Malalignment after minimally invasive plate osteosynthesis in distal femoral fractures

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\textbf{Introduction:} Although minimally invasive plate osteosynthesis (MIPO) is a preferred operative treatment for fractures of the distal femur, malalignment is a significant concern because of indirect reduction of the fracture. The purpose of this study, therefore, was to evaluate radiologic alignment after MIPO for distal femoral fractures.

\textbf{Patients and methods:} Of the 138 patients with fracture of the distal femur who underwent MIPO, we enrolled 51 patients in whom bilateral rotational alignment could be assessed by postoperative computed tomography (CT). The patients included 32 men and 19 women, with a mean age of 54.3 years. Thirteen patients had femoral shaft fractures (according to the AO/OTA classification: 32-A, n = 2; 32-B, n = 6; 32-C, n = 5), whereas 38 patients had distal femoral fractures (33-A, n = 7; 33-C, n = 31). Coronal and sagittal alignments were assessed using simple radiography, whereas rotational alignment was assessed using CT. According to the difference between the affected and unaffected sides, we divided the patients into satisfactory and unsatisfactory groups (reference point of 8\degree, using Handolin’s classification).

Thereafter, we determined which factors can lead to malalignment, including fracture location (distal femoral shaft fracture or metaphyseal fracture), fracture pattern (simple fracture, n = 15; complex fractures, n = 36 patients), coronal and sagittal alignments, and combined ipsilateral long bone fractures.

\textbf{Results:} Coronal and sagittal alignment were satisfactory in 96.2\% (average, 2.8\degree) and 98\% (average, 2.2\degree), respectively, whereas the rotational alignment was satisfactory in 56.9\% of patients. Leg length discrepancy was satisfactory in 92.3\% of the patients (average, 10.9 mm). Concerning rotational malalignment, an unsatisfactory result was obtained in 48.6\% of subjects with complex fractures and 26.7\% of subjects with simple fractures (p = 0.114). No significant correlation was noted between the angular deformity in the coronal and sagittal planes and the degree of rotational alignment (p = 0.607 and 0.774, respectively).

\textbf{Conclusions:} Regardless of the fracture pattern, rotational malalignment may occur at an extremely high rate after MIPO for fractures of the distal femur.

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\textbf{Introduction}

Because of its biological superiority, minimally invasive plate osteosynthesis (MIPO) has been frequently used recently to reconstruct metaphyseal or diaphyseal fractures if intramedullary nailing is not feasible. Many authors have reported better outcomes, including decreased healing time and a lower complication rate, compared with conventional open plating [1–4]. However, restoration of appropriate alignment with indirect reduction might lead to unpromising results, particularly with rotational malalignment. Adequate rotational alignment on two-dimensional fluoroscopic images is difficult to determine during surgery or postoperative physical examination. A recent study reported that 38.5\% of distal femoral fractures treated with MIPO showed malrotation >10\degree compared with the uninjured side [5], and another study reported that the MIPO technique was associated with significantly greater rotational malalignment compared with open reduction in distal femur fracture fixation [6]. Accordingly, this study was conducted to determine the
incidence of malalignment of distal femoral fractures treated with MIPO and to identify the influencing factors and their clinical significance.

Patients and methods

This study was approved by the authors’ institutional review board. A total of 138 distal femoral fractures were treated with MIPO between 2005 and 2013. Surgical treatments and clinical follow-up visits were conducted at a single institution. Patients with bilateral lower limb injuries, segmental femoral fractures, no postoperative anteversion computed tomography (CT) of both legs, periprosthetic fractures, severe soft tissue damage, and follow-up period less than 12 months were excluded. Patients who refused postoperative anteversion CT because of fear of radiation, pecuniary affairs, and claustrophobia in the CT scanner were also excluded. Fifty-one of the 138 patients with fracture of the distal femur for whom bilateral rotational alignment could be assessed by postoperative anteversion CT were included in our study.

Surgical technique

Patients were placed in the supine position on a radiolucent table under adequate anesthesia. Before sterile draping, correct anteroposterior fluoroscopic images of the contralateral hip and knee were obtained, which were used as a reference for appropriate intraoperative rotational alignment. The standard lateral parapatellar approach was used with the knee in 30° flexion, supported by a rolled sheet. If a distal femoral articular fracture was present, it was reduced anatomically under direct visualization and fixed with two or three fully threaded 3.5-mm screws while avoiding the area of the lateral plate, followed by indirect reduction of the meta-diaphyseal fracture. Reduction and maintenance were aided by a temporary external fixator (n = 22), manual holding maneuver (n = 15), temporary K-wires (n = 10), and minimally invasive percutaneous wiring (n = 5). Thereafter, an anatomically pre-contoured locking plate (locking compression plate-distal femur in 37 cases [Depuy Synthes, Oberdorf, Switzerland]; a less invasive stabilization system in 5 cases [Depuy Synthes, Paoli, PA, USA]; a Zimmer periarticular locking plate in 10 cases [Zimmer, Warsaw, IN, USA]) was inserted submuscularly and preliminarily fixed with temporary K-wires. Before definitive screw fixation of the plate, the coronal alignment was checked by the cable method, the sagittal alignment was verified by lateral fluoroscopic images, and the rotational alignment was assessed by comparing the lesser trochanteric profile to that of the contralateral leg using the fluoroscopic images obtained for the opposite side. When alignments were thought to be satisfactory, definitive plate fixation with screws was performed. After plate fixation, coronal, sagittal, and rotational alignments were reconfirmed.

Rehabilitation started on the second postoperative day with quadriceps setting and continuous passive motion of the hip and knee joints. After discharge, patients were encouraged to perform straight leg-raising exercises. Non-weight bearing was recommended until callus bridging was visualized on plain radiographs. Coronal and sagittal plane angulations were assessed on anteroposterior and lateral full-length femur films obtained immediately after surgery and at the latest follow-up visits. Postoperative anteversion CT of both legs for femoral version was performed to assess rotational alignment 3–7 days after surgery or on the next outpatient clinic visit after discharge for regular follow-up. Callus formation on 3/4 cortices and fading of fracture lines on the radiographs were considered signs of fracture union. After union, whole-extremity scanogram was performed to determine leg length discrepancies between the injured and uninjured femurs.

Coronal, sagittal, and rotational alignments and limb shortening were classified into four groups, as described by Handolin et al. [7] (side-to-side difference of alignment: <3°, excellent; 4°–7°, good; 8°–12°, fair; >12°, poor; side-to-side shortening difference: <9 mm, excellent; 10–19 mm, good; 20–29 mm; fair; >30 mm; poor). The excellent and good categories were considered satisfactory, whereas fair and poor were regarded as unsatisfactory. Thereafter, we tried to determine which factors could lead to malalignment, including fracture location, fracture pattern, and the presence of combined ipsilateral long bone fracture. Associations between potential influencing factors and postoperative malalignment were analyzed using Pearson’s χ² test. Statistical significance was accepted for p values < 0.05.

Results

There were 32 men and 19 women, with a mean age of 54.3 years (range, 13–98 years). Causes of injury were simple fall in 10 patients, fall from a height in 12, and motor vehicle accident in 29. Thirteen patients had distal femoral shaft fractures (32-A, 2; 32-B, 6; 32-C, 5 according to the AO/OTA classification), whereas 39 patients had distal femoral fractures (33-A, 7; 33-C, 31). There were 15 cases of simple fractures and 36 cases of complex fractures. Of the 51 fractures, 16 were open fractures (grade I, grade II, 10; grade III, 5), according to the Gustilo-Anderson criteria. Thirty-two patients had fractures of other sites that required fixation. The mean follow-up period was 22.5 months (range, 12–80 months).

Primary bony union was achieved in 44 (86.3%) of 51 patients at an overall average of 18.6 weeks after surgery (range, 12–28 weeks). There were 8 cases of non-union, all of which healed after grafting with autogenous cancellous bone and/or calcium sulfate bone graft substitute. Three patients needed implant change. Revision surgery was performed in 2 patients secondary to coronal and rotational malalignment.

Coronal and sagittal alignments were satisfactory in 96.2% (mean side-to-side difference, 2.8°; range, 0.2°–10.3°) and 98% (mean side-to-side difference, 2.2°; range, 0°–8.1°) of the subjects, respectively, whereas the rotational alignment was satisfactory only in 56.9% of patients (Figs. 1–4). Postoperative rotational difference between the injured and uninjured limbs ranged between 0.5° and 31°. The mean degree of malrotation was approximately 11.8°. Using a previously described malrotation classification [7], excellent results were obtained in 16 patients (31.4%), good results in 14 (27.5%), fair result in 7 (13.7%), and poor result in 14 (27.4%). Of the 51 patients, 20 had a version angle of minus value, suggesting that the distal fragment of the fractured femur was relatively externally rotated compared with the uninjured limb. The leg length discrepancy was satisfactory in 92.3% of the patients (mean side-to-side difference, 10.9 mm; range, 0–20.6 mm). Concerning rotational malalignment, an unsatisfactory result was obtained in 48.6% of subjects with complex fractures (AO/OTA type C) and 26.7% of subjects with simple fractures (AO/OTA types A and B), suggesting that complex fracture was prone to a higher rate of malrotation after MIPO, but it was not proven to be statistically significant (p = 0.114, Pearson’s χ² test) (Figs. 5 and 6). For complex fractures, patients with a concomitant ipsilateral long bone fracture appeared to have higher rates of malrotation (fair or poor outcomes in 63.6% of patients with ipsilateral long bone fracture and 42.3% without ipsilateral long bone fracture), although the difference in the rate between these was not significant (p = 0.235, Pearson’s χ² test) (Figs. 7 and 8). No significant correlation was noted between the angular deformity in the coronal and sagittal planes and the degree of malrotation (p = 0.607 and p = 0.774, respectively, Pearson’s correlation analysis), which suggests that even if proper alignments of the coronal and sagittal planes were achieved after surgery, this
could not guarantee appropriate postoperative rotational alignment.

Discussion

Since Krettek et al. introduced MIPO using dynamic condylar screw in proximal and distal femoral fractures [1], minimally invasive plating for operative treatment of fracture fixation has been replacing traditional open plating due to its advantages and its ability to overcome the complications of open reduction. Although MIPO has biologic advantages, inherent indirect reduction and plate application without direct visualization may yield insufficient restoration of alignment. Therefore, we tried to investigate how often malalignment occurs and what factors exert an influence on malalignment after MIPO in fractures of the distal femur. To the best of our knowledge, this is the largest series concerning malalignment after MIPO in distal femoral fractures, with its influencing factors.

Many studies revealed adverse effects of rotational malalignment in the lower extremity [8–11] including articular cartilage deterioration and resultant early arthrosis, pain in the hip and knee with motion limitation, gait abnormality, and functional impairment. In addition, patients with external rotation deformity have significantly more symptoms than those with internal rotation and cannot tolerate their condition well [8]. While compensating for external rotation malalignment with internal...
rotation of the leg, retroversion of the femoral neck occurs, and this is known to cause more symptoms [11,12]. In the current study, 39.2% of study subjects had relative external rotational deformity, but nearly none of them complained of discomfort during daily activity.

We proved that MIPO led to satisfactory coronal and sagittal alignments. Nevertheless, unsatisfactory rotational malalignment occurred in 43.1% of subjects, which was higher than expected. Buckley et al. [5] found that 38.5% of distal femoral fractures treated with MIPO showed unsatisfactory malrotation and a mean degree of postoperative malrotation of 11.5°. More recently, Lill et al. [6] presented that MIPO was associated with significantly more rotational malalignment compared with open reduction and internal fixation in distal femoral fracture fixation. The authors of that study found that 70% of patients had a mean rotational difference >10°. Although direct comparison is difficult because they used different malrotation criteria, their results are comparable to ours. Although rotational deformity of the femur after MIPO is a significant problem, it is likely that it has been underreported, as Collinge et al. [13] described.

Generally, rotational differences <10° are considered inconsequential, and those >15° are considered problematic [9]. Rotational alignment between 10° and 14° is the gray zone, as it may represent a possible deformity without symptoms or a real deformity with clinical symptoms. In our experience, the mean rotational difference was 11.8°, which is within this threshold, although revision surgery was performed in two cases because of alignment problem. As to revision cases, one had side-to-side

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**Fig. 3.** A 50-year-old man with simple distal femoral shaft fracture (A and B). Postoperative radiograph reveals excellent coronal (3.9°) and sagittal (1.7°) alignments, with a mechanical lateral distal femoral angle (α) of 87.1° (C and D).

**Fig. 4.** Follow-up radiograph after 1 year demonstrates fracture union, with satisfactory alignment (A and B). However, anteversion computed tomography reveals poor rotational alignment, with a side-to-side difference of 31.8° (C).
difference in rotation of only 4.7°. However, that patient had unacceptable valgus deformity with a mechanical lateral distal femoral angle of 80° (side-to-side difference, 9.6°). The other case showed rotational difference of 27.7°.

In the current study, 48.6% of subjects with complex fractures had unsatisfactory result due to rotational alignment, whereas that of simple fractures was 26.7%, which seems to be a naturally expected outcome. Buckley et al. [5] reported that AO/OTA type A femoral fractures appeared to have a more significant degree of malrotation than comminuted type C fractures, which is contradictory to our result. In addition, Lill et al. [6] also described that the majority of malrotations after MIPO occurred in type A fractures, rather than in type C fractures. The authors concluded that fracture severity and degree of malrotation were not correlated. They attributed this counterintuitive result to the operative method. In type C fractures, open reduction is required to reconstruct articular fracture and perform more extensive dissection compared with the standard minimally invasive approach required, which may allow for better assessment of alignment. However, those authors only included fractures of AO/OTA type 33, whereas our series included 13 fractures of AO/OTA type 32. Because fracture reduction and plate applications are performed

Fig. 5. A 33-year-old man with complex distal femoral fracture (A and B). Good coronal (6.6°) and excellent sagittal alignments (2.5°) achieved postoperatively, with a mechanical lateral distal femoral angle (α) of 84.5° (C and D).

Fig. 6. Follow-up radiograph after 1 year demonstrates fracture union (A and B). However, anteversion computed tomography reveals poor rotational alignment, with a side-to-side difference of 18.3° (C).
without direct visualization, restoration of adequate alignment with the MIPO technique is problematic and critical, as Collinge et al. [13] described. Furthermore, the existence of ipsilateral long bone fracture seems to play a role in rotational malalignment in complex fractures. It was not easy for us to restore appropriate rotational alignment in complex fractures with ipsilateral tibial shaft fracture. Patients who had complex fractures and concomitant ipsilateral long bone fracture had a tendency toward malalignment (63.6%) compared to those without ipsilateral long bone fracture (42.3%). We attribute this to a varied range of femoral anteversion and tibial rotation among the patients. It was not easy to restore perfect rotational alignment of the complex femoral fracture during surgery because we could not ascertain the exact pre-injury rotation and status of both the femur and the tibia. Ultimately, close attention should be paid to complex fracture and complex fracture with ipsilateral long bone fracture in order to avoid rotational malalignment.

Intraoperative control of rotational malalignment poses a big challenge for surgeons who use modern MIPO techniques with the aid of intraoperative fluoroscopy, which only provides two-dimensional estimation. Moreover, fluoroscopy may provide some assistance in the restoration of coronal and sagittal alignments [5]. To date, there is no reliable method of assessing intraoperative alignment of the lower extremity. Correct anteroposterior fluoroscopic images of the contralateral hip and knee are widely used as reference. However, the limited field of projection of fluoroscopy

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**Fig. 7.** A 32-year-old man with complex distal femoral fracture (A and B). He concomitantly sustained distal tibial shaft fracture (C). Postoperative radiograph demonstrates good coronal (4.9°) and excellent sagittal (1.3°) alignments (D and E). Distal tibial fracture is also fixed (F).

**Fig. 8.** The radiograph after 3 years demonstrates fracture union, with minimal leg length discrepancy (A and B). Anteversion computed tomography reveals poor rotational alignment, with a side-to-side difference of 18.8° (C).
does not provide whole alignment of the lower extremity and accurate assessment of limb rotation is difficult intraoperatively. Recently, “cortical step” was shown to be effective in determining rotational malalignment [14], but it is difficult to apply in comminuted or complex fractures. A true lateral image of the knee with an aligned femoral condyle and a lateral image of the femoral neck without any subtle movement of the distal femoral condyle in the uninjured limb reveal normal anteversion in the patient. In addition to acquiring preoperative anteroposterior fluoroscopic images, comparing these lateral images after fracture fixation may be beneficial in getting better alignment. Simultaneous preparation of the uninjured leg can be helpful in comparing the degree of internal and external rotation with each other during surgery, although a poor correlation between these clinical measurements of hip rotation and femoral torsion has been reported [15]. More recently, studies using computer-assisted surgery for femoral fracture fixation have been described [16–18]. However, some of these studies concluded that even computer navigation-assisted surgery could not significantly improve the accuracy of rotation [17,18]. Relevant techniques that assess rotational alignment during the surgery and are reproducible need to be developed, as Krettek et al. claimed early on [1].

Our study has a couple of limitations. Different types of adjunct temporary reduction of fracture and maintenance methods, including temporary external fixator, holding with a manual maneuver, temporary K-wires, and minimally invasive percutaneous wiring, may influence the quality of reduction. In addition to its small cohort size, the use of different types of plate for fracture fixation is another shortcoming. Finally, clinical correlation between the degree of malrotation and reproducible patients’ satisfaction using any functional scoring system was not performed.

Conclusions

Regardless of the fracture pattern, rotational malalignment may occur at an extremely high rate after MIPO for distal femoral fractures, whereas satisfactory alignment is obtained for coronal and sagittal alignments and limb length. Complex fractures were prone to a higher rate of malrotation. Effort should be devoted to controlling intraoperative rotation, and a reliable method of assessing intraoperative rotational alignment of the lower limb that can be used consistently needs to be developed.

Conflict of interest statement

All authors have certified that they have no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with this article.

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