	Implant	Primary bone graft (%)	Time to radiological union (weeks)	Mean follow-up time	Implant failures	Infections	Secondary procedures	Scoring system
Bolhofner et al. 1996 <sup>(7)</sup>	57	8 A2 14 A3 10 C1 16 C2 9 C3	47/10	Condylar buttress plate 29 Condylar plate 28	0	10.7 (8-16)	12 months	2	1	Not stated	Schatzker 44% excellent 40% good 11% fair 5% poor
Vallier et al. 2006 <sup>(13)</sup>	46	5 A3 5 C1 9 C2 27 C3	21/25	LCP	2 allograft 6 iliac crest bone graft (17%)	Not stated	Not stated	6	1	6	Not stated
Kolb et al. 2009 <sup>(8)</sup>	41	13 A 29 C	33/8	Condylar plate	5 (12%)	14 (8-13)	9.5 (7-12) years	4	2	6	Neer 48% excellent 30% good 12% fair 9% poor

reduction using the indirect reduction technique is technically demanding and involves a significant learning curve. Although these outcomes were satisfactory, a further randomized controlled trial is needed.

### Conclusion

The Indirect reduction technique for the treatment of comminuted distal femoral fractures provides satisfactory results when combined with LCP fixation.

### What is already known on this topic?

Previous studies of the treatment of distal femoral fractures using the biological indirect reduction technique and LCP fixation usually were combined with “MIPO and LISS”<sup>(12)</sup>. Vallier et al<sup>(13)</sup> reported on LCP fixation for distal femoral fractures (33-C3) using the indirect reduction technique without “MIPO and LISS”, in some cases with primary bone grafting as well.

### What this study adds?

The present study is similar to the study of Vallier et al, but without primary bone grafting.

### Acknowledgement

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### Potential conflicts of interest

None.

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## ผลการรักษากระดูกต้นขาส่วนปลายหักด้วยวิธีจัดกระดูกเข้าที่โดยทางอ้อมและตามกระดูกด้วยโลหะแผ่นตามกระดูก

โชติ ภาวศุทธิกุล, ต้อม จันทรสัทพ์

**วัตถุประสงค์:** เพื่อศึกษาผลรักษากระดูกต้นขาส่วนปลายหักด้วยการผ่าตัดและจัดกระดูกเข้าที่โดยทางอ้อม (*indirect reduction technique*) และตามกระดูกด้วยโลหะแผ่นตามกระดูกชนิด *locking compression plate*

**วัสดุและวิธีการ:** ศึกษาในผู้ป่วย 40 ราย เป็นผู้ป่วยกระดูกหักแบบแผลเปิด 28 ราย แบบแผลเปิด 12 ราย แบ่งตาม AO/OTA classification เป็นชนิด A2 5 ราย A3 17 ราย C2 8 ราย และ C3 10 ราย ผู้ป่วยทุกรายได้รับการผ่าตัดจัดกระดูกเข้าที่โดยทางอ้อม และตามกระดูกด้วยโลหะแผ่น ตามกระดูก *locking compression plate* ระยะเวลาเฉลี่ยในการนัดผู้ป่วยเท่ากับ 18.35 เดือน (12-36 เดือน) ประเมินผลการรักษาโดย *Neer score* ที่ 6 เดือน ภายหลังการผ่าตัด

**ผลการศึกษา:** ผู้ป่วย 38 ราย (95%) มีกระดูกเชื่อมติดสมบูรณ์โดยไม่ต้องมีการผ่าตัดแก้ไข เวลาที่ใช้ในการติดของกระดูกเฉลี่ย 14.45 สัปดาห์ (12-24 สัปดาห์) พิสัยการเคลื่อนไหวของข้อเข้า  $2^{\circ}$  (0-5) ถึง  $110^{\circ}$  (20-140) ผู้ป่วย 2 ราย มีการสูญเสียการยึดตรึงของโลหะตามกระดูกที่ต้องผ่าตัดแก้ไข ไม่พบการเชื่อมติดของกระดูกผิดปกติรูปแบบอื่นๆ และไม่พบภาวะแทรกซ้อนใดๆ *Neer score* ได้ค่าเฉลี่ย 83.6 (50-100) ผลดีมาก 18 ราย (45%) ผลดี 14 ราย (35%) ผลพอใจ 6 ราย (15%) และผลไม่ดี 2 ราย (5%)

**สรุป:** การผ่าตัดและจัดกระดูกเข้าที่โดยทางอ้อมในการรักษากระดูกต้นขาส่วนปลายหักให้ผลการรักษาเป็นที่น่าพึงพอใจ โดยเฉพาะเมื่อผ่าตัดร่วมกับการตามกระดูกด้วยโลหะแผ่นตามกระดูกชนิด *locking compression plate*

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