Effect of the degree of displacement of single fracture fragment on healing of femoral shaft fracture treated by intramedullary nailing

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Abstract

Objective: To investigate the effect of the degree of displacement of a femoral shaft fracture with a single fracture fragment on fracture healing after intramedullary nailing.

Methods: 216 patients with closed comminuted femoral fracture admitted to Lianyungang Hospital affiliated to Xuzhou Medical University from February 2010 to February 2016 were analyzed retrospectively. Among these patients, 142 were males and 74 were females, the mean age was 38 (17–64) years, and 95 cases were on the right, while 121 cases were on the left. All patients were treated with a femoral interlocking intramedullary nail. Referring to the femoral shaft diameter, the degree of displacement of the fracture fragment was classified into four grades: grade I (displacement was less than a third of the diameter of the shaft): 121 cases; grade II (greater than a third of the diameter and less than two thirds): 52 cases; grade III (greater than two thirds of the diameter): 28 cases; and grade IV (fracture fragment turnover): 15 cases. According to the radiographic union score of the femur, the fracture union rate and the mean union time of the fracture, the effect of the degree of displacement of the fracture fragment on fracture healing were evaluated.

Results: All the indexes of the four graded groups were statistically significant. The best fracture healing was the grade I displacement, with a fracture union rate of 89.2% and a mean union time of 7.7 months. The poorest fracture healing was for the grade III and grade IV displacements, with a union rate of 25.0% and 20.0%, respectively, and a mean union time of 13.7 months and 17.0 months, respectively. The union rate was 65.4% and the mean union time was 8.7 months for grade II displacement.

Conclusions: A fracture fragment with grade I displacement requires no intervention, whereas fractures with grade II displacement should be reduced to as near as possible to the diaphyseal bone defect to avoid nonunion. Fracture fragments with the grade III or IV displacement should be treated with closed reduction whenever possible to achieve a displacement within the range of grade I to minimize the incidence of nonunion.

Introduction

Femoral shaft fractures are widespread in clinical practice. Compared with a steel plate, the advantages of an intramedullary nail in its closed reduction and the postoperative fracture union rate have made it the gold standard for the treatment of femoral shaft fractures^{1–3}. However, fractures with large single fragment present unique challenges, and are present in up to 10–34% of femoral shaft fractures⁴. For Winquist type I–II femoral shaft fractures with a femoral fragment, delayed union or nonunion may occur if the fracture fragment is displaced by a large amount or reversed after the femoral intramedullary nail is inserted into the medullary cavity. Open reduction and fixation of the fracture fragment may further disrupt its blood supply and affect the healing of the fracture end, consequently, there remains considerable debate regarding the indications for open reduction of free fracture fragments after intramedullary nail fixation and the method of fixation after reduction. The present study retrospectively

analyzed the data of 216 patients who were treated for a closed comminuted femoral fracture using an interlocking intramedullary nail and with a follow-up from February 2010 to February 2016. According to the type of fracture, the displacement distance of the bone block, and whether an intervention was performed on the bone block, we analyzed and drew conclusions based on the different groups, providing some guidance for the clinical treatment of such conditions.

Patients And Methods

The inclusion and exclusion criteria The inclusion criteria were: (1) radiographic examination confirmed a femoral shaft fracture with displacement of the fracture fragment with clear surgical indications; (2) no intraoperative intervention for displaced fracture fragments; (3) the time from injury to operation was less than 3 weeks; (4) closed femur injury, excluding vascular and neurological injuries; (5) no obvious surgical contraindications such as cardiorespiratory dysfunction; (6) no preoperative cognitive impairment that could affect postoperative follow-up. The exclusion criteria were: (1) complicated with femoral neck or condyle fracture of the ipsilateral limb; (2) complicated with diseases affecting fracture healing; (3) patients with incomplete follow-up data or uncooperative treatment; (4) pathological fracture (Fig. 1).

General information. This retrospective study was approved by the Medical Ethic Committee of the First People's Hospital of Lianyungang, Jiangsu Province, China. The study was conducted in accordance with code of ethics of the Declaration of Helsinki. All patients agreed to participate and provided written informed consent prior to treatment. A total of 216 patients, mean age 38 (17–64) years, complied with the inclusion criteria in this study, including 142 males and 74 females with 95 fractures on the right and 121 on the left. Causes of injury were: 37 cases of a cycling fall, 116 cases of a traffic accident, 33 cases of a fall from height, and 30 cases of crush injury. Combined with medical diseases: 13 cases of diabetes mellitus and 19 cases of essential hypertension. The time from injury to surgery ranged from 3 to 10 days, with a mean of 4.3 days (Table 1). According to the Winquist–Hansen classification: type 0: no fracture fragment between the fracture ends; type I: fracture fragment less than 25% of the femoral diameter; type II: fracture fragment greater than 25% and less than 50% of the femoral diameter; type III: fracture fragment greater than 50% of the femoral diameter; type IV: comminuted fracture between the femoral fracture ends. Of the cases, 18 were type I, 154 were type II, 38 were type III and 6 were type IV.

Referring to the femoral shaft diameter, the degree of displacement of the fracture fragment was divided into four grades: grade I: the displacement of the wedge-shaped fracture fragment was less than a third of the shaft diameter at the fracture; grade II: the displacement of the wedge-shaped fracture fragment was greater than a third of the shaft diameter at the fracture while less than two thirds of the shaft diameter; grade III: the displacement of the wedge-shaped fracture fragment was greater than two thirds of the shaft diameter at the fracture; grade IV: the wedge-shaped fracture fragment was turned over. The displacement distance of the bone block was the vertical distance between the midpoint of the fracture fragment cortical bone line and the femoral cortical bone. The midpoint of the fracture fragment cortical bone line was the midpoint of the upper and lower vertices of the femoral anteroposterior view (the

fracture fragment was located medial or lateral to the femoral shaft) or the lateral view (the fracture fragment was located anterior or posterior to the femoral shaft). There were 216 cases in this study, including 121 patients with grade I displaced fracture fragments, with a mean fragment size of 51.0 mm and a mean displacement distance of 5.6 mm; 52 patients with grade II displaced fracture fragments, with a mean fragment size of 71.8 mm and a mean displacement distance of 12.8 mm; 28 patients with grade III displaced fracture fragments, with a mean fragment size of 78.3 mm and a mean displacement distance of 27.0 mm; and 15 patients with grade IV displaced fracture fragments, with a mean fragment size of 64.2 mm and a mean displacement distance of 18.5 mm. The mean length of the fracture fragment of this study was 60.5 mm, and the mean displacement distance of the fracture fragment was 11.0 mm ($P < 0.05$).

Table 1. Demographic data of patients with femoral shaft fracture.

Demographic data	
Age (mean $\pm$ SD)	38.0 $\pm$ 12.0
Gender	
Male	142
Female	74
Side	
Right	95
Left	121
Cause of injury	
Cycling fall	37
Traffic accident	116
Fall from height	33
Crush injury	30
Winquist grade (n–pts)	
I	18
II	154
III	38
IV	6

Preoperative preparation. Following admission, the patient was placed in traction of the tibial tubercle and given detumescence, analgesia, and other symptomatic treatment. Preoperative attention should be paid to swelling of soft tissue, and whether there are vascular or neurological injuries. Preoperative

routine examinations included anteroposterior and lateral views of the hip and knee joint. When necessary, three-dimensional computed tomography(CT) reconstruction of the femur was performed to unequivocally determine the direction and degree of fracture displacement and to plan the fracture reduction sequence and fixation method. Patients with essential hypertension control blood pressure hypertension below 120 to 150 mmHg, and those with diabetes control blood glucose below 12 mmol/L. Low-molecular-weight heparin was preoperatively routinely injected subcutaneously to prevent deep venous thrombosis from the lower extremity until the day before the operation. The fracture was photographed in the anteroposterior and lateral views on the side of the bed to understand the reduction of the fracture end, while adjusting the traction weight at the same time to maintain the alignment of the fracture end and avoid excessive traction. Preoperative routine examinations should be perfected, and surgery should be performed as soon as possible without surgical contraindications.

Surgical methods. Surgical methods for anterograde intramedullary nail cases: Following general anesthesia, the patient was placed on a supine orthopedics traction bed. The traction arm was used to pull and reduce the femoral fracture end. "C" arm fluoroscopy was applied to adjust the traction force, direction and internal and external rotation angles of the affected limb, and the contralateral limb was maintained in the flexion abduction position. A 3–5 cm incision was made along the apex of the greater trochanter of the femur to the proximal femur, and the fascia was incised. The gluteus medius muscle was obtuse separated, and the guide pin was inserted to the distal femur after the spreader was used to open the femur at the insertion point of the piriform fossa. Keeping the guide pin centered in the medullary cavity, the medullary cavity was reamed to 1 mm greater than the diameter of the intramedullary nail to be used. The femoral intramedullary nail (Kang Hui Medical Devices Co. Ltd., Smith & Nephew adolescent intramedullary nail for minors) was rotated into the medullary cavity, and the intramedullary nail was maintained centered in the distal femoral medullary cavity. Two locking nails were placed in the distal femur, and the need to knock back the intramedullary nail to pressurize the fracture end was decided upon based on intraoperative fluoroscopy. A locking nail was positioned in the proximal femur. In all cases, no intervention was performed on the displaced fracture fragments during surgery.

Surgical methods for retrograde intramedullary nail cases: Following general anesthesia, the patient was placed on a supine orthopedics operation bed. An anterior incision of the knee in the affected lower limb was made of approximately 5 cm in length, and the medial side of the patellar tendon was sharply separated. The knee was bent and the intercondylar fossa was exposed. A guiding Kirschner wire was drilled approximately 2 cm in front of the starting point of the posterior cruciate ligament. A guide wire was inserted under "C" arm fluoroscopy after opening. Following satisfactory fluoroscopy, the medullary cavity was reamed step by step to 1 mm greater than the diameter of the intramedullary nail to be used. The main nail with appropriate length was selected and inserted into the medullary cavity (Kang Hui Medical Devices Co. Ltd). After installing the positioner, the locking nail was screwed in the distal and proximal ends and the nail tail was inserted 3 mm below the articular surface. In all cases, no intervention was performed on the displaced fracture fragments during surgery.

Postoperative treatment. Postoperative electrocardiogram monitoring was applied to closely observe the vital signs of the patients. The blood routine was reexamined and attention was given to the correction of anemia. Antibiotics were used for 1–2 days, and low-molecular-weight heparin was routinely injected subcutaneously. Quadriceps isometric contraction training and flexion and extension activities of the hip, knee, and ankle articular were performed on the first day post surgery. The patients could support themselves on the ground after pain relief 3 days post surgery, but the affected limb could not bear any weight. At 1, 2, 3, 6, 9, and 12 months, postoperative reexamination was performed by taking anteroposterior and lateral views view of the fracture, and callus growth and fracture healing around the fracture and the fracture fragments were observed. According to the modified radiographic union score of femur (RUSF) scoring system of the radiographic union score of tibia⁵ was used to perform the evaluation. The respective anteroposterior and lateral views of the affected limb were photographed. The scoring criteria were: 1 point, there was a clear fracture line between the fracture ends; 2 points, there was callus between the fracture ends, but the fracture line remained visible; 3 points, there was bone bridge formation between the fracture ends, without a fracture line. When a total of 12 points were obtained in four cortices in the anteroposterior and lateral views, this suggested complete fracture healing.

Results

Major outcome. All 216 patients were followed up post surgery for a mean of 18.7 (6–31) months. There were 121 cases of grade I displacement and 108 cases of final healing; 52 cases of grade II displacement and 34 cases of final healing; 28 cases of grade III displacement and 7 cases of final healing; 15 cases of grade IV displacement and 3 case of final healing. The diagnosis of fracture nonunion followed the Food and Drug Administration (FDA) established criteria: the fracture ends remained unhealed 9 months post surgery, and there was no evidence of any healing for three consecutive months. For those cases with expected heavy postoperative fracture nonunion, surgical intervention was performed in patients without signs of fracture healing on reexamination of radiographs at 6 months post surgery, including cortical denudation of the fracture end and bone grafting around the cancellous fracture end. When the fracture was unstable, lateral plate fixation was applied to increase the stability of the fracture end. Typical cases of grade I–III displacement are shown in Figs. 2–5.

Bone-related and functional results. According to the RUSF scoring system, grade I displacement was scored at 7.5, 9.5, and 10.9 at 6, 9, and 12 months, respectively; grade II displacement was scored at 6.9, 8.1, and 9.1 at 6, 9, and 12 months, respectively; grade III displacement was scored at 4.6, 5.4, and 6.4 at 6, 9, and 12 months, respectively. The final fracture union rates post surgery for grades I–III were 89.3%, 65.4%, and 25.0%, respectively, with a mean union time of 7.7 months, 8.7 months, and 13.7 months, respectively. In these three groups, the union rate and the union time were statistically significant ($P < 0.05$) (Table 2). The scores of the fracture fragment of the non-reversal and reversal groups were 7.0 and 4.5, 8.6 and 5.1, and 9.8 and 5.9, respectively, at 6, 9, and 12 months, respectively. When comparing the reversal and non-reversal groups, the union rate and the union time were statistically significantly different ($P < 0.05$) (Table 3).

Table 2. Comparison of the results at different postoperative periods in the patient groups with Grade I, II and III displacement.

	Grade I displacement (n=121)	Grade II displacement (n=52)	Grade III displacement (n=28)	P-Value
RUSF (3 months) (S.D.)	5.8 (1.3)	5.4 (1.1)	4.6 (1.2)	< 0.001*
RUSF (6 months) (S.D.)	7.5 (1.6)	6.9 (1.7)	5.4 (1.9)	< 0.001*
RUSF (9 months) (S.D.)	9.5 (1.9)	8.1 (2.1)	5.9 (2.2)	< 0.001*
RUSF (12 months) (S.D.)	10.9 (2.0)	9.1 (2.4)	6.4 (2.5)	< 0.001*
Union rate / %	89.3	65.4	25.0	< 0.001*
Mean union time (month) (S.D.)	7.7 (2.2)	8.7 (1.5)	13.7 (1.6)	< 0.001*

* $P < 0.05$.

Table 3. Comparison of the results at different postoperative periods in the patient groups with fragment non-reversal and reversal.

	Non-reversal (n=201)	Reversal (n=15)	P-Value
RUSF (3 months) (S.D.)	5.5 (1.3)	4.2 (0.4)	< 0.001*
RUSF (6 months) (S.D.)	7.0 (1.8)	4.5 (1.0)	< 0.001*
RUSF (9 months) (S.D.)	8.6 (2.4)	5.1 (1.4)	< 0.001*
RUSF (12 months) (S.D.)	9.8 (2.7)	5.9 (1.8)	< 0.001*
Union rate / %	74.1	20.0	< 0.001*
Mean union time (month) (S.D.)	8.2 (2.4)	17.0 (1.7)	0.001*

* $P < 0.05$.

Statistical analysis. We analyzed the data using an independent t-test for continuous variables (non-parametric tests were used if normal distribution was not met), and chisquare test or Fisher exact test for categorical variables. All database management and statistical analyses were performed using SPSS

software version 26.0 (IBM Corp., Armonk, NY, USA). A value of $P < 0.05$ was taken as statistically significant.

Discussion

With ever increasing cases of comminuted femoral fracture caused by the transportation industry and severe trauma, femoral intramedullary nail fixation has become the gold standard for femoral long bone fracture treatment. Compared with conventional plate internal fixation surgery, closed reduction of the fracture end and maximum protection of the blood circulation are the greatest advantages of the intramedullary nail technique. In particular, femoral shaft fractures with large single fragments present unique challenges to internal fixation^{6–8}. Salminen et al.⁹ reported that among femoral shaft fracture cases, the probability of the presence of a fracture fragment was 10.5%, and a nonunion occurred in 34% of these cases. In the opinion of Vicenti et al.⁸, there are four factors that influence the healing of a femoral shaft fracture with a fracture fragment: the size and displacement of the fracture fragments, the angulation between the fracture fragments and the shaft, and the fracture gap, of which the size and displacement of the fracture fragments are the most influential among these four factors. When the fracture fragment size is greater than 40 mm or the displacement greater than 12 mm, this increases the rate of bone nonunion. Therefore, the size and degree of displacement of the fracture fragment are two important factors for the occurrence of nonunion after intramedullary nail fixation of femoral fractures. The size and shape of the fracture fragment are determined by the injury mechanism of the fracture. However, whether to further intervene regarding the displacement of the fracture fragment after intramedullary nail fixation is determined by the operator, while the indications for intervention for the fracture fragments remain strongly debated.

According to the follow-up results of the clinical cases, the present study found that the greater the displacement of the fracture fragments, the longer the union time between the fragment and the shaft, or even the occurrence of nonunion, after intramedullary nail fixation (including anterograde and retrograde) of femoral fractures. Liu et al.¹⁰ in animal model studies of radial fractures in rabbits showed that fracture healing was unaffected when the displacement of the wedge-shaped fracture fragment was less than 20% of the shaft diameter; when the displacement was greater than 20% of the shaft diameter and less than 60%, delayed fracture healing was clear; while when the displacement of the wedge-shaped fracture fragment was greater than 80% of the shaft diameter, the fracture fragment became smaller and was absorbed, and nonunion occurred. In addition, the greater the distance between the free fracture fragment and the main bone, the lower the concentration of bone morphogenetic protein-2, which is also one of the causes of nonunion^{11–13}. Wang et al.¹⁴ proposed that the fracture union rate and the clinical curative efficacy post surgery were clearly reduced when the bone block displacement distance was more than 10 mm. Lin et al.⁷ assigned 48 cases of femoral shaft fracture with fracture fragments to groups with a displacement of either less than or equal to 10 mm or greater than 10 mm. The fracture union rate was 75.9% and 21.1%, respectively, and the mean union time was 7.8 months and 13.0 months, respectively, which confirmed that the greater the degree of displacement of the fracture fragment, the

greater the influence on fracture healing. Because a large displacement of fracture fragments is frequently associated with potential soft tissue injury or even combined with open fracture, periosteal denudation at the fracture end and destruction of blood circulation around the fracture can occur, resulting in a prolonged union time of the fracture. Furthermore, the greater the displacement of the fracture fragment, the larger the volume of the callus formed between the fracture fragment and the shaft, thus the longer the remodeling time of the callus, and consequently the longer the fracture union time. In addition, the movement of the affected limb after intramedullary nail fixation is affected by muscle contraction, and the movement of the large displaced fracture fragment is often greater than that of the shaft, such that this excessive movement of the fracture fragment will affect the healing between the fracture fragment and the shaft. This is more evident during the healing process of the reversed fracture fragment, and is even absorbed after a long period of nonunion.

The quality and score of cortical continuity in the anteroposterior and lateral views of the radiograph in the RUSF scoring system are indeed effective for evaluating the postoperative healing of femoral fractures, and can effectively predict the probability of nonunion^{15,16}. In clinical work, it is simple and convenient to grade the degree of displacement of the fracture fragment according to the shaft diameter, which provides a means to judge the fracture healing, particularly for the intraoperative judgment of whether the displacement of the fracture fragment is acceptable. Referring to the femoral shaft diameter, the degree of displacement of the fracture fragment was divided into four grades: grade I: the displacement of the wedge-shaped fracture fragment was less than a third of the shaft diameter at the fracture; grade II: the displacement of the wedge-shaped fracture fragment was greater than a third of the shaft diameter at the fracture while less than two thirds of the shaft diameter; grade III: the displacement of the wedge-shaped fracture fragment was greater than two thirds of the shaft diameter at the fracture; grade IV: the wedge-shaped fracture fragment was turned over. We found that the RUSF scores of grade I and II displacement cases were statistically significantly lower than those of grade III displacement cases, according to the results of anteroposterior and lateral views during the reexamination from 6 months to 1 year post surgery ($P < 0.05$). Cases with grade II displacement of the fracture fragment had a lower probability of nonunion than grades I and III displacement. Although the RUSF scoring system did not include whether or not the fracture was reversed, the RUSF score in the grade II displacement group, the fragment reversal group, was significantly lower than that in the non-reversal group. This may be due to the fact that cases with a reversed fracture tend to be caused by a greater external force. On the one hand, when the soft tissue injury at the fracture end is severe, the blood flow is greatly reduced and at the same time it also affects the formation of new blood vessels¹⁷. On the other hand, when the reversed fragment alignment is poor, and there is no contact between the fracture fragment and the shaft, this is unfavorable to the healing of the fracture fragment. The follow-up results of multiple cases in the present study showed that the fracture healing was unaffected by the larger fracture fragment with a small degree of displacement. However, if the fracture fragment was large and the degree of displacement was greater at the same time, the probability of delayed union or nonunion was greatly increased. Therefore, from our study it can be concluded that the degree of the fracture fragment displacement has a greater

impact on fracture healing than the size or shape of the fracture fragment, and sufficient attention should be paid to the degree of displacement of the fracture fragment during surgery.

Following intramedullary nail fixation of femoral fractures, vascular forceps or a periosteal detacher can be used to pry apart a fracture fragment that is displaced more than grade Ⅱ and reduce the distance between it and the shaft. There is frequently soft tissue compression or filling between the fracture fragment and the shaft, resulting in a large displacement of the fragment from the shaft. When it is difficult to complete the reduction by prying, open reduction and fixation of the fracture fragment is necessary at the time. A steel plate, screw or steel wire or other fixation methods can be used to fix the fracture fragments, of which the cerclage wire fixation with less trauma is the leading choice. The single-wire cerclage fixation has less influence on the blood circulation of the fracture fragments, while the blood circulation of the fracture fragment is affected more by more than a single-wire cerclage fixation, such that single-wire cerclage fixation of fracture fragments should be chosen whenever possible.

This study still has the following limitations: This was a retrospective study, and the clinical case data were from a single hospital. In the future, a large-sample, multi-center prospective randomized controlled study will be needed to further clarify the impact of fracture fragment displacement size on fracture healing.

Conclusions

The degree of fracture fragment displacement is the most important factor affecting fracture healing. Following intramedullary nail fixation of a femoral shaft fracture, no intervention is required for a grade Ⅰ displacement of the fracture fragment. A grade Ⅱ displacement, a reversed fracture fragment, should be reduced as near to the position of the diaphyseal bone defect as possible to avoid nonunion. Minimally invasive surgery should be used to restore the reversed bone block during the operation, but minimally invasive surgery is not equivalent to the absolute closed operation. When it is difficult to reduce the fracture fragment by repeated application of vascular forceps or periosteal detacher to pry apart the fracture fragments, it is recommended to perform small incision open reduction. Repeated poking and prying can cause more damage to the blood circulation of the soft tissue attached to the bone block. For grade Ⅱ and Ⅲ displaced fracture fragments, closed reduction procedures should be used whenever possible to achieve fragments within the range of grade Ⅱ displacement to minimize the incidence of nonunion.

Declarations

Data availability

Most of the data generated or analyzed during this study are included in this published article. The remaining data generated or analyzed during this study are available from the corresponding author on reasonable request.

Author contributions

Designed the study: Y.Z., Jian Yin and L.X. Searched databases and collected full-text papers: Y.S. and Y.Y. Extracted and analyzed the data: H.Y. and Jian Yu. Statistical analyses: S.L. and S.X. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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Figures

Figure 1

Flow chart to identify patients with femoral shaft fractures meeting the inclusion and exclusion criteria.

Figure 2

Example of a femoral shaft fracture where the degree of fracture fragment displacement is grade $\square$. (A) A 36-year-old man sustained a right femoral shaft fracture with a fracture fragment; (B) the lateral views after closed intramedullary nailing showing a fragment size of 133.6mm and a displacement distance of 9.9 mm; (C) the anteroposterior and lateral views after closed intramedullary nailing showing a displaced fragment presenting as a gap of grade $\square$ displacement; (D) the anteroposterior and lateral views at 3 months postoperatively showing that the callus at the fracture site has grown well; (E) the anteroposterior and lateral views at 16 months postoperatively showing complete fracture reunion.

Figure 3

Example of a femoral shaft fracture where the degree of fracture fragment displacement is grade Ⅲ. (A) A 12-year-old girl sustained a left femoral shaft fracture with a fracture fragment; (B) the anteroposterior view after closed reduction showing the fracture fragment located in the medial side of the shaft (grade Ⅲ displacement); (C) the anteroposterior view at 3 months postoperatively showing good callus growth at the fracture site; (D) the lateral view at 3 months postoperatively showing good callus growth at the fracture site; (E) the anteroposterior view at 9 months postoperatively showing complete fracture reunion.

Figure 4

Example of a femoral shaft fracture where the degree of fracture fragment displacement is grade 1. (A) A 25-year-old man sustained a right femoral shaft fracture with a fracture fragment; (B) the lateral view after closed reduction showing that the fracture is at the anterolateral aspect of the shaft (grade 1 displacement); (C) the anteroposterior view after closed reduction showing that the fracture is at the anterolateral aspect of the shaft (grade 1 displacement); (D) the anteroposterior view at 3 months postoperatively showing poor callus growth at the fracture site; (E) the lateral view at 3 months postoperatively showing poor callus growth at the fracture site; (F) the anteroposterior view at 9 months postoperatively showing that the proximal and distal fracture fragments are connected to the shaft; (G) the lateral view at 9 months postoperatively showing that the proximal and distal fracture fragments are connected to the shaft.

Figure 5

Example of a femoral shaft fracture where the degree of fracture fragment displacement is grade Ⅲ. (A) A 28-year-old man sustained a right femoral shaft fracture with a fracture fragment; (B) the lateral view after closed reduction showing that the fracture fragment is turned over and greatly displaced (grade Ⅲ displacement); (C) the lateral view at 3 months postoperatively showing that the fracture site defect and that the medial callus has grown well; (D) the lateral view at 3 months postoperatively showing that the fracture fragment is free in front of the shaft and that the callus has grown well behind the fracture; (E) the anteroposterior view at 1 year postoperatively showing good medial callus growth and the lateral bone defect at the fracture site; (F) the lateral view at 1 year postoperatively showing partial absorption of the free fracture fragment.