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ORIGINAL ARTICLE

Retrograde Intramedullary Nailing for the Fixation of Distal Femoral Fractures

Distal Femur Kırıklarının Tespitinde Retrograd İntramedüller Çivileme

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Abstract

Introduction: Retrograde intramedullary nailing (RIN) is one of the most preferable surgical method for distal femoral fractures. In this study, we aim to evaluate the clinical and radiological outcomes of applying RIN method in distal femoral fractures.

Methods: In this retrospective study, 27 patients treated with RIN surgical method for distal femoral fractures were evaluated. The fractures were assessed according to AO classification, and Gustilo-Anderson classification was used for the open fractures. We have utilized the mini-arthrotomy approach. Modified Knee Rating Scale of the Hospital for Special Surgery (HSS) was used to evaluate the clinical and functional outcomes of the patients at the latest follow-up. The radiological assessment of the patients was done from consecutive direct X-rays, and the radiological union times were recorded.

Results: The mean follow-up period was 19.26±8.59 months (range, 7–40 months). The mean union time was calculated as 26.47±5.34 weeks (range, 21–72 weeks). One patient had delayed union (10 months). The mean knee joint range of motion was measured as 102.29°±15.70° (range 60°–135°). This was calculated as 105.60°±13.51° in type A and as 95.67°±15.70° in type C fractures. In total, there were six (31.6) excellent, ten (52.6%) good, two (10.5%) fair, and one (5.3%) bad result.

Discussion and Conclusion: Owing to its safety and reliability, RIN was considered as a safe and effective surgical technique in the management of distal femoral fractures and was applicable in all fractures except for Gustilo-Anderson types 3B and C.

Keywords: Distal femur fractures; Fracture fixation; Retrograde intramedullary nailing

Distal femoral fractures are described as severe injuries which might be technically challenging to operatively manage.[1] Distal femoral fractures account for 1% of fractures and between 3% and 6% of femoral fractures; however, its incidence and prevalence are noted to vary, depending on the population and geographic region.[2,3] Distal femur fractures are generally caused by two basic traumas that tend to occur in young men and older women.[4] Younger patients have high-energy trauma with good bone quality, whereas older patients have low-energy injuries with osteoporotic femur.[2,4]

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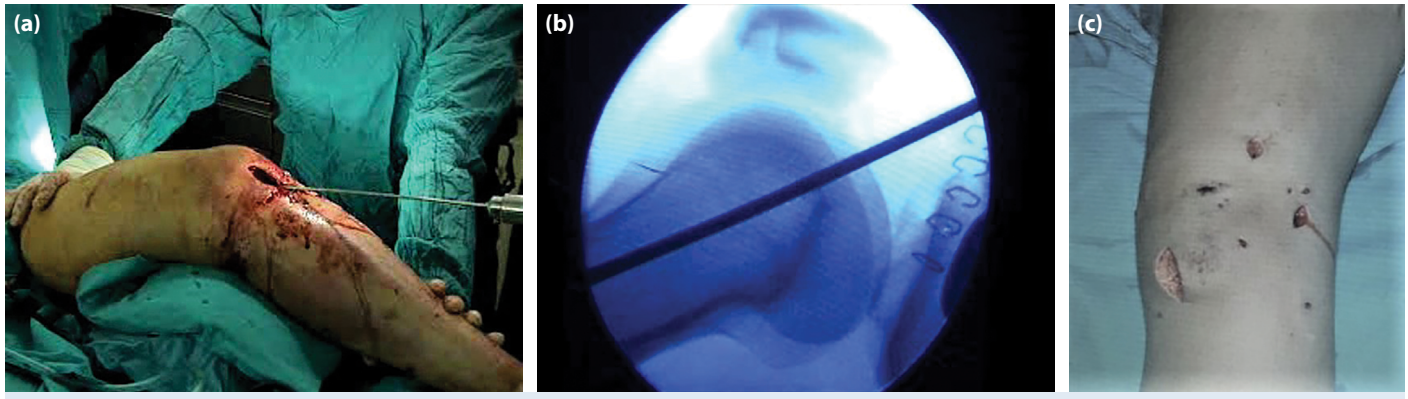

Figure 1. (a) The image indicating the surgical technique. **(b)** The fluoroscopic imaging showing the surgical technique. **(c)** Skin incision of mini-arthrotomy technique.

The surgical treatment of distal femoral fractures remains controversial. Surgical methods for distal femoral fractures include antegrade intramedullary nail, retrograde intramedullary nail, buttress condylar plate, less invasive stabilization system (LISS), and dynamic condylar screwing (DCS).[1,2,4–6] The success rate of the treatment of distal femoral fractures relies on the preservation of the fracture biology and the use of implants that are biomechanically more effective.[6] For the last two decades, new implants have been developed to gain biological osteosynthesis through minimally invasive approach.[7,8] Once antegrade intramedullary nail cannot reach the distal femoral fractures, we might apply retrograde intramedullary nailing (RIN) which is an alternative approach to plate fixation especially in osteoporotic bone.[1,2,6,7] RIN can potentially stabilize distal femoral fractures, allow the patients early knee mobilization, and prevent joint stiffness.[4,9] Moreover, RIN offers minimal disruption of the fracture site and early loading by means of load sharing due to its intramedullary localization; it also provides rapid healing owing to less soft tissue dissection.[5,10,11] Although the RIN provides more advantages to patients, some studies showed loss of reduction, failure of fixation devices, pain in the anterior part of the knee, knee arthrosis due to potential knee joint damage, and thromboembolic complications which can result from reaming the intramedullary bone, especially in patients with concomitant thorax trauma.[3,4,6,8,10–12]

In this study, we aimed to evaluate the clinical and radiological outcome of applying RIN method in distal femoral fractures. We hypothesize that distal femoral fractures can be successfully treated with RIN fixation.

Materials and Methods

We retrospectively evaluated 27 patients who underwent RIN for supracondylar and intercondylar distal femoral fractures between March 1998 and February 2002. AO type B fractures were excluded from this study. Eight patients were lost to follow-up despite maximum efforts to contact them. We could only reach 19 patients who were included in this study at the end of the last follow-up. In total, 19 patients were followed up for an average 19.3 months (range, 7–40 months). There were 10 (52.6%) women and 9 (47.4%) men with a median age of 52 years (range, 19–77 years). This study was approved by the Ethics Committee (E-10840098-772.02-1408), and informed consent was obtained from the patients included in this study.

The AO classification was used to grade the fractures, and patients with open fractures were classified according to Gustilo-Anderson classification.[13] Nailing was performed as soon as the patient's medical condition stabilized. Antibiotic prophylaxis with cefazoline 2 mg was administered to all patients before the surgery. Open fractures were treated with immediate irrigation and debridement; thereafter, cefazoline 4x1 g/d, gentamicin sulfate 2x80 mg/d, and metronidazole 2x500 mg/d were intravenously administered for 3 days in all cases. All surgeries were accomplished under spinal or general anesthesia. The patients were operated in the supine position on radiolucent surgical table. Fixation was made under fluoroscopic control in all surgical patients (Fig. 1). We utilized mini-arthrotomy approach at the beginning of the surgery; however, if open approach to the knee is deemed necessary, we switched from mini-arthrotomy to open intervention. Pneumatic tourniquet was then applied, but it was not inflated in all cases. Manual traction was used to avoid shortness, and the knee was positioned by putting a radiolucent bolster under the knee to set the knee in 60° flexion in order to relax the deforming force of gastrocnemius, thereby avoiding the typical hyperextension of distal fragment. The joint was then accessed with distal parapatellar approach, and K-wire was used to open

the medulla which is located in the intercondylar notch just 1 cm anterior to the femoral attachment of the posterior cruciate ligament. Closed reduction of the supracondylar fractures was performed under fluoroscopic control, and the guidewire was extended to intubate the proximal fragment up to a level proximal to the lesser trochanter. Nail with appropriate length and thickness was determined after medullar reaming. The RIN (Smith & Nephew Inc., Trigen Retrograde Nail, USA) was then inserted over the nail guide with hand by controlling the alignment of the fracture with fluoroscopy. Firstly, we applied the distal locking screws, followed by the proximal locking screws. Static locking was performed in all patients. We did not utilize any bone graft in primary cases.

All patients received anticoagulant prophylaxis with low-molecular-weight heparin (Clexane 0.4 IU). Postoperatively, isometric quadriceps, knee range of motion, and non-weight-bearing exercises with two crutches were encouraged as early as possible. All patients underwent double-sided plain radiographs monthly until union was completed. Partial weight bearing was allowed after union began to appear on the plain radiographs. Progressive weight bearing was depended on the degree of fracture healing that was seen on follow-up radiographs. When we did not see any sign of union on the plain radiographs, dynamization, which refers to the removal of the proximal screw of a statically interlocked nail 3 or 4 months after nailing, was performed.

All patients were then assessed with regard to operative time, blood loss, period of hospital stay, and postoperative complications. The radiological assessment of the patients was performed in two planes and assessed for callus formation and varus-valgus and flexion-extension deformity from consecutive plain X-rays. The radiological union times were then recorded. Malalignment was defined as varus-valgus greater than 5°, apex anterior-posterior greater than 10°, and rotational malalignment greater than 15°. Patients were evaluated using the Modified Knee Rating Scale of the Hospital for Special Surgery (HSS), as modified by Leung et al.,[14] to examine the clinical and functional outcomes of patients at the latest follow-up. This evaluation system contains subjective (54%) and objective (46%) criteria, including pain (30 points), function (22 points), range of motion (18 points), muscle strength (15 points), flexion deformity (10 points), and instability (10 points). The final evaluation point was calculated by subtracting 1 to 5 points from the total points, taking into account extension loss (5 points), use of support (3 points), and the presence of deformity (1 point). The values over 85 were classified as "excellent" whereas those between 70 and 84 as "good," between 60 and 69 as "fair," and under 60 as "bad." Leg length was measured from the anterior and superior iliac spine to the medial malleolus.

Fracture union was clinically defined as lacking of pain and tenderness at the fracture site and the ability to walk without aids. In addition, solid callus was considered satisfactory when plain X-rays indicate bone trabeculae or cortical bone crossing the fracture site.

Statistical Analysis

NCSS (Number Cruncher Statistical System) 2007 statistical software (Utah, USA) program was used for statistical analysis. We expressed nominal data as frequencies or percentages and quantitative data as mean±SD. The Shapiro-Wilk test was performed for testing the normality of the study data. Groups were then compared using independent t-test for normally distributed continuous variables. Analyses for non-normally distributed data were conducted using the nonparametric Mann-Whitney U test. A p-value below 0.05 was considered statistically significant.

Results

In total, 19 patients with a mean age of 51.79±18.33 years (range, 19–77 years) were followed up for an average 19.26±8.59 months (range, 7–40 months). Ten patients were women, while nine patients were men. Sixteen fractures were identified as closed, whereas three fractures were open fractures. The most common mechanism of injury was a simple fall, which occurred in eight patients. Ten patients had additional pathologies. The mean operation time was 132.74±49.16 minutes (range, 50–195 minutes) (Table 1).

According to AO/ASIF, seven fractures were A1, two fractures were A2, one fracture was A3, four fractures were C1, and five fractures were C2 (Table 1). A1 and A2 fractures were found mostly in women, while A3 fracture was found in a man. In addition, C1 fractures were noted to be equally common among women and men; however, we found more C2 fractures in men compared in women. According to Gustilo-Anderson classification, one patient was type 1 and two patients were type 3A open fracture (Fig. 2). Mini-arthrotomy was performed in nine knees, and open reduction was performed in ten knees via parapatellar approach. In addition, 7 patients who had inflated tourniquet have lost an average 220.71±85.46 ml (range, 120–350 ml) of blood, while 12 patients who did not have tourniquet lost an average 246.25±95.89 ml (range, 100–370 ml) of blood (p=0.569) (Table 2).

Table 1. Patient demographic data and use of insert type/head size

Variable	
Mean age (year)	51.79±18.33
Gender (female/male)	10 (52.63%)/9 (47.37%)
Side (right/left)	6 (31.58%)/13 (68.42%)
Mechanism of injury	
Simple fall	8 (42.11%)
Road accident	7 (36.85%)
Industrial accident	1 (5.26%)
Fall from a height	1 (5.26%)
Gunshot	1 (5.26%)
Pathologic fracture	1 (5.26%)
Fracture type	
A1	7 (36.85%)
A2	2 (10.53%)
A3	1 (5.26%)
C1	4 (21.05%)
C2	5 (26.31%)
Open fracture	
Type I	1 (5.26%)
Type IIIA	2 (10.53%)
Closed fracture	16 (84.21%)
Mini-arthrotomy	9 (47.37%)
Parapatellar	10 (52.63%)
Operation time (min)	132.74±49.16
Tourniquet inflated	7 (36.85%)
Blood loss (ml)	
Tourniquet applied	7 (36.85%)
No tourniquet	12 (63.15%)
Additional pathologies	
Intracranial trauma	2 (10.53%)
Tibial fracture	3 (15.79%)
Vertebral fracture	1 (5.26%)
Acetabular fracture	1 (5.26%)
Lateral malleolus fracture	1 (5.26%)
Distal radius fracture	1 (5.26%)
Abdominal trauma	1 (5.26%)
Union	19 (100%)
Delayed union	1 (5.26%)
Nonunion	1 (5.26%)
Limp length discrepancy (cm)	1.20±0.49
Follow-up time (month)	19.26±8.59

Values are given as mean (SD, range) or n (%) as appropriate.

Table 2. Comparison of patients with and without tourniquet

Blood loss (ml)	
Tourniquet applied (n=7)	220.71±85.46 (120–350)
No tourniquet (n=12)	246.25±95.89 (100–370)
P-value	0.569

Values are given as mean (standard deviation, range) and p calculated using unpaired t-test.

Figure 2. (a) An AO type C2 and Gustilo-Anderson type 1 open fracture in a 19-year-old man. **(b)** X-rays taken 5.5 months.

Union was seen in all patients (Fig. 3). The mean union time was calculated as 26.47±5.34 weeks (range, 21–72 weeks). While this period was 26.38±12.43 weeks (range, 21–72 weeks) in closed, it was 27.00±2.65 weeks (range, 24–29 weeks) in open fractures (p=0.109) (Table 3). Three patients needed dynamization of the nail after 5 months postoperatively. These fractures achieved union 6 months after the operation; however, one patient had delayed union, wherein union was achieved 10 months after the operation. Nonunion was noted in only one patient who needed autologous iliac crest bone grafting. Union was accomplished 20 months after the surgery with a leg shortening of 2 cm.

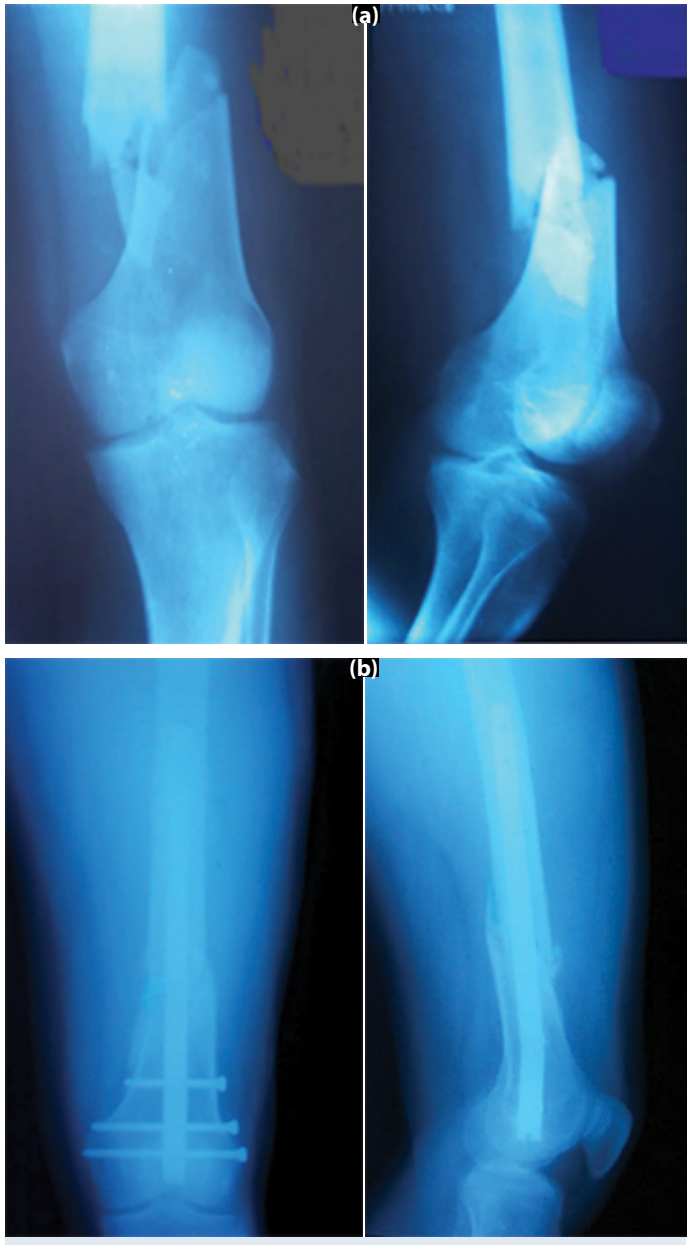

Figure 3. (a) An AO type A3 closed pathologic fracture in a 38-year-old man. **(b)** X-rays taken 6 months later.

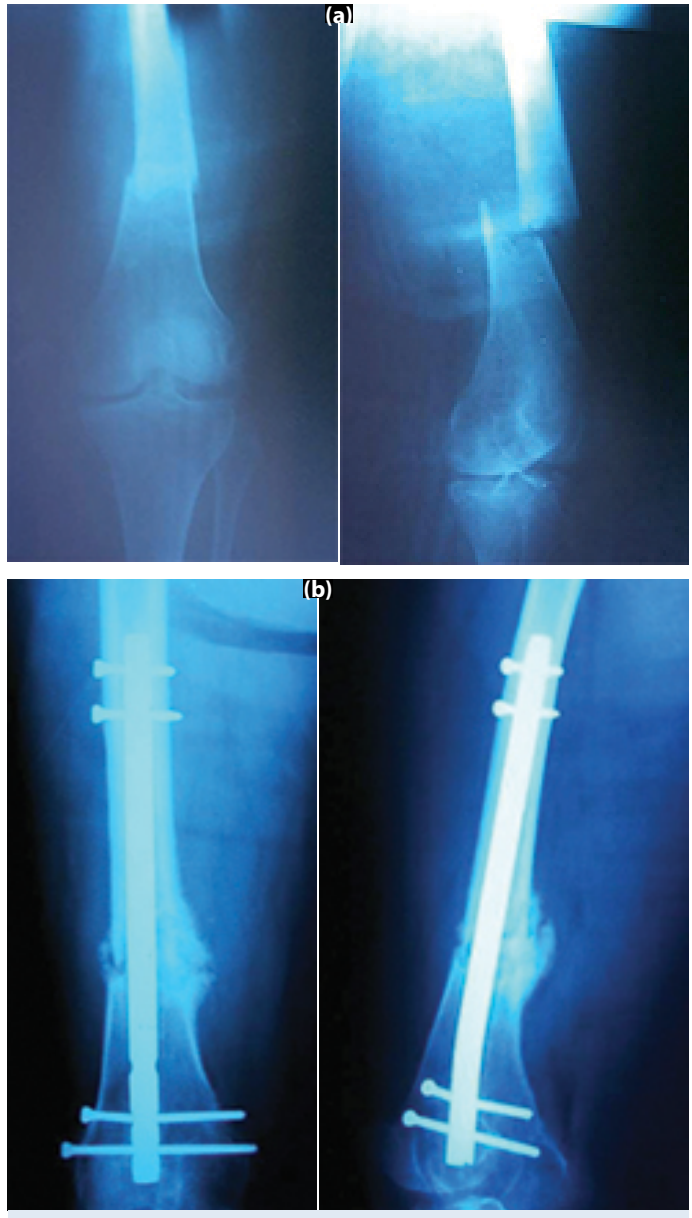

Figure 4. (a) An AO type A1 closed fracture in a 57-year-old woman. **(b)** X-rays taken 6 months later postoperatively showing screw breakage.

Sixteen knees had no flexion contracture, and three knees had an average flexion contracture of 11.5° (range, 5°–20°). The mean knee joint range of motion was measured as 102.29°±15.70° (range, 60°–135°). This was calculated as 105.60°±13.51° in type A and as 95.67°±15.70° in type C fractures (p=0.175) (Table 4). Gonarthrosis was detected in eight patients preoperatively.

There were six excellent, ten good, two fair, and one bad result according to the Modified Knee Rating Scale of the HSS Knee Assessment System (Table 5). No significant difference was noted between mini-arthrotomy and open medial parapatellar approach in terms of modified HSS Knee Assessment Scores (78.44±13.03 and 77.0±7.81 scores, respectively) (p=0.848) (Table 6). Two patients had to change their occupation One of them had L2 vertebral fracture, and the other had type 3A open fracture.

We encountered a proximal part of femoral fracture when we placed the nail intraoperatively. In one patient, patellar abrasion occurred when we performed the mini-arthrotomy. Eleven knees experienced union with less than 5° varus or valgus deformities and 10° anterior or posterior angulation. The average shortening was 1.20±0.49 cm (range, 0.5–2 cm). In two patients, the distal screw that was used to lock the nail was noted to have backed out; however, fracture

Table 3. Union time

Variable	
Mean union (week)	
According to fracture type (weeks)	26.47±5.34 (21–72)
Open fracture	27.00±2.65 (24–29)
Closed fracture	26.38±12.43 (21–72)
P-value	0.109

Values are given as mean (standard deviation, range) and p calculated using Mann-Whitney U test.

Table 4. Knee joint range of motion

Variable	
Mean ROM	102.29±15.70 (60–135)
In type A fracture	105.60±13.51 (60–135)
In type C fracture	95.67±15.70 (60–117)
P-value	0.175

Values are given as mean (standard deviation, range) and p calculated using unpaired t-test.

Table 5. Patient numbers according to modified HSS scores

Variable	n	%
Excellent	6	31.58
Good	10	52.63
Fair	2	10.53
Poor	1	5.26

Values are given as n (%) as appropriate. Modified HSS: Modified Hospital for Special Surgery Knee Scoring System.

Table 6. Comparing mini-arthrotomy and medial parapatellar approach in terms of modified HSS scores

Variable	
Mini-arthrotomy	78.44±13.03 (59–94)
Parapatellar approach	77.50±7.81 (65–89)
P-value	0.848

Values are given as mean (standard deviation, range) and p calculated using unpaired t-test.

healing was not affected in either of the patients. There was a screw breakage in one patient (Fig. 4). No breakage of the nail was noted in any of the patients. None of the patients had any infection or neurovascular injury.

Discussion

The most important outcome in this present study was that RIN was considered as a safe and effective surgical technique in the management of distal femoral fractures owing to not needing large dissection and its reliability. We may keep this technique in our mind as a viable option for distal femoral fractures.

This minimally invasive approach is known to preserve the hematoma, periosteum, and peripheral soft tissues at the fracture site by means of decreasing soft tissue dissection and periosteal damage, which, in turn, result in increased union rates.[5,15] There are two commonly applied minimally invasive methods in treating distal femoral fractures, that is, RIN and LISS.[4] Although RIN has many advantages, some authors suggested that RIN technique can lead to pain in the anterior part of the knee, knee arthrosis due to potential knee joint damage, and thromboembolic complications which can result from reaming the intramedullary bone, especially in patients with concomitant thorax trauma.[3,4,6,8,10–12] Du et al.[4] conducted a biomechanical study in which LISS was plated in 16 cadaveric femur bones and RIC in 16 femur bones. At the end of this study, they found that the RIC method was more stable than LISS method. In contrast, a recent meta-analysis conducted by Koso et al.[12] in 2018 compared the outcomes for RIN and LISS technique and indicated that LISS plate had similar healing occurred in 86.4% compared with 86.8% of fractures treated with RIN.

One of the most important advantages of RIN is that it allows the patients to move their knee as early as possible. Papadokostakis et al.[16] performed a meta-analysis in which 419 distal femoral fractures treated with RIN were evaluated and found that the mean time to union was 3.4 months and the mean range of knee motion was 104.6°. In a study conducted by Neubauer et al.,[17] examining 41 distal femoral fractures treated with RIN, the fractures healed in 16.5 weeks after the operation and gained 105° of the average range of knee motion at the end of the study. Moreover, Gurkan et al.[18] evaluated 16 patients treated with RIN for distal femoral fractures and revealed that the mean union time was 25 weeks in all patients, except for 1 patient who had a union time of 42 weeks. According to this study, the range of motion at the latest follow-up examination was 135° in three knees, 100°–110° in nine, 80°in four, and under 80° in one knee. In this present study, the mean union time was quite similar to Gurkan et al.'s report. Nevertheless, the mean union time in our study was longer than Papadokostakis et al.'s and Neubauer et al.'s outcomes. Possible reason for this discrepancy between our present results and their results is that the limited number of fractures which were heterogeneous samples. In terms of the average range of knee motion, our results were quite similar to the literature. Leung et al.[14] conducted a study in which there were 37 cases and indicated that according to the Modified Knee Rating Scale of the HSS system, 13 knees

(35%) had an excellent result, 22 knees (59%) had a good result, 2 knees (5%) were rated fair, and no knee was rated poor. Meanwhile, Gurkan et al.[18] found that five patients (29.4%) were rated excellent, six patients (35.3%) were rated good, five patients (29.4%) were rated fair, and one patient (5.9%) was rated poor, as per the Modified Knee Rating Scale of the HSS system. Our outcomes in terms of the clinical and functional results were deemed consistent with most of the findings of other studies in the literature.

A retrospective study conducted by El-Kawy et al.[19] with 23 patients who underwent RIN suggested that union occurred in all patients; however, 9 patients (39.2%) had angular malalignment. Gurkan et al.[18] found that radiologically all cases united; nevertheless, 8 of 16 patients (23.5%) encountered 10° of varus malalignment, four patients (23.5%) had 10°–20° of posterior angulation, and one patient had 30° of posterior angulation. In contrast, Watanabe et al.[20] have evaluated 24 distal femoral fractures, wherein they found that 3 fractures (12.5%) had angular malalignment. Although this present study gained similar outcomes regarding malalignment of femur compared to the literature, a high incidence of angular malalignment was noted. We believe that one of the most common problems of using RIN technique is malalignment, which can result from wide inner medullary canal and the barrel-shaped distal part of the femur in osteoporotic elderly patients.

Knee pain may occur after treating the distal femoral fractures especially in RIN method. Hartin et al.[21] conducted a randomized controlled trial including 23 fractures treated with RIN and blade plate and suggested that both methods provide very satisfactory recovery. Nevertheless, three patients (13%) encountered pain in the knee treated with RIN, whereas no patient treated with blade plate suffered from knee pains. Three patients underwent implant removal due to persistent knee pain. Papadokostakis et al.[16] performed a meta-analysis wherein their study showed that the patients who underwent RIN surgery had 16.5%–24.5% incidence of knee pain. In our study, we had similar incidence of knee pain compared with other reports using the same technique.

Some authors revealed that distal femoral fractures occur as a result of low-energy trauma in patients over 50 years of age.[7,22] A prospective study performed by Dunlop et al.[22] had 31 distal femoral fractures treated with RIN and showed that most patients were female compared with men in elderly patients (28 females and 3 males, respectively). The same result was revealed by El-Kawy et al.[19] (16 females and 7 females, respectively). Moreover, the same outcomes emerged in our study. Eight of ten female patients had reportedly suffered from low-energy trauma such as a fall in the street or at home. As per our study results, a relationship between the mechanism of trauma and sex was observed in terms of distal femoral fractures. Fractures during low-energy trauma primarily occur in elderly female patients, while fractures during high-energy trauma were noted to occur frequently in younger male patients.

Fractures close to the knee joint are known to be caused by high-energy trauma such as motor vehicle accident or fall from a height in younger patients and frequently are associated with concomitant injuries, including intracranial trauma, pelvic fractures, chest injuries, and tibial fractures.[9,23] Floating knee injuries or isolated supracondylar femur fractures with major concomitant injuries as mentioned before may be associated with blood loss, which might be life-threatening.[24] In these patients, RIN can provide some advantages such as less blood loss and using the same surgical side for supracondylar femur and tibial shaft fractures.[23,24] In this present study, it was determined that associated injuries such as tibial fractures, vertebral fractures, and acetabular fractures occurred in five patients who obtained good results except for one patient with a fair result. According to our study outcomes, we suggested that distal femur fractures with concomitant injuries can be treated with RIN method, as it can reduce blood loss.

The incidence of open fractures that comprise 27% of supracondylar femur fractures has been noted to be higher due to high-energy trauma such as gunshot and motor vehicle accident.[23–26] This present study obtained three open fractures which were caused by motor vehicle accident, industrial accident, and gunshot. Comparing our data with other previous series, no patients experienced any nonunion and infection in terms of open distal femoral fractures in our trial.[25,27,28] We believed that we gained these outcomes as a result of aggressive debridement which we performed within the first 24 hours after injuries and a standard of three kinds of antibiotics which ordered for patients after injuries. On the other hand, two patients had lack of extension of the knee at last follow-up, and one patient had a leg shortening of 1 cm. These findings revealed that open fractures can lead to worsening outcomes of distal femoral fractures.

RIN technique can suffer from substantial rates of nonunion caused by open reduction, open fractures, and multiple fragments of fracture.[12,16,21,29,30] Koso et al.[12] indicated that the patients treated with RIN had 5.4% of nonunion rates. In addition, Hierholzer et al.[29] revealed that in the RIN group, 5 out of the 59 patients (9%) had nonunion com-

pared with LISS group in which nonunion was observed in 6 out of 56 patients (12%). However, no statically significant difference was noted between the two groups in terms of nonunion rates. Koso et al.[12] indicated that the patients treated with RIN had 5.4% of nonunion rates. This finding is similar to our data, which indicated that one patient (5.2%) who needed autologous iliac crest bone grafting suffered from nonunion.

RIN technique can be applied to nonunions, pathological fractures, and correction osteotomy for malunions in supracondylar femoral fractures as well as primary fractures.[14,30,31] Wu et al.[31] conducted a retrospective study using RIN technique in treating 36 of aseptic supracondylar femoral nonunions after DCS treatment. The study results showed that all nonunions healed with a union rate of 100%, and the average time to union was 4.2 months (range, 2.5–5.5 months). Comparing our data with their outcomes, we found similar results regarding union rates. However, the average time to union in this present study was longer than that in the literature. This discrepancy could be possibly attributed to the small study size.

This study has several limitations. The main drawback of our study is that this is the only retrospective study without a control group. Thus, it is difficult for us to conduct a prospective randomized control study owing to the few numbers of patients who have distal femoral fractures. Another limitation was that the limited number of fractures which were heterogeneous samples was insufficient to strengthen the rates of nonunion and delayed union. In addition, loss to follow-up is often an issue in trauma studies. We encountered a 29.6% loss of patients which may lead to a shortcoming of this present study. Lastly, we could have ordered magnetic resonance imaging (MRI) for the patients who need to be detected due to ligament or meniscal injuries.

In conclusion, owing to its safety and reliability, RIN was considered as a safe and effective surgical technique in the management of distal femoral fractures and was applicable in all fractures except for Gustilo-Anderson types 3B and C.

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