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TRAUMA SURGERY

Treatment of infra-isthmal femoral fracture with an intramedullary nail: Is retrograde nailing a better option than antegrade nailing?

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Abstract

Introduction Antegrade intramedullary (IM) nailing is ideal for femoral shaft fractures, but fixing the fracture distal to the isthmal level may be difficult because of medullary canal widening and the proximity of fracture location from the distal femoral joint line. This study aimed to compare treatment results between antegrade and retrograde nailing for infra-isthmal femoral shaft fracture, and to identify influencing factors of nonunion and malalignment.

Materials and methods Sixty patients with infra-isthmal femoral shaft fractures treated with IM nailing and followed-up for > 1 year were enrolled in this retrospective study, 38 in the antegrade nailing group, and 22 in the retrograde nailing group. The two groups had no significant differences in age, sex, and fracture location ($p = 0.297$, Mann–Whitney test). Radiological evaluation was performed, and functional result was assessed using the Knee Society scoring system. Complications were analyzed in accordance with fracture location, fracture type, and operative method.

Results According to the AO/OTA classification, 35, 16, and 9 cases were type A (A1: 1, A2: 11, A3: 23), B (B1: 2, B2: 7, B3: 7), and C fractures (C2: 4, C3: 5), respectively. The mean follow-up duration was 29.5 months. In the antegrade and retrograde nailing groups, the primary bony union rates were 73.7% in 20.7 weeks (range 12–41) and 86.4% in 17.4 weeks (range 12–30), respectively. The two groups showed no significant differences in union rate ($p = 0.251$, Pearson's Chi-square test) and union time ($p = 0.897$, Mann–Whitney test). No cases of malalignment of > 10° in any plane were found in both groups. The mean Knee Society scores were 92 (range 84–100) and 91 (range 83–95) in the antegrade and retrograde nailing groups, respectively, showing no significant difference ($p = 0.297$, Pearson's Chi-square test). Although fracture location was not significantly related to union rate ($p = 0.584$, Mann–Whitney test), patients with an effective working length of the distal segment of < 0.75 were prone to nonunion ($p = 0.003$, Pearson's Chi-square test).

Conclusions Although no significant difference was found in IM nail type, the IM nail with a shorter working length distal to the fracture showed a strong relationship with nonunion.

Keywords Femoral shaft fracture · Infra-isthmal fracture · Intramedullary nailing · Antegrade nailing · Retrograde nailing

Introduction

Intramedullary (IM) nailing has been the treatment of choice for fractures of the femoral shaft in adults [1–3]. Numerous previous investigators have documented its high union rates and low complication rates [4–8]. In particular, antegrade IM nailing is currently a gold standard method for the treatment of diaphyseal fracture of the femur. However, fixing the fracture distal to the isthmal level effectively may be difficult because of widening of the medullary canal. Moreover, because of the relatively short working length in such a situation, complications, including nonunion, malunion, and fixation failure, may be encountered [9]. Interference screws

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or additional adjuvant plating can be an alternative method for increasing the fixation strength of the distal segment, but operation time can be longer and perioperative complications such as bleeding and infection can be developed more frequently.

On the other hand, retrograde IM nailing can achieve a relatively longer working length, and more interlocking screws can be applied to the distal segment. In spite of damage of the articular cartilage and postoperative knee pain, retrograde nailing is known to offer a potential advantage over antegrade IM nailing for infra-isthmal femoral shaft fractures in terms of implant insertion, control of the short distal segment, and fixation strength [10, 11]. Comparative studies have been conducted between two operative methods that do not distinguish the fracture level [3–5, 8, 9, 12, 13]. However, to the best of our knowledge, the antegrade and retrograde IM nailing methods for femoral diaphyseal fractures of the infra-isthmal portion have not been compared in any report yet. Thus, the aim of the present study was to compare the result of treatment with antegrade and retrograde IM nailing for infra-isthmal femoral shaft fractures and to address the factors (fracture location, fracture type, and operative method) that affect complications, including nonunion and malalignment.

Patients and methods

We retrospectively reviewed the medical records of patients visited our institution between October 1999 and July 2014 for the diagnosis of infra-isthmal femoral shaft fracture and treatment with IM nailing. The study design and protocol were approved by our institutional review board. The infra-isthmal region was defined as the lower edge of the narrowest point of the medullary cavity to the upper border of the transepicondylar width of the knee [14]. Sixty consecutive patients (46 men and 14 women) followed up for > 1 year were enrolled, including 38 cases of antegrade nailing and 22 cases of retrograde nailing.

Operation

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 entire leg was prepped and draped free to allow for the assessment of limb length and rotation. The operations were performed by two expert surgeons.

Antegrade nailing

The patient was placed supine on a radiolucent table with a bolster under the ipsilateral buttock to allow access to the entry portal, which was either the piriformis fossa or tip of the greater trochanter. After determining the adequate nail insertion point, marrow was opened with a sharp awl or starting reamer, followed by insertion of a nail with an optimal diameter and possible longest length to provide optimal stability [an Expert Antegrade Femoral Nail in 7 cases (Depuy Synthes, Oberdorf, Switzerland); a Cannulated Femoral Nail in 3 cases (Depuy Synthes); a Unreamed Femoral Nail in 6 cases (Depuy Synthes, Oberdorf, Switzerland); a Sirus Antegrade Femoral Nail in 8 cases (Zimmer, Warsaw, IN, USA); a Zimmer Natural Antegrade Femoral Nail in 13 cases (Zimmer, Warsaw, IN, USA); a Targon Femoral Nail in 1 case (B. Braun, Melsungen, Germany)]. Closed nailing was performed without open of fracture site in all the cases. The nail was locked with 2–4 screws distally and 2 screws proximally. In eight cases, the blocking screw was used in the distal segment to obtain better alignment and to provide additional stability.

Retrograde nailing

Retrograde nailing was performed on a radiolucent table, with the patient in the supine position and a bolster under the knee to maintain flexion at approximately 30°–40°. A vertical midline approach through the patellar tendon was used in all the cases. An intercondylar notch and Blumensaat's line were identified by using a fluoroscopic guide, and a guide pin was inserted just anterior to the intercondylar notch. Then, the tunnel for the nail entry was made using a 13-mm reamer, followed by insertion of a nail [a Unreamed Femoral Nail in 14 cases (Depuy Synthes, Oberdorf, Switzerland); an M/DN femoral retrograde nail in 3 cases (Zimmer, Warsaw, IN, USA); a supracondylar retrograde nail in 3 cases (DK Medical, Seoul, South Korea); a Cannulated Femoral Nail in 1 case (Depuy Synthes, Oberdorf, Switzerland); a Distal Femoral Nail in 1 case (Depuy Synthes, Oberdorf, Switzerland)]. Closed nailing was performed in all the cases. The thickest intramedullary nail was chosen to achieve optimal stabilization, and the nail length was chosen to be located near to 2–3 cm below the lesser trochanter. The nail was locked with 2 screws proximally and distally.

Postoperative care and assessment

Rehabilitation was started on the second postoperative day with quadriceps setting and continuous passive motion of the hip and knee joints. After discharge, the patients were encouraged to perform straight leg-raising exercise and active flexion of the hips and knees, from a tolerable range of motion followed by a gradual increase similar to the range in the unaffected limb. Partial weight bearing with crutches was started as soon as pain became tolerable, followed by full weight bearing. Routine follow-up radiographs were

obtained every 6–8 weeks until solid continuous callus formation was observed; callus formation on 3/4 cortices and radiographic evidence of fracture line fading were considered signs of fracture union. Frontal and sagittal plane angulations were assessed on anteroposterior and lateral plain radiographs obtained immediately after surgery and at final follow-up visits. Functional result was assessed using the Knee Society scoring system. Complications, including nonunion, malalignment, and fixation failure, were analyzed in accordance with the fracture level, fracture type, operative method, and number of distal interlocking and blocking screws.

To determine the location of the fracture that is prone to failure in the antegrade nailing group, we developed a new parameter, the effective working length of the distal segment (EWLD), which is defined as the ratio of the shortest distance from the distal end of the IM nail to the fracture to the shortest distance from the distal femoral joint line to the fracture (Fig. 1).

Statistical analysis

We performed the Mann–Whitney test to identify differences in sex, age, fracture location and type, union time, and relationship between union rate and the number of distal screws between the two groups. Pearson's Chi-square test was used to identify differences in union rate, Knee Society score, and relationship between the union rate and EWLD. Statistical significance was accepted for p values of < 0.05.

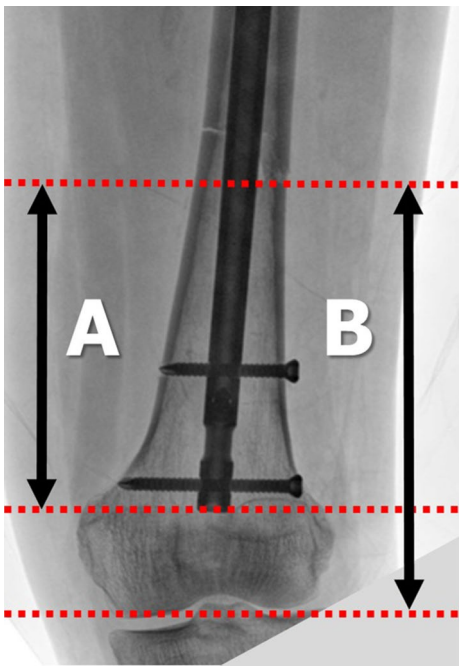

Fig. 1 Effective working length of the distal segment (EWLD, A/B), defined as the ratio of the shortest distance from the distal end of the IM nail to the fracture (A) to the shortest distance from the distal femoral joint line to the fracture (B)

Results

According to the AO/OTA classification system, 35 cases were type A fractures (A1:1, A2: 11, and A3: 23), 16 were type B fractures (B1: 2. B2: 7. and B3: 7), and 9 were type C fractures (C2: 4 and C3: 5). Of the patients, 29 were men and 9 were women, with a mean age of 36.2 years (range 17–71 years) in the antegrade nailing group, and 17 were men and 5 were women, with a mean age of 36.7 years (range 19–71 years) in the retrograde nailing group. No significant differences in age ($p = 0.673$, Mann–Whitney test), sex ($p = 0.933$, Mann–Whitney test), and fracture type ($p = 0.257$, Pearson's Chi-square test) were found between the two groups. The mean follow-up duration was 29.5 months (range 12–133 months).

Primary bony union was achieved in 73.7% (28/38 patients) of patients in the antegrade nailing group and 86.4% (19/22 patients) in the retrograde nailing group. The mean union time was 20.7 weeks (range 12–41 weeks) in the antegrade nailing group and 17.4 weeks (range 12–30 weeks) in the retrograde nailing group. Although retrograde IM nailing seemed to show a higher union rate and shorter union time, we could not discover significant differences in union rate ($p = 0.251$, Pearson's Chi-square test) and union time ($p = 0.897$, Mann–Whitney test) between the two groups. No case of malalignment of $> 10°$ in any plane was found in both groups. In addition, no infections occurred in any of the patients. The mean Knee Society score was 92 (range 84–100) in the antegrade nailing group and 91 (range 83–95) in the retrograde nailing group, showing no statistical difference ($p = 0.297$, Pearson's Chi-square test). The fracture location was not significantly related to the union rate ($p = 0.584$, Mann–Whitney test). The numbers of distal interlocking or blocking screws did not affect the union rate in both groups ($p = 0.091$, Mann–Whitney test), even in the antegrade nailing group ($p = 0.093$, Mann–Whitney test) and retrograde nailing group ($p = 0.929$, Mann–Whitney test). The comparative results between the two groups are summarized in the Table 1.

With regards to the effect of the working length of the antegrade IM nail, 11 patients had an EWLD of < 0.75, 8 of whom developed nonunion (72.8%) (Figs. 2, 3). On the other hand, 27 patients had an EWLD of ≥ 0.75, 6 of whom developed nonunion (22.2%) (Fig. 4). Fractures with an EWLD of < 0.75 were found to be particularly prone to nonunion ($p = 0.003$, Pearson's Chi-square test).

Table 1 Summary of comparative results

Patients' characteristics	Antegrade nailing group	Retrograde nailing group	*p* value
No. of patients	38	22	
Age (years)	36.2 (17–71)	36.7 (19–71)	0.673
Sex			0.933
Male	29	17	
Female	9	5	
Fracture type (AO/OTA)			0.257
32-A	25	10	
32-B	9	7	
32-C	4	5	
Union rate (%)	73.7	86.4	0.251
Union time (weeks)	20.7 (12–41)	17.4 (12–30)	0.897
Knee Society score	92 (84–100)	91 (83–95)	0.297
Fracture location (mm)	153.4 (101–205)	152.9 (108–215)	0.584
No. of screws in the distal segment	3.1 (2–6)	2 (in all cases)	0.091

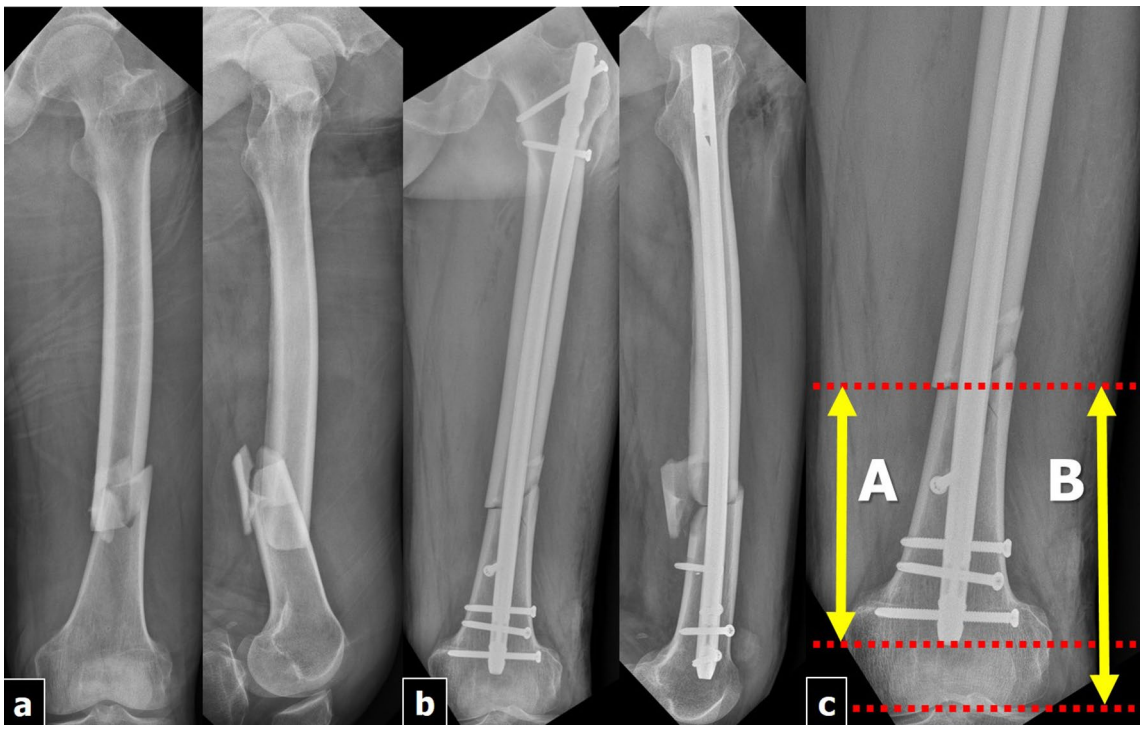

Fig. 2 **a** 77-year-old man had an AO/OTA type B1 femoral shaft fracture. **b** Antegrade nailing with blocking screw was performed. **c** Calculated EWLD was 0.7

Discussion

The consensus is that IM nailing is the best-treatment modality for diaphyseal fractures of the lower extremity. IM nailing has several advantages in that it is a load-sharing device, which has a better mechanical advantage and high union rate, less blood loss, reduced infection risk and operating time, and decreased hospital stay [15, 16]. Particularly, for femoral shaft fractures, it can be performed either antegradely or retrogradely.

The previous investigators [3–5, 12, 13] described comparative results between two different operative methods. However, as far as we know, comparative results between antegrade and retrograde nailing confined to infra-isthmal femoral shaft fractures have not been documented yet. Therefore, the purpose of this study was to investigate

Fig. 3 **a** Follow-up radiograph at 6 weeks, showing fixation failure with fracture displacement. **b** Antegrade nailing was performed again, followed by additional augmentative minimally invasive plating. **c** Radiographs obtained after 1 year shows healing of the fracture

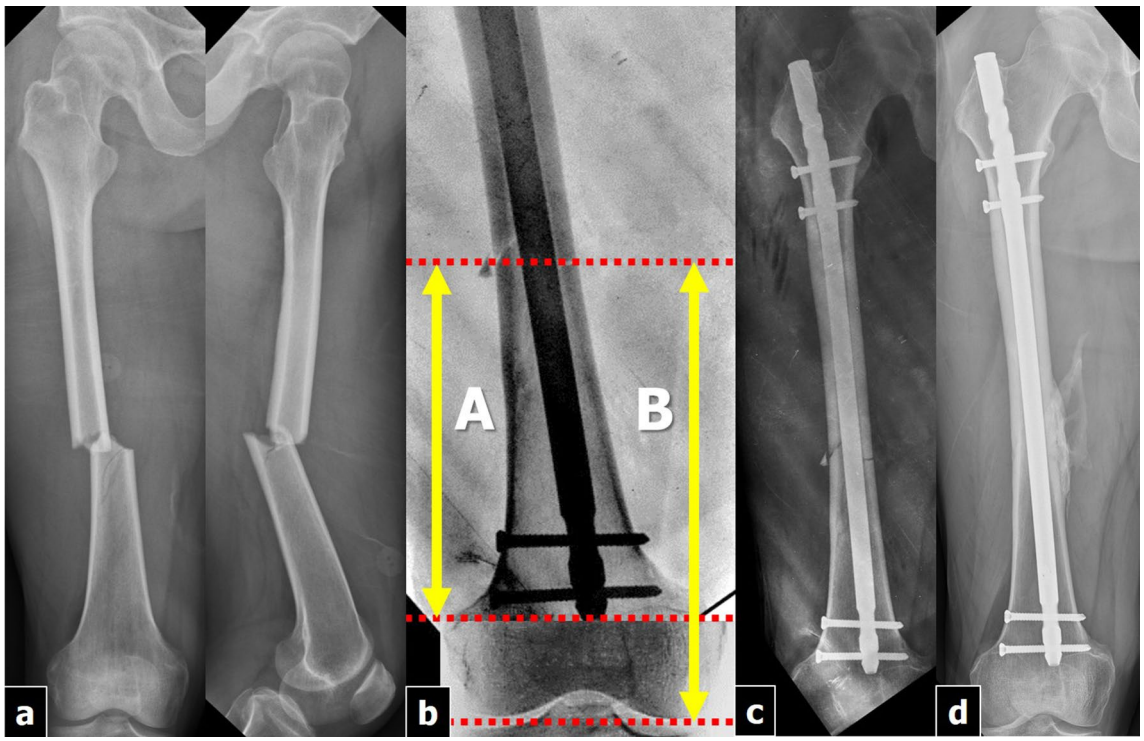

Fig. 4 **a** 52-year-old man sustained an AO/OTA type A3 femoral shaft fracture. **b** Calculated EWLD was 0.8. **c** Antegrade nailing was performed in standard fashion. **d** Radiograph obtained after 18 months shows solid union of the fracture

differences between antegrade and retrograde IM nailing for infra-isthmal femoral shaft fractures.

In the retrograde nailing group, the primary union rate was 86.4% at a mean of 17.4 weeks postoperatively. On the other hand, the primary union rate was 73.7% at a mean of 20.7 weeks after operation in the antegrade nailing group. Although retrograde nailing seems to have higher union rate and shorter union time, these did not reach statistical significance ($p = 0.251$ and 0.897, respectively). Ostrum et al. [5] reported that antegradely nailed femurs healed faster than those treated with retrograde insertion. Moed et al. [17] found an apparently higher prevalence of nonunion after retrograde IM nailing, which is not recommended for use in routine treatment of isolated fracture of femoral shaft. On the contrary, Yu et al. [18] described that the retrograde nailing group showed a significantly earlier union. Herscovici et al. [19] reported that retrograde nailing showed a union rate of 96% in their series. Nevertheless, most of the previous studies that used both techniques [2, 8, 13] demonstrated comparable union rates. This is consistent with our findings, although direct comparison is difficult, because our study subjects were confined to patients with infra-isthmal femoral fractures.

Despite that retrograde femoral nailing can minimize or eliminate some of the shortcomings of an antegrade nailing technique, concerns remain regarding the violation of the knee and its deleterious effect on subsequent knee function. Some authors [4, 20] found that retrograde nailing resulted in a significantly higher incidence of knee pain and worse function. However, most previous comparative studies [3, 5, 6, 8, 13, 18, 21] showed no significant differences in range of knee pain, range of motion, and functional outcome, which concurs with our result.

Contrary to our expectation, fracture location (distance from the distal femoral joint line to the fracture) proved to be not significantly related to union rate and the number of screws (either interlocking or blocking screw). The previous studies have shown that fractures involving the distal third of the femur have an incidence of malalignment after treatment with IM nailing, either antegradely or retrogradely [9, 22]. The large metaphyseal volume does not allow the IM nail to have rigid cortical contact. Moreover, if the fracture is close to the distal segment, the IM nail cannot stabilize the distal segment effectively because of short inherent working length of the nail. Complications, including nonunion, malalignment, and fixation failure, are likely to occur under such situation. The working length of the IM nail, defined as the length of a nail spanning the fracture site from its distal point of fixation in the proximal fragment to the proximal point of fixation in the distal fragment, is commonly mentioned with regard to fixation strength. However, it cannot precisely predict the outcome in infra-isthmal femoral shaft fracture, because the distal segment is short and has a wide medullary canal, which can lead to gain inappropriate structural stiffness. Hence, we proposed a new parameter named "EWLD" (Fig. 1), particularly in antegrade nailing. As the desired location of the distal tip of the retrograde nail is at the level of the intercondylar notch, it is difficult to apply this concept in retrograde nailing. We think that this point deserves further attention, because it provides objective and reproducible criteria when using antegrade nailing for infra-isthmal femoral shaft fracture. Even though the consensus is that an IM nail with a shorter working length has poor outcome, no proven objective numerical value exists for this fact as far as we know. In our study, the patients with an EWLD of < 0.75 were found to be particularly prone to nonunion ($p = 0.003$). Each kind of IM nail has a consistent distance from the distal end of the nail to the interlocking hole, so we can predict the value of the EWLD preoperatively. Therefore, when poor results are expected by these criteria, adjunctive procedures such as blocking screw and/or adjuvant plating can be considered in addition to nailing.

Diverse types of nails were used in this series, which is a limitation of our study. Moreover, no significant differences in comparative results were found, probably owing to the relatively small size the cohort. The retrospective study design is also another shortcoming. Additional larger scale, prospective, randomized comparative studies are needed to fully describe the pros and cons of each technique.

Conclusions

Although retrograde IM nailing seems to show a higher rate and shorter time of union, no significant differences were with antegrade nailing for the treatment of infra-isthmal femoral shaft fracture. However, fractures treated with IM nails with a shorter working length distal to the fracture (i.e., EWLD of < 0.75) were particularly prone to nonunion.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. The design and protocol of this study were approved by the institutional review board of Kyungpook National University Hospital (IRB no: KNUH 2016-07-010).

Informed consent Informed consent was obtained from all individual participants included in the study.

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