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ORIGINAL ARTICLE

Retrograde intramedullary nailing of comminuted intra-articular distal femur fractures results in high union rate

Samantha Nino[1] · Joshua A. Parry[2] · Frank R. Avilucea[1] · George J. Haidukewych[1] · Joshua R. Langford[1]

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Abstract

Purpose Retrograde intramedullary nailing of intra-articular distal femur fractures with metaphyseal and/or epiphyseal comminution is controversial and considered a contraindication to nailing. The purpose of this study was to report union rate, complications, and secondary procedures after open reduction and retrograde intramedullary nailing of comminuted, intra-articular, distal femur fractures.

Materials and methods A retrospective review performed at an urban level one trauma center identified 16 patients AO/Orthopedic Trauma Association (OTA) 33-C2 and 33-C3 femur fractures treated with open reduction, lag screws, and retrograde intramedullary nail fixation. Radiographic union, complications, secondary operations were reviewed.

Results At the 3-month follow-up 12 (86%) of the 14 patients with radiographs had healed. At last follow-up, all 16 femur fractures achieved radiographic union after the index procedure. No patient required a revision procedure for delayed union or nonunion. Complications occurred in 6 (38%) patients, including failed distal interlocking screws ($n=2$), knee arthrofibrosis ($n=3$), superficial wound infection ($n=1$), and wound dehiscence ($n=1$). Three (19%) patients required secondary procedures, which included knee manipulation under anesthesia ($n=3$), distal interlocking screw removal ($n=2$), and closure of a wound dehiscence ($n=1$).

Conclusions Comminuted intra-articular distal femur fractures that can be successfully treated with retrograde IMN fixation will reliably go on to union with a complication rate that is favorable to that reported for plate fixation.

Level of Evidence: Level IV, retrospective case-series.

Keywords Retrograde nail fixation · Intraarticular distal femur fractures · AO/OTA 33C · Union · Nonunion · Comminuted · Extremenailing

Introduction

Despite advances in distal femur locking plates, the management of comminuted intra-articular distal femur fractures remains complicated by high rates of nonunion [1–5]. While retrograde intramedullary nail fixation is an accepted and often preferred alternative to distal locking plates for the treatment of supracondylar distal femur fractures and fractures with simple intra-articular involvement, retrograde intramedullary nailing of intra-articular distal femur fractures with metaphyseal and/or epiphyseal comminution (AO/OTA Classification 33-C2 and 33-C3, respectively) is controversial and considered a contraindication to nailing by some [2, 3, 6–9]. However, in our experience retrograde nail fixation can be successful in certain comminuted fractures. There is a paucity of evidence for this treatment strategy; therefore, the purpose of this study is to report the outcomes of AO/OTA 33-C2 and 33-C3 intra-articular distal femur fractures managed with retrograde intramedullary nail fixation.

✉ Joshua A. Parry
Joshua.alan.parry@gmail.com

[1] Department of Orthopaedics, Orlando Health, Orlando, FL, USA

[2] Department of Orthopaedics, Denver Health Medical Center, University of Colorado School of Medicine, 777 Bannock St, MC 0188, Denver, CO 80204, USA

Materials and methods

After institutional review board approval, a retrospective chart review was performed at a single level one trauma institution spanning five years (2011–2016) to identify comminuted intra-articular distal femur fractures (AO/OTA 33-C2 or 33-C3) treated with retrograde intramedullary nailing by a single surgeon (JRL). Exclusion criteria included less than 6 months of follow-up and bone loss requiring staged management.

The senior author determines if intra-articular distal femur fractures are amenable to retrograde nail fixation by reviewing preoperative computed tomography (CT) scans. If an intra-articular block can be reconstructed with lag screws and is sufficiently sized for a minimum of three distal interlocking screws, then retrograde nail fixation is his preferred construct, regardless of age, bone quality, or comorbidities. All fractures were fixed with the T2 Supracondylar Nailing (SCN) System (Stryker, Kalamazoo, MI).

In order to assess rotational alignment, the contralateral leg is placed on the same sized radiolucent triangle that will be used during the case prior to prepping and draping. A perfect lateral of the knee is taken with fluoroscopy, then a 90-degree image of the hip is taken to assess less trochanter profile. To determine length, usually only in cases of severe metaphyseal comminution, a non-sterile radiopaque rule is placed over the femur while on the radiolucent triangle. The length from top of the femoral head to the bottom of the femoral condyles is measured. All of these fluoroscopic images are saved for use during the procedure to assess length and rotation.

An open approach and reduction were performed on all patients. Procedures were performed with the patient supine, without a hip bump, on a radiolucent table with a sterile, radiolucent triangle. An open approach was utilized in all cases through an anterior midline skin incision and a lateral parapatellar arthrotomy. The intercondylar fracture was first reduced and lagged together with two 6.5 mm partially threaded cannulated screws to reconstruct the main articular block. Additional fractures, such as Hoffa fractures, were then reduced and fixed in place with wires for two partially threaded 4.0 mm screws. Placement of the 4.0 mm screws was typically reserved for after nail insertion to prevent blocking the critical interlocking screw holes. Reduction in the articular block to the femoral shaft was obtained with

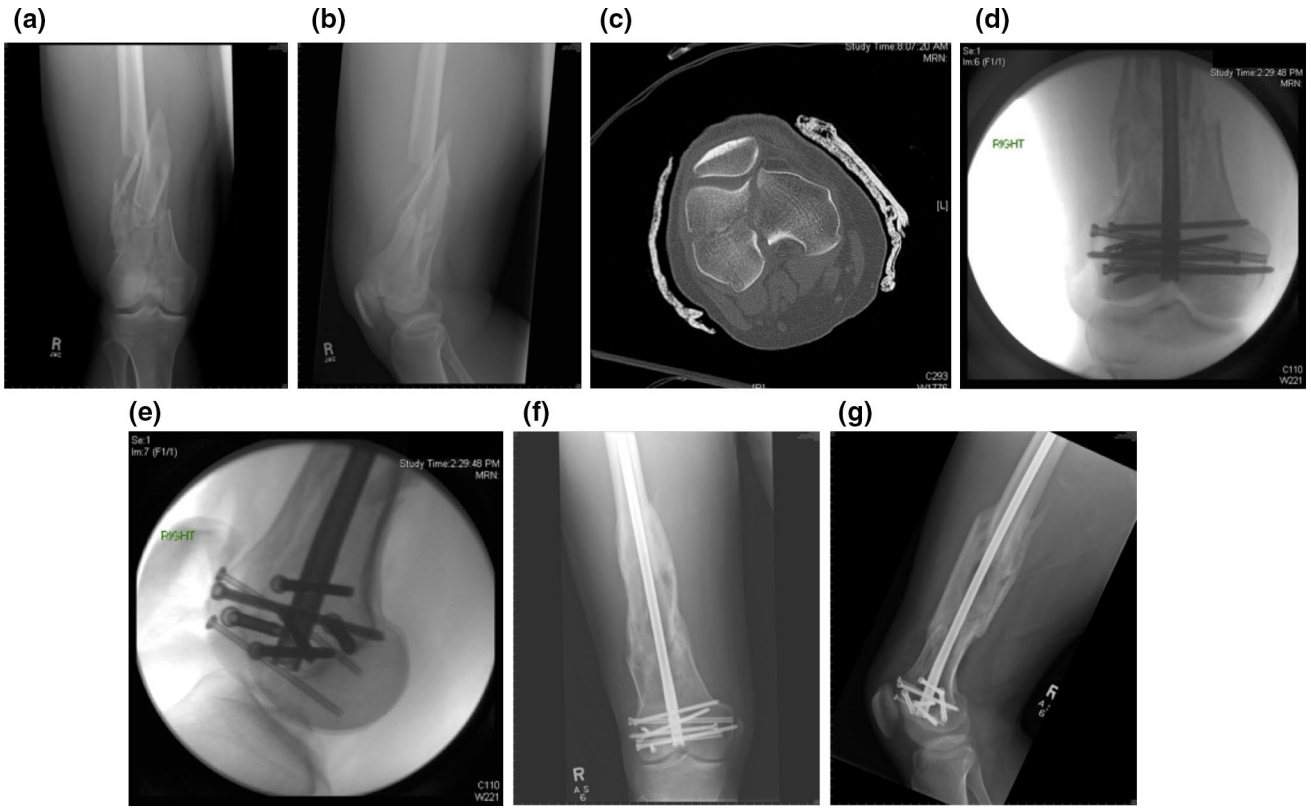

Fig. 1 **a** Anteroposterior (AP) and **b** lateral femur radiographs of a comminuted distal femur fracture (AO/OTA 33-C2). **c** Computed tomography scan demonstrating intra-articular fracture extension in the sagittal and coronal planes. **d** AP and **e** lateral fluoroscopy images after fixation with cannulated screws and a retrograde intramedullary nail. **f** AP and **g** lateral femur radiographs at one-year follow-up show fracture union

gross traction over bump to correct the extension deformity. All femurs were over-reamed by 1.5 mm prior to insertion of the nail. A minimum of three distal interlocking screws and two proximal interlocking screws were used on all fractures. The distal-most interlocking screw was locked in place as a fixed angle construct by insertion of the interlocking endcap (Fig. 1). Postoperatively, each patient's weight-bearing was limited to touch-down for six weeks unless further limited by ipsilateral injuries.

The electronic medical record and associated radiographs for each patient were reviewed to document age, sex, tobacco use, the presence of diabetes, ipsilateral extremity injuries, final knee range of motion, complications, and revision procedures. One author (J.A.P.), a trauma-fellowship trained surgeon, reviewed all follow-up radiographs to document radiographic union, which was defined as bridging of 3 out of 4 femoral cortices on anterior-to-posterior and lateral radiographs of the femur at each follow-up visit.

Results

Chart review identified 20 patients with comminuted intra-articular distal femur fractures (AO/OTA 33-C2 or 33-C3) treated with retrograde intramedullary nailing. Four patients were excluded, including one patient with a 12 cm diaphyseal defect that was treated with an antibiotic spacer at the index procedure, and three patients with less than 6 months of follow-up. Sixteen patients were included in analysis.

Details for each of the 16 patients are presented in Table 1. The mean follow-up was 16 months (range, 6–48 months). The mean age was 62 years (range, 24–90 years), 7 (44%) were male, 4 (25%) were tobacco users, and 3 (19%) were diabetic. Open fractures were present in seven patients (44%), all of which were considered type IIIA according to the Gustilo-Anderson classification. None of the fractures had segmental bony defects requiring spacer placement or bone grafting. Ipsilateral lower extremity injuries were present in 5 (31%) patients. Fractures types included 10 (62%) AO/OTA 33-C2 and 6 (38%) AO/OTA 33-C3. Coronal fractures of the femoral condyle, or Hoffa fractures, were present in 25% ($n=4$), all of which were fixed separately with 4.0 cannulated screws (Stryker, Kalamazoo, MI) placed anterior-to-posterior.

Radiographs at 3-month follow-up were obtained in 14 patients with 12 (86%) of these patients demonstrating radiographic union. One patient united at 7 months. The time to union in the remaining three patients is unknown. Two of these patients missed both 3- and 6-month follow-up and were united at last follow-up, and one patient was not united at 3 months, missed their 6-month follow-up, and were united at last follow-up. No patient required a revision fixation procedure for loss of fixation, delayed union, or nonunion. Knee range of motion at last follow was 0 degrees of extension for all patients and an average of 122 degrees of flexion (range, 70–140 degrees).

Eight minor complications occurred in six patients (38%), five of which had open fractures, including: backing out of a distal interlocking screw (×3), arthrofibrosis of the knee (×4), traumatic wound dehiscence (×1), and a superficial wound infection that resolved with a course of oral antibiotic treatment.

Three (19%) patients returned to the operating room for a secondary procedure. The first patient underwent a knee manipulation under anesthesia for arthrofibrosis 3 months postoperatively. The second patient underwent a knee manipulation under anesthesia for arthrofibrosis and removal of a loose distal interlocking screw 6 weeks postoperatively. The third patient underwent knee manipulation under anesthesia for arthrofibrosis and debridement of a non-healing traumatic open wound 7 weeks postoperatively.

Discussion

This is the largest study to-date analyzing retrograde intramedullary nail fixation of comminuted, intra-articular distal femur fractures (AO/OTA 33-C2 and 33-C3). This technique was successful in achieving union in all of patients without any additional bone grafting or revision fixation procedures.

A previous review of the 18 studies analyzing 479 distal femur fractures (AO/OTA 33A, B, and C) treated with open reduction and internal fixation reported nonunion rates ranging from 0 to 19% and revision fixation or grafting procedures ranging from 0 to 32% [5]. Three separate studies evaluated the outcomes in a total of 60 comminuted intra-articular fractures (33C) and found that 12 (20%) patients developed nonunions and 13 (22%) patients required major revision procedures [1, 10, 11]. In contrast, our study reported no nonunions and no major revision procedures. The differences in complications between intramedullary nail and plate fixation may be secondary to the nail's ability to minimize soft-tissue stripping and provide a load-sharing construct [1, 4, 12, 13].

Although retrograde intramedullary nail fixation is an accepted treatment for simple intra-articular fractures distal femur fractures (AO/OTA 33-C1), its use for comminuted metaphyseal and epiphyseal segments (AO/OTA 33-C2 and 33-C3) is controversial with scant evidence [2, 6, 7]. The current literature utilizing modern implants (AO/OTA 33-C) is limited to two studies with limited patient numbers. Thomson et al. [6] compared 22 intra-articular distal femur fractures (AO/OTA 33-C1) undergoing plate fixation versus retrograde IMN fixation and found that the plating

Table 1 Case details

#	Age	Sex	Tobacco use	Mechanism	Open fracture (grade)	OTA/AO fracture type	Follow-up length (months)	Time to union (months)	Knee ROM at last follow-up (°)	Complications	Secondary procedures	Ipsilateral lower extremity injuries
1	71	M	N	MCC	Type 3A	C3	15	7	0–70	Knee arthrofibrosis		Open tibia and fibula fractures requiring free flap
2	46	F	N	ATV	Type 2	C3	48	3	0–130	Wound dehiscence; Knee arthrofibrosis	Closure of wound dehiscence; Knee MUA	–
3	54	F	N	MVC	–	C3	16	3	0–130	–	–	
4	59	M	Y	MCC	Type 2	C2	11	3	0–110	Loose distal interlocking screw removed in clinic	–	Distal tibial and fibular shaft; 5th metacarpal fracture
5	51	F	Y	MCC	–	C2	29	**	0–120	–	–	
6	72	F	N	FALL	–	C3	14	**	0–130	–	–	–
7	71	M	Y	MVC	–	C2	12	*	0–140	–	–	
8	67	F	N	FALL	–	C3	12	3	0–130	–	–	–
9	24	M	N	MCC	Type 3A	C3	9	3	0–120	–	–	
10	70	F	N	FALL	–	C2	21	3	0–110	Loose distal interlocking screw; Knee arthrofibrosis	Knee MUA; Removal distal screw	
11	90	M	N	FALL	–	C2	12	3	0–140	–	–	–
12	42	M	Y	MVC	Type 3A	C2	21	3	0–140	Knee arthrofibrosis	Knee MUA	Patella, tibial shaft, 1st & 2nd metatarsal fractures
13	49	M	N	MVC	Type 3A	C2	12	3	0–120	Superficial infection, resolved with oral antibiotics	–	Tibial plateau, tibial shaft, calcaneus, 2nd–4th metatarsals fractures
14	69	F	N	FALL	–	C2	9	3	0–120	–	–	
15	81	F	N	MVC	–	C2	12	3	0–110	–	–	Patella, tibial plateau fractures
16	74	F	N	FALL	Type 2	C2	6	3	0–130	–	–	–

(MCC—motor cycle collision; ATV—All-terrain vehicle accident; MVC—Motor vehicle collision; MUA—Manipulation under anesthesia)

*Time to union is unknown: Fracture was not united at 3 months and patient missed 6-month follow-up. Last follow-up showed union

**Time to union is unknown: Patient missed 3- and 6-month follow-up. Last follow-up showed union

group required more bone grafting procedures (67% vs. 9%), had more malunions (42% vs. 0%), and had more nonunions (33% vs. 9%). In addition, Siefert et al. [7] reported on 37 type A and 11 type C fractures fixed with retrograde nail fixation and found that all fractures healed primarily, with no differences in functional, clinical, or radiographical outcomes between type A and C fracture groups. Complications in the type C group included two cases of leg length shortening > 1 cm, two cases of intra-articular nail prominence, one fracture malreduction, and one iatrogenic fracture of the femoral shaft. Similarly, our study found that retrograde nail fixation of these fractures resulted in reliable union without revision procedures.

Another technique described by Liporace and Yoon [14] for treatment of comminuted intra-articular fractures is the combination of nail and plate fixation—

a construct advocated for patients where poor bone quality could compromise interlocking screw fixation. In their series of six patients with native distal femur fractures treated with this method, Liporace and Yoon [14] reported no cases of reoperation, nonunion, or implant failure. Five of the six patients regained their pre-injury ambulatory status. The nail-plate construct is a useful technique if the surgeon feels additional fixation is warranted after retrograde nail fixation.

Our study, like most of the literature on the use of retrograde IMN fixation for intra-articular distal femur fractures, is limited by its small sample size, retrospective design, lack of functional outcomes, and lack of control group. Based on our observed nonunion rate, a total sample size of 146 patients would be necessary to determine a 10% difference in nonunion between plate and IMN fixation with a power of 0.8 and an alpha of 0.05. Such a sample size would require a large multi-center effort.

Conclusion

This study demonstrated that comminuted intra-articular distal femur fractures can be successfully treated with retrograde IMN fixation and will reliably go on to union with a complication and revision surgery rate that is favorable to that reported for plate fixation.

Declarations

Conflict of interest This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have no specific disclosures related to this study.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent The institutional review board approved this study. Due to the retrospective nature of this work, informed consent was waived.

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