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Original Article

Clinical efficacy of augmented medial assisted plate for treating comminuted metaphyseal fracture of the distal femur

Rongbin Sun*, Yu Zhang*, Zhongjie Yu

*Department of Orthopedics, The Second Changzhou People's Hospital Affiliated to Nanjing Medical University, Changzhou 213003, China. *Co-first authors.*

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Abstract: Objective: To investigate the clinical efficacy of lateral locking plate (LLP) combined with medial assisted plate (MAP) for treating comminuted distal femoral fracture (CDFF). Methods: A total of 32 patients with distal femoral fractures (DFF) were treated at our hospital between January 2012 and December 2014; of them, 11 received LLP+MAP (Group A) and 21 received LLP internal fixation (Group B). The operation time, intraoperative blood loss, fracture healing time, and postoperative knee function recovery were compared between the two groups. Results: The operation time of Group A was statistically longer than that of Group B ($P < 0.05$), but there was no significant intergroup difference in intraoperative blood loss ($P > 0.05$). The patients were followed up for 11-25 months after surgery. Group A had one case of incision infection, but all fracture cases healed with the average healing time of 5.39 ± 0.69 months. Group B had two cases of nonunion, with the average healing time of 5.86 ± 0.59 months (except for cases of nonunion). HSS (hospital for special surgery) score performed 1 year after surgery revealed that Group A had seven cases with excellent results, three with good results, and one with acceptable results, while Group B had 12 cases with excellent results, six with good results, and three with acceptable results. Conclusions: MAP can increase the stability of comminuted fracture of the distal femur and improve the fracture healing rate.

Keywords: Distal femoral fracture, medial plate, nonunion

Introduction

Distal femoral fractures (DFF) account for 4-6% of femoral fractures, and most cases are caused by high-impact injury and characterized by multiple onset, comminution, instability, and easy spread to the articular surface. The main surgical goal is to reconstruct the anatomical structure of articular surface, restore the rotation and axis, and ensure the stability of early postoperative functional activities. In recent years, treatments against DFF have progressed greatly, and the lateral locking plate (LLP) has gradually replaced the intramedullary nail or common blade plate and become the standard internal fixation material in treating DFF because the mutual locking of its screw and the steel plate can form a stable, reliable, and fixed fracture frame [1, 2]. However, with the increase in LLP use, delayed fracture healing, nonunion, internal fixation failure, or other complications have gradually increased [3]; the incidence of nonunion in particular is reportedly 0-10% [4-6]. Diabetes, open fractures, infection, and the use of stainless steel materials are all important reasons [7]. As for comminuted metaphyseal fracture of the distal femur (CMFDF), another important factor is the instability of fixation mechanics, especially medial cortical defect varus or collapse, which can often lead to early failure of internal fixation [8, 9]. Single LLP fixation for CMFDF often lacks adequate support for medial cortical defects, so the vertical load may cause a bending tendency and instable fixation; furthermore, because the stress concentrates on the lateral plate, it may result in internal fixation failure, delayed healing, or nonunion [10, 11]. Due to the increased risk of LLP, MAP is considered an effective way to prevent deformities such as varus or collapse. We retrospectively analyzed the clinical data of the patients with CMFDF

Table 1. Comparison of basic preoperative information between the two groups (P > 0.05)

	A	B	P
n	11	21	
Average age (years)	46.8 ± 10.5	44.0 ± 11.4	0.491
Sex (M/F)	6/5	13/8	0.687
AO-Type			
A2/3	6	13	
C2/3	5	8	
Open fracture Gustilotype I (n)	1	2	

between January 2012 and December 2014 to investigate one more solid and effective internal fixation techniques for the clinical treatment of such fractures to reduce such fractures causing nonunion.

Materials and methods

Inclusion and exclusion criteria

Inclusion criteria were: (1) age ≥ 18 years old; (2) diagnosis of Type A2, A3, C2 or C3 unstable fracture by the AO classification of DFF; and (3) use of LLP.

Exclusion criteria were: (1) Previous knee trauma or surgery; (2) Lower-extremity deformity; (3) No use of LLP as the internal fixation; and (4) follow-up duration < 12 months.

General information

The clinical data of a total of 32 patients (19 men, 13 women; age 18-67 years; mean age, 48 years) with DFF in whom LLP was used between January 2012 and December 2014 were retrospectively analyzed. Eighteen cases were on the left side and 14 were on the right side; there were no cases of bilateral fracture. Fracture AO classification classified six cases of type 33A2, 13 of type 33A3, 11 of type 33C2, and two of type 33C3.

Injury causes included: 15 cases, traffic accident; seven cases, a heavy objecting falling; and 10, falling. Combined injuries included one case of closed craniocerebral injury, one of pelvic fracture, three of patellar fracture, and one of tibial fracture. There were 29 cases of closed fracture and three cases of open fracture (Gustilo type I: two in Group B, one in Group A). Group B had a total of 21 cases, while Group A had 11 cases; there was no significant intergroup difference in sex, age, AO fracture classification, or injury cause (P > 0.05, **Table 1**), meaning that Groups A and B were comparable.

Preoperative preparation and treatment

The two groups were subjected to preoperative bone traction to improve the alignment; the three cases of open fracture were first subjected to debridement and suturing together with treatment of swelling and symptoms and underwent surgery when their skin and soft-tissue conditions met the surgical requirements. The time interval from injury to surgery was 5-12 d (mean, 7 d).

Anesthesia and posture

After the administration of continuous epidural anesthesia, each patient was placed in the supine position on one operating bed equipped with an X-ray machine; the lesioned limb was padded with one pillow below and the knee joints were slightly flexed.

Surgical procedures

The patients with extra-articular fracture (AO type 33A2 or 33A3) were treated with a distal femoral incision: one 6-cm incision was made from the Gerdy nodule to the proximal end and the iliotibial bundle was cut open along the longitudinal axis. The patients with intra-articular comminuted fracture (AO type 33C2 or 33C3) were treated with a lateral patellar approach to incise the joint capsule; the patella was then inverted inward to fully reveal the distal articular surface for anatomical reduction. If necessary, screws alone were used to fix the fracture fragments to convert the femoral intercondylar fracture to a supracondylar fracture; meanwhile, the screwing location and direction were carefully chosen to prevent impeding the plate and locking screw placement.

The MIPPO technique was used to reset the metaphysis and skeletal transition region to restore the relationships of their alignment, length, and rotation. The plate was inserted via the surgical incision and the tunnel under the periosteal muscle; another 4-cm incision was made in the proximal end of the plate, which

Figure 1. Female, 53 years, falling-caused injury, AO-Type 33C2. A, B: Normal and lateral X-ray images of knee joint; C, D: Lateral LLP fixation after surgery; E, F: Nonunion 1 year after surgery.

was attached to the lateral femur and temporarily fixed with one Kirschner wire. After good plate positioning was confirmed using a C-arm X-ray machine, the locking screws were secured. Locking screws of the appropriate length should be selected at the metaphyseal end to avoid irritating the medial soft tissue and penetrating joints.

Medial incision: One 5-cm-long longitudinal incision was made at the distal end of the femoral medial muscle, followed by blunt separation to protect the peri-muscle vessels and nerves; a bone stripper was then used to make a tunnel in the anteromedial surface of the femoral medial muscle and one medial plate was then inserted along the tunnel (optional plates: humeral proximal or reconstruction); one 3-5-cm longitudinal incision was then made along the sartorius muscle proximal to the plate. The femoral rectus and femoral medial muscles were bluntly separated to the medial plate, whereas the lateral fracture was not cut open and exposed. The plate was then adjusted under X-ray guidance and the locking screws were inserted in turn.

Postoperative treatment

Postoperative external fixation was performed together with infection prevention, analgesia, detumescence, and the subcutaneous injection of low molecular weight heparin to prevent deep vein thrombosis. On the first day after surgery, the diseased limb muscle was subjected to isometric contraction; at 1-2 weeks postoperative, the affected knee joint was gradually subjected to activities and non-weight-bearing walking. When postoperative images showed trabecular bone appearing in the fractured end, partial weight-bearing walking was allowed; once the fracture healed completely, full weight-bearing walking was allowed.

Follow-up and efficacy evaluation criteria

Imaging examination: All patients underwent anteroposterior and lateral X-ray imaging of the distal femur (including the knee joint) before surgery, immediately after surgery, and 6 weeks, 3 months, 6 months, 9 months, 12 months and 18 months after surgery to assess the internal fixation and fracture healing. Fracture healing was defined as painless full weight-bearing walking and continuous callus passing through the bilateral cortexes in normal or lateral femoral X-ray films. The following complications should also be noticed: (1) Reduction loss consisting of a fracture angle change > 3° in intraoperative and follow-up X-ray; and (2) poor alignment of fracture consisting of coronal or sagittal fracture angle ≥ 5° the normal and an affected limb deformity > 10°.

Evaluation method of clinical efficacy: The HHS scoring system [12] was used for the clinical efficacy evaluation, namely scoring of clinical efficacy according to pain, range of motion, muscle strength, flexion deformity, walking ability, and daily life activities. Scores indicated the following results: 100 points, completely normal; 91-99 points, excellent; 75-90 points: good; 50-74 points, acceptable; and < 50 points, poor.

Statistical analysis

SPSS19.0 statistical software was used; the classification data between the two groups

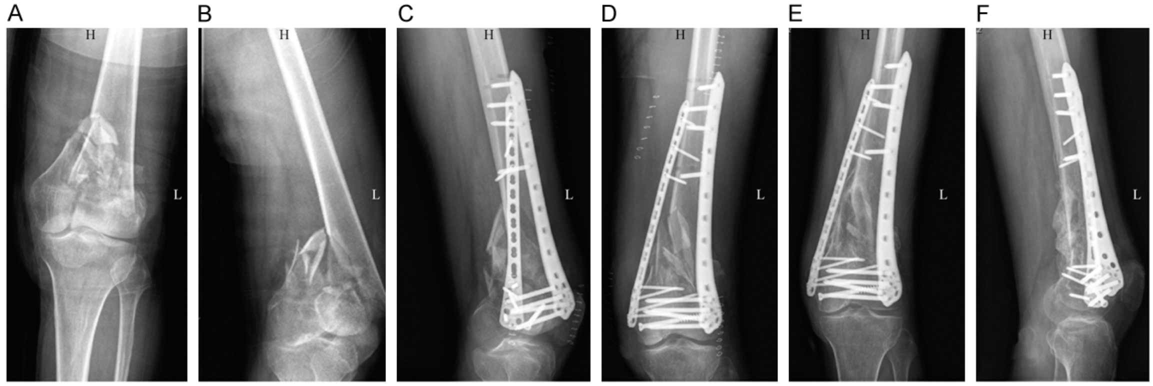

Figure 2. Male, 64 years, car accident, AO-Type: 33C2. A, B: Normal and lateral X-ray images of knee joint; C, D: LLP+MAP after surgery; E, F: Fracture healing 1 year after surgery.

were compared using the chi-square test. The measured data are expressed as $\bar{x}$ ± SD and were compared using the two-sample independent t-test. The intergroup HSS (hospital for special surgery) scores were compared using the chi-square test. Values of $P < 0.05$ were considered statistically significant.

Results

Basic surgical situations

Surgery was successful in all 32 patients, and the lateral sides of all patients used LLP (18 with DePuy Synthes; 14 with Wego); the 11 cases of MAP included six cases using a PHILOS plate (three with DePuy Synthes and three with Wego); five cases with a reconstruction plate (three with DePuy Synthes and two with Wego).

Operation time in Group A was longer than Group B

The mean operation time was 129.5 ± 22.4 min in Group A and 98.8 ± 16.1 min in Group B, and the difference was statistically significant ($P < 0.05$).

Blood loss difference was not statistically significant

The mean blood loss was 359.1 ± 81.2 mL in Group A, not statistically different from that of Group B (301.4 ± 70.4 mL) ($P > 0.05$).

Postoperative follow-up

The follow-up time in this study was 11-25 months (mean, 12.3 months). Group A included one case (open fracture) of superficial wound incision infection that healed after re-dressing.

Bone healing time was no significant difference between two groups

Group B included two cases of nonunion (9%), and the mean healing time (except for nonunion) was 5.86 ± 0.59 months. The two cases of nonunion (**Figure 1**) healed after a medial structural bone graft; all the fractures in Group A healed (**Figure 2**) with a mean healing time of 5.39 ± 0.69 months; there was no significant intergroup difference in the mean healing time.

HSS scores with excellent and good results in Group A were higher than in Group B

One-year postoperative HSS scoring revealed that Group B included 12 cases with excellent results, six with good results, and three with acceptable results (excellent or good results in 85.7% of cases); Group A included seven cases with excellent results, three with good results, and one with acceptable results (excellent or good results in 90.0% of cases) (**Table 2**).

Discussion

Weight defines types 33A2, 33A3, 33C2, and 33C3 (AO classification) as unstable DFF. These fractures are often caused by high-energy impact and accompanied by metaphyseal comminution and bone defects, so the treatments are more difficult and often complicated by incomplete fixation, infection, nonunion or delayed healing, reduction loss, knee valgus, joint stiffness, or other complications [13, 14]. The conventional treatment mainly combines LLP with MIPPO, which can induce secondary fracture healing through micro-movements at the fracture end [15-18]; however, incidence of no-

Table 2. Comparison of operation time, intraoperative blood loss, clinical healing time, total incidence of complications, and HSS scores between the two groups

	A	B	P
Operation time (min)	129.5 ± 22.4	98.8 ± 16.1	0.001
Intraoperative blood loss (ml)	359.1 ± 81.2	301.4 ± 70.4	0.062
Average healing time (mon) (except for nonunion)	5.39 ± 0.69	5.86 ± 0.59	0.071
Infection (n)	1	0	
Nonunion (n)	0	2	
HHS (1-year postoperative ratio of excellent and good results)			
Excellent	7	12	
Good	3	6	
Acceptable	1	3	
Excellent+Good	90.9%	85.7%	

nunion is almost 16% because of early internal fixation instability [19, 20].

To obtain stability of the fracture end, multi-plate techniques have been widely used to treat fractures of the tibial plateau, distal humerus, and ankle joint; certain scholars have also recently used them to treat proximal femoral and humeral fractures [21]. In the distal femur fracture, if a medial defect appears in the fracture end, the use of single lateral fixation may make it difficult to obtain adequate stability, and the medial support plate can then be augmented. Biomechanical test has proved the MAP can significantly reduce excessive strain at the fracture site [22]. Sanders reported that MAP for distal femoral fracture can effectively reduce the fracture reduction loss and internal fixation loosening caused by early postoperative activities [23].

But LLP is a kind of biological fixation, and because bone healing needs secondary fracture healing by callus formation, which is stimulated by interfragmentary motion in the millimeter range, and strain should be controlled at 2-10%, strain that is too large or too small can cause difficulties with fracture healing. However, whether MAP may suppress fracture healing due to its excessively rigid internal fixation devices, which reduce the interfragmentary motion, remains unclear. It is also unclear whether this strain reduction is suitable for fracture healing without producing excessive stress occlusion.

So presently, MAP for distal femur is less commonly applied, and only a few experiment researches have explored [24, 25]. Khalil made V-shaped incisions for MAP in the treatment of severe comminuted metaphyseal medial bone defects and achieved better stability, but the long incisions increased the trauma and adhesion of quadriceps [26]. Holzman only used MAP to treat post-LLP nonunion and achieved good healing [27]. We selected the patients with types A2, A3, C2 and C3 medial supracondylar defects, which are often caused by high-energy impacts and normally combined with comminuted metaphyseal fracture, so LLP alone often cannot provide sufficient stability for fracture, resulting in larger micro-movements of the fracture end, especially the medial side of the fracture [12]. Medial plates normally use a 3.5-mm Ti alloy upper limb or reconstruction plate according to the long-plate-less-screw principle to reduce the overall stiffness of the internal fixation system, and even the distal end of the fracture may not undergo screw placement and the plate only plays its anti-slide role. The external plate acts as the main plate, playing is role of stable support; the inner assisted plate has certain flexibility, playing the roles of inner splint and protective support, which can both stabilize the fracture and avoid excessive stiffness of the internal fixation devices. Combined with MIPPO, medial fracture segments are not easily exposed to protect the fracture's blood supply, so the first-stage medial defect requires no bone grafting.

Under normal circumstances, medial incisions of the distal femur are often used to complete a tumorectomy or osteomyelitis, and fewer results have been reported about this approach, most of which consider these incisions more limited and risky. Jiamton used the data of lower-limb vascular CTA to evaluate the relationship among the femoral artery, deep femoral artery, and femur and determine the safe area of MIPO-related medial approach of distal femur. The author believes that in the anteromedial side of femur, the safe area of medial MIPO for plate insertion is 15 cm below the lower edge of the lesser trochanter to the adductor tubercle; furthermore, the maximum distance from the lesser trochanter to the deepest branch of the deep femoral artery is 80 mm, which is sufficient to insert a plate with adequate length [28]. The author applied the MIPPO technique to insert plates into the medial side of the distal femur, and no blood vessel injury occurred.

However, MAP will increase surgical trauma and operation time, so we used the MIPPO technique, in which we exposed the medial side of the fracture and stripped the periosteum, which relatively protected the local blood circulation of the internal fracture side and reduced the surgical trauma. Moreover, the average prolongation of the operation time in our study was 25 minutes; one patient with open fracture (Gustilo type I) of the patients with double-plate locking developed a superficial wound infection, and the bacterial culture was confirmed as *Staphylococcus aureus*; this patient's wound healed after the application of sensitive antibiotics and re-dressing. Our experience is that when the soft tissue conditions are poor in open fracture, the application of MAP should be carefully considered.

In summary, we believe that MAP for treating CMFDF can increase fracture stability and improve the healing rate, but how to configure the inner plates to achieve the best mechanical effects requires further technical studies. Furthermore, due to the restrictions of this study, such as its small sample size, non-strict random controlled trial design, and retrospective analysis, we must accumulate more cases for future investigations.

Disclosure of conflict of interest

None.

Address correspondence to: Zhongjie Yu, Department of Orthopedics, The Second Changzhou People's Hospital Affiliated to Nanjing Medical University, Changzhou 213003, China. Tel: +86 519 81087536; E-mail: cnzhongjieyu@163.com

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