Comparison of Knee Function After Antegrade and Retrograde Intramedullary Nailing for Diaphyseal Femoral Fractures: Results of Isokinetic Evaluation

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Objective: To evaluate knee function in patients having femoral diaphyseal fractures treated with antegrade or retrograde intramedullary nail insertion.

Design: Prospective.

Setting: Level I referral center.

Patients and Methods: Seventy patients having 71 OTA 32 fractures were randomly allocated into 2 groups to be treated with either antegrade or retrograde intramedullary nails inserted with reaming.

Intervention: Antegrade nail in 41 fractures and retrograde femoral intramedullary nails in 30 fractures.

Main Outcome Measures: Postoperative knee range of motion, Lysholm Knee Score, and isokinetic knee muscle function testing at least 6 months after documented fracture healing, minimum 1 year postoperatively.

Results: Groups had similar data with regard to demographics and injury patterns. Mean follow-up time was 44 (range: 25–80) months. Mean knee flexion angle was 132 and 134 degrees, and mean Lysholm Score was 84 and 83.1 in antegrade and retrograde groups, respectively ($P = 0.893$ and $P = 0.701$). Isokinetic evaluation revealed similar results for peak torque deficiencies at 30 and 180 degrees per second and total work deficiencies at 180 degrees per second ($P > 0.05$). Age affected the knee functioning as the higher the age of the patient is, the lower the Lysholm Score and knee flexion angle ($r = -0.449$, $P = 0.0321$ and $r = -0.568$, $P = 0.001$, respectively).

Conclusions: Knee function seems to have similar clinical results after either antegrade or retrograde nail insertion for femoral diaphyseal fractures when knee range of motion, Lysholm Scores, and isokinetic knee evaluation are considered as outcome measures. With increasing patient age, a decrease in knee functioning should be anticipated in patients with femoral fractures treated with intramedullary nails regardless of technique.

Key Words: femoral fractures, fracture fixation, intramedullary nailing, isokinetic testing

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INTRODUCTION

In 1940, Küntscher introduced intramedullary nailing of femoral shaft fractures, which was a turning point in the area of fracture treatment for the long bones. He later added the intramedullary reaming principle in 1952. The intramedullary nailing technique was further improved by the introduction of locking screws by Klemm and Schellmann in 1968.[1] Since then, locked intramedullary nail insertion with reaming has become a standard procedure for almost all femoral diaphyseal fractures. Although both ends of the femur are suitable for nail entry, the antegrade approach through the proximal femur has gained more popularity than the retrograde approach through the distal femur mainly because of theoretical problems encountered in the knee including articular cartilage damage, cruciate ligament disruption, knee sepsis, stiffness, patellofemoral degeneration, osteomyelitis, and quadriceps atrophy.[2] For a long time retrograde nailing has been used by many orthopaedic surgeons only as an alternative to antegrade nailing in particular situations where intramedullary fixation was indicated and an antegrade insertion technique might have drawbacks. These include patients with ipsilateral femoral neck or intertrochanteric fractures, ipsilateral acetabular or pelvic injuries, obese patients, patients with multiple fractures and pregnancy.[3–5] In recent years, prospective studies comparing antegrade versus retrograde nailing of femoral fractures have reported similar results for both groups with respect to the fracture union rate, incidence of malalignment, and limb length inequality were concerned.[4,6–8] To date, however, there is still controversy concerning the effects on knee function of intra-articular entry portal during retrograde nailing.

We designed a prospective protocol to investigate knee function in a specific patient population. Using validated instruments, we evaluated knee function in all patients who had femoral diaphyseal fractures that underwent either antegrade or retrograde intramedullary nail insertion as

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definitive treatment. We also investigated coexisting factors that could have influenced knee function in these patients. Our hypothesis was that knee function would be the same regardless of nail entry portal.

PATIENTS AND METHODS

Between September 2000 and September 2005, all adult patients with acute femoral diaphyseal fractures were considered for this study. Our institutional Ethical Review Committee reviewed and approved the study protocol. Patients with AO/OTA 32 fractures treated with intramedullary nailing were included in the study. Exclusion criteria included (1) patients with severe head trauma, (2) polytrauma patients necessitating an intensive care unit stay of more than 15 days, (3) patients who underwent damage control musculoskeletal surgery that had had delayed intramedullary nail stabilization more than 2 weeks after initial trauma, (4) type III open fractures according to Gustilo–Anderson classification, (5) AO/OTA 31 and isolated 33 fractures, (6) patients aged below 16 years or older than 70 years, (7) pathologic fractures, (8) those who had previous knee operations, (9) grade IV knee osteoarthritis assessed from x-rays of both knees according to Kellgren and Lawrence[9] at presentation, and (10) those who refused to participate or with a follow-up period of less than 2 years. Demographic, trauma, operative, and follow-up data were collected prospectively. The presence of knee effusion before the operation was determined with physical examination by the treating surgeon in the operating theatre and was noted. Patients were randomly allocated to 1 of 4 surgeons who had a minimum of 10 years experience in the treatment of femoral shaft fractures, by random numbers in sealed envelopes that were chosen by the patients on the day of surgery. Of the 4 surgeons, 2 routinely performed antegrade and the other 2 retrograde nailing on their patients for the purposes of this study. Concomitant skeletal injuries, when present, were treated according to established clinical protocols. Nail type and patient positioning were chosen according to the surgeon's preference and the patient's characteristics. Possible nail length and diameter were templated on x-rays obtained preoperatively. Three different types of nails were used in this series (Universal Femoral Nail and Cannulated Femoral Nail; Synthes GmBH, Switzerland and Trigen intramedullary interlocking nail; Smith and Nephew, Memphis, TN). Universal Femoral Nail and Cannulated Femoral Nail were used in both antegrade and retrograde nailing according to the allocated treatment group. Specific Trigen nails were used (antegrade and retrograde) according to entry portal. The nail type to be used was solely dependent upon availability and the surgeon's preference. All femoral nailing procedures were performed on a standard, radiolucent, flat, operating table without traction. For the antegrade nailing technique, an incision of approximately 4 cm was made proximal to the tip of the greater trochanter in line with the femoral shaft, and the nail was inserted through the point just medial to the greater trochanter at the piriformis fossa. For the retrograde technique, a skin incision of 4–5 cm was made just medial to the patellar tendon beginning at the lower pole of the patella proximally. After visual confirmation of the possible entry point, a guide pin was inserted approximately 1 cm anterior to the posterior cruciate ligament insertion in the middle of the intercondylar sulcus. The correct position of the guide wire was then checked by fluoroscopy. All reaming and nail insertion procedures were completed over this correctly introduced guide wire. Sequential reaming with 0.5-mm increments was performed in all cases. Static interlocking with 2 proximal and 2 distal screws was performed in all patients. Ligamentous knee instability was examined manually after fracture fixation and noted. The operative time for femoral nailing was recorded as the time from skin incision to closure in minutes. The same postoperative regimen was followed for all femoral fractures. Patients were allowed to bear weight as tolerated and active hip and knee motion was instituted immediately. In patients with intra-articular lower extremity fractures, rehabilitation was changed accordingly. Although passive and active knee range of motion exercises begun immediately, weightbearing was delayed until the treating surgeon allowed. Radiographic examinations were performed at 6, 10, 14, 18, and 24 weeks. Patients were evaluated by 2 of the authors who were not involved in their index surgery. Functional evaluation included Lysholm Knee Score and isokinetic knee testing besides the physical examination at least 6 months after fracture union. Patients with hip, patella, tibial plateau, and tibial diaphysis fractures were not involved in isokinetic testing because these fractures were previously proved to effect knee muscle function evaluation results negatively. Knee flexor and extensor muscles of both extremities were tested using the Biodex isokinetic system (Biodex Corp, Shirley, NY) in all patients at least 6 months after documented fracture healing, minimum 1 year postoperatively, by 2 of the authors blinded to the surgical technique used. During the tests, patients were in a sitting position, positioned and stabilized as described in the system manual. Isokinetic measurements were carried out at angular velocities of 30 and 180 degrees per second. Subjects had at least 3 experimental trials to become familiar with the process for each angular velocity and performed 3 maximal repetitions at 30 degrees per second and 10 maximal repetitions at 180 degrees per second. Peak torque deficiencies (%) at 30 and 180 degress/sec and total work deficiencies (%) at 180 degrees per second in the fractured extremity in comparison to the healthy one were determined in all patients for knee flexors and extensors, and the results of the antegrade and retrograde groups were compared.

Limb length was measured by using standing whole lower extremity anteroposterior x-rays with standard scale ruler at 1 year postoperatively, and inequality was considered to be present if the difference was >2 cm between the 2 lower extremities.[9,10] Similarly, malalignment was considered to be present if any deviation >10 degrees was observed either in the frontal or sagittal plane.

During the study period, 98 acute AO/OTA 32 fractures in 94 patients were treated in our department. Seventy-one fractures of 70 patients who met the inclusion criteria as stated above were evaluated. There were 48 males and 22 females with a mean age of 38.9 (range 17–67) years. Mean follow-up time was 44 (range: 25–80) months. The injury mechanism was a road traffic accident in 50 cases (71%). According to the Gustilo–Anderson classification, 8 fractures were open

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(5 type I and 3 type II). Twenty-one patients had 1 or more additional systemic chronic illnesses, the 2 most common being hypertension (6 cases) and diabetes mellitus (4 cases). Additional skeletal traumatic injuries were seen in 28 cases, the most common being distal radius fracture (7cases, 4 in antegrade and 3 in retrograde groups) and additional systemic injuries in 10 (7 in antegrade and 3 in retrograde groups, the most prevalent being head trauma. Other associated skeletal injuries within each treatment group are 3 patella fractures (1 in antegrade and 2 in retrograde groups), 1 lateral femoral condyle fracture in antegrade group, 2 tibial diaphyseal fractures 1 in each group, 1 tibial plateau fracture in antegrade group, 3 ankle fractures (2 in antegrade and 1 retrograde groups), 2 vertebral fractures 1 in each group, and 1 humeral diaphyseal fractures in antegrade group. The Injury Severity Score was mean 14.7 (9–34) and mean preoperative time was 9 (range 1–28) days. Thirty-one femoral fractures in 30 patients were treated with retrograde and 40 fractures in 40 patients were treated with antegrade nailing. The mean operation time was 124 minutes for all femoral nailing procedures. Closed reduction was attempted in all. Reduction was achieved with open procedure in 7, with limited open in 18, and with closed in 46 cases.

Statistical analysis of the data was performed by using SPSS 13.0 software. Percentages and dichotomous data were compared using the χ^2 test. Normally distributed data was compared using independent samples *T* test and data with non-parametric properties was compared using the Mann–Whitney *U* test. Any relation between the parameters and the resultant data was investigated using appropriate correlation analysis techniques.

RESULTS

Thirty fractures in 30 patients were available for the isokinetic muscle testing with a minimum follow-up at 24 months (range 25–80 months). There were 17 antegrade and 13 retrograde nails placed. Ligamentous knee instability was manually detected in 5 patients. No correlation was found between the presence of effusion and positive ligamentous knee instability tests ($r = 0.232$ and $P = 0.218$). The mean healing time was 20.7 weeks (range 12–52 weeks) and the mean follow-up period 44 (25–80) months. The mean knee flexion was 133 degrees and mean extension deficit was 2.1 degrees. The mean Lysholm Score was 79.2. In comparison of antegrade and retrograde groups, only the mean operative time showed statistical significance (122 versus 108 minutes for antegrade and retrograde nailing groups, respectively, $P = 0.029$). No correlation was found between the Lysholm Scores and the presence of knee effusion or preoperative osteoarthritis grade. Presence of knee ligamentous instability did not affect either Lysholm Scores (80 versus 84 for knee ligamentous instability–positive and knee ligamentous instability–negative patients, $P = 0.360$), mean of knee flexion angle (134 versus 136 degrees for ligamentous knee instability–positive and ligamentous knee instability–negative patients, $P = 0.799$), and evaluated isokinetic muscle functioning results ($P > 0.05$). Similarly, preoperative time and type of reduction did not show any correlation with any of the outcome measures. Lysholm Score and knee flexion at the final follow-up were both found to be affected by the patient's age. It was found that the older the patient is, the lower the Lysholm Score and knee flexion angle ($r = -0.449$, $P = 0.0321$ and $r = -0.568$, $P = 0.001$, respectively).

Isokinetic evaluation revealed similar results for peak torque deficit ratio values at 30 and 180 degrees per second angular velocities and total work deficit ratio values at 180 degrees per second ($P > 0.05$). Uninvolved side values were higher than the fractured side in both groups. Comparison of clinical data between the antegrade and retrograde groups are presented in Table 1 and the comparison of isokinetic data in Table 2.

Delayed union was observed in 3 cases, of which union was achieved only by dynamization in 1 and by bone grafting in the other 2. Isokinetic muscle testing was performed after fracture union in patients with delayed union. Recurrent knee effusion was observed in 1 case of retrograde nailing and heterotrophic bone formation at the hip in 2 cases of antegrade nailing. With standing whole lower extremity x-rays, shortening >2 cm was observed in 3 patients (2 in antegrade and 1 in retrograde groups) and malalignment >10 degrees in any direction in 3 cases (2 in antegrade and 1 in retrograde groups).

TABLE 1. Clinical Data Summary of Patients That Completed Isokinetic Knee Muscle Testing

	Antegrade	Retrograde	*P*
No. fractures	17	13	—
Mean age (yrs)	34.0	44.1	0.156
Preoperative osteoarthritis grade according to Kellgren and Lawrence			
Grade 1	14	8	0.435
Grade 2	2	3	
Grade 3	1	2	
Presence of knee effusion before fracture fixation	3	7	0.056
No. open fractures	2	1	0.415
Mean ISS	15.2	14.3	0.689
Mean preoperative time in days	8.8	7.5	0.745
Type of reduction			
Open	4	3	0.701
Limited open	2	3	
Closed	11	7	
Ligamentous knee instability after fixation			
Valgus stress	1	—	0.178
Varus stress	1	1	
Anterior drawer	—	2	
Posterior drawer	—	—	
Time to union weeks	23.1	17.6	0.113
Varus–valgus malalignment >10 degrees	2	1	0.441
Limb length inequality >2 cm	2	1	0.317
Delayed union	2	1	0.591
Additional surgery (including asymptomatic implant removals)	6	3	0.467
Knee flexion angle	132	134	0.893
Lysholm Score	84	83.1	0.701

ISS, Injury Severity Score.

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TABLE 2. Summary of Isokinetic Knee Muscle Performance Data According to Groups

	Antegrade Mean (SD)	Retrograde Mean (SD)	*P*
Extension peak torque deficiency at 30 degrees/s	36.06 (17.1)	39.05 (28.3)	0.740
Flexion peak torque deficiency at 30 degrees/s	14.32 (37.1)	22.96 (25.1)	0.453
Extension peak torque deficiency at 180 degrees/s	27.08 (15.1)	34.14 (15.3)	0.218
Flexion peak torque deficiency at 180 degrees/s	14.45 (17.3)	10.76 (19.8)	0.599
Extension total work deficiency at 180 degrees/s	25.64 (22.3)	38.07 (23.7)	0.156
Flexion total work deficiency at 180 degrees/s	15.3 (38.4)	24.35 (38.5)	0.205

The most frequent cause for reoperation was delayed union in 3 cases. This was followed by implant irritation around the hip necessitating removal in 2 cases, all in the antegrade group and iliotibial band irritation due to locking screw head in 1 case and 1 case of patellar irritation due to protruding end cap in the retrograde group.

DISCUSSION

Authors reporting knee function in patients treated with intramedullary nails for femoral fractures usually measure knee range of motion using a goniometer and overall knee function using a disease-specific patient response questionnaire.[7,11–15] Currently, none of the frequently used disease-specific knee function measurement tools are accepted as the standard for the evaluation of knee function after traumatic injuries.[16] In our study, we evaluated knee function by both the disease-specific Lysholm Score and the isokinetic knee evaluation. Although originally described for the evaluation of treatment results in ligamentous knee injuries, Lysholm Score has been reliably and reproducibly used to evaluate the treatment results of other traumatic knee lesions,[17,18] and in its current version, the Lysholm Score reliably determines function and disability in the traumatic knee.[16] The results reported in the current study are very similar to those reported in the literature when mean Lysholm Scores and mean knee range of motion have been considered. The differences we recorded for Lysholm Scores after antegrade and retrograde nail insertion were not significant.

Another important finding of our study that needs to be emphasized separately was that the older patients had lower Lysholm Scores and knee flexion angle than younger patients, in both treatment groups. To the best of our knowledge, this is the first study to publish the relevant data as stated above for femoral diaphyseal fractures treated with intramedullary nails. One explanation for the finding may be the possible coexistence of knee arthrosis in older patients. However, considering our mean age of 38.9 years, primary osteoarthrosis of the knee is not a frequent problem in this age group, and we cannot completely explain this finding only by existence of knee arthrosis. Another possible explanation may be the presence of intra-articular knee injuries associated with femoral diaphyseal fractures. In a study of closed femoral fractures by Blacksin et al,[19] 97% of patients demonstrated knee effusions and 27% meniscal tears, with the posterior horn of the medial meniscus being the most frequently torn. The medial collateral ligament was the most frequent site of ligamentous knee injury (38%) followed by the posterior cruciate ligament (21%); injuries of the extensor mechanism were seen in 50% of the patients and bone bruises in 32%; and articular cartilage injuries were confined to the patella, tibial plateau, and femoral condyles.[19] Another study reporting results of arthroscopy on knees with ipsilateral femoral shaft fractures by De Campos[20] revealed partial (48%) and complete (5%) anterior cruciate injuries, posterior cruciate injuries (7.5%), and medial (12%) and lateral (20%) meniscus tears. Dickson[21] similarly reported anterior cruciate ligament and posterior cruciate ligament injuries (19% and 7%, respectively), complete medial meniscus tears (15%) and complete lateral meniscus tears (26%), medial collateral ligament injuries (41%), and lateral collateral ligament injuries (30%) in their series. Bone contusions identified by postoperative magnetic resonance imaging (MRI) studies (periarticular infractions of cortical and medullary trabecular bone) were seen in tibia (30%) and femur (63%).[21] Obviously, all these lesions disturb the knee function, although it is not yet known whether the above-mentioned lesions occur more frequently in older age groups. Because we did not evaluate our patients postoperatively by arthroscopy or MRI, a definite conclusion cannot be drawn as to whether concomitant knee injuries affected knee flexion and Lysholm Scores in our series.

Isokinetic muscle performance evaluation provides an objective functional measurement for the knee. Reliability of isokinetic muscle testing for the knee was previously studied by many authors for different subsets of patients and normal individuals.[22–27] Negatively affected isokinetic knee muscle measurements have been reported after tibial shaft, tibial plateau, and patellar fracture treatment,[28–31] a comprehensive review of literature identified few reports that used isokinetic knee testing after the treatment of femoral diaphyseal fractures with intramedullary nailing. In our study, we found that Lysholm Knee Scores and isokinetic muscle functioning test results were not different in patients treated for femoral diaphyseal fractures with either antegrade or retrograde intramedullary nailing. To the best of our knowledge, our study is one of the few in the English literature to publish an assessment of knee function using isokinetic knee testing after the treatment of femoral diaphyseal fractures with intramedullary nailing. Although Lysholm Scores yielded results similar to our findings, we believe that the addition of isokinetic testing clearly demonstrates the actual knee function independent of the patients' psychology, which can possibly influence patient response–based evaluation results.[32] Isokinetic test results are reliable and objective predictors of returning to work or sports after injuries.[33] We believe that the isokinetic measurement of the knee function added valuable

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data to the evaluation of our patients who showed significant deficits compared with the uninjured side even a year after the fracture.

Our study has some limitations. The main disadvantage of this study is the small number of patients on which isokinetic testing was performed. Patients with ipsilateral fractures involving the knee, such as patella, tibial plateau, femoral condyle fractures, tibial diaphyseal fractures, and bilateral femoral fracture, were not included in the isokinetic muscle testing because these fractures have previously been shown to affect test results and make comparisons more complicated.[28–31] We also did not include patients who were not cooperative in the muscle testing procedure. Studies with larger patient numbers evaluated by isokinetic muscle testing may be needed to further investigate the thigh muscle performance after femoral fractures treated with intramedullary nailing. Another possible limitation of our study may be the lack of a more objective evaluation method for accompanying knee lesions. Although some previously mentioned studies detected a high rate of intra-articular soft tissue lesions by arthroscopy or MRI, we did not find it necessary to further evaluate our patients by either method because none of our patients had symptomatology related to possible intra-articular lesions during the follow-up.

In conclusion, our data support current literature findings. Therefore, we submit that similar clinical results can be obtained with both antegrade and retrograde nailing of femoral diaphyseal fractures. When we focus on knee function after intramedullary nailing, both patient response evaluations and isokinetic measurements are similar for both techniques. However, with increasing patient age, a decrease in knee function should be anticipated in patients with femoral fractures treated with intramedullary nailing by either technique. Either antegrade or retrograde nail insertion technique can be used for the treatment of femoral diaphyseal fractures with similar clinical outcomes and knee functions. It seems therefore that retrograde nail insertion does not have a detrimental effect on knee function.

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