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Results of Low Distal Femur Periprosthetic Fractures

Walter Virkus, MD[1], Charles Lieder, DO[2], Yohan Jang, DO[1], Parker R a, BS reg Gas MD[4]

[1]Department of Orthopaedic Surgery, Indiana University School Medi ne

[2]Illinois Bone and Joint Institute

[3]Rush University Medical College

[4]Inova Fairfax Medical Campus

Corresponding author: Walter Virkus D Dep ment of Orthopedic Surgery, Indiana University School of M icine, 1801 N. S ate Blvd, MPC1, Suite 535 Indianapolis, IN 46202, United States Fax: 317-9 1955 Ph ne: 317-944-9400 Email: wvirkus@iuhealth.org

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Abstract

Objectives- To compare retrograde intramedullary nail (RIMN) and open reduction internal fixation (ORIF) in very distal periprosthetic distal femur fractures (PDFF) to determine if RIMN

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is an acceptable option for these fractures that are often considered too distal for IMN due to limited bone stock.

Design- Retrospective comparative series

Setting- Level One trauma center

Patients- Patients treated with fracture fixation for a very distal PD F, def d as th acture extending to the anterior flange of the implant or distal. Fif six pa nts met clusion criteria, with eight excluded for less than twelve months of fol w-up

Intervention- Fracture fixation with RIMN or RIF

Main Outcome Measurements- The pri ary ou e was unplanned return to surgery. Secondary outcomes included fra re uni n, radiographic alignment, Visual Analog Score (VAS) and Patient-Reported tcome asur ment Information System (PROMIS) Physical Function (PF) and Pain terference PI).

Results- Mean llow up wa nths. Twelve patients were treated with ORIF and 36 with RIMN. Twe y-one frac res were at the flange and 27 extended distal to the flange. There we no differen een fixation methods with respect to reoperation, deep infection, non ion a n, VAS pain score, and PROMIS PI score. Mean PROMIS PF score was higher the RIMN group compared to ORIF. There were five reoperations in the RIMN group (14%) and three in the ORIF group (25%).

Conclusion- This is the largest series, to our knowledge, of a subset of very distal PDFFs. The results suggest that RIMN may be an acceptable treatment option for these very difficult fractures.

Keywords: periprosthetic fracture; retrograde intramedullary nail; complications; Total knee arthroplasty

Introduction:

Fractures around total knee arthroplasty (TKA) are ncreasing omm n in an aging population. [1] A majority of distal femur periprosthetic frac s around TKA result from low-energy injuries.[2] These fractures affect 0.3% o 2. of primary (TKA) patients. [3-5] Fractures around TKA are often difficult to tr du o limited bone stock, generalized osteoporosis, and short distal segm ts. [1] Non-op tive treatment of displaced fractures is associated with high complication ra [6] resul ng in the vast majority of these fractures requiring surgical stabil ation. [1] Goals urgical treatment include restoration of alignment, application of stable fixa n to enco age immediate knee range of motion, facilitation of early weight-beari g, and promotion to return to pre-injury level of ambulation. The options for surgical treat nt includ etrograde intramedullary nail (RIMN), open reduction and internal fix i ORIF) and revision TKA, typically with a hinged prosthesis.

dvantages of RIMN for treatment of periprosthetic distal femur fractures (PDFF) include minimally invasive exposure, preservation of the local fracture biology, ability of long implants to span complex fractures, and load sharing fixation to potentially allow immediate weight bearing. [7-9] Despite perceived advantages, studies on RIMN and ORIF for PDFFs have demonstrated conflicting results.[10-13] Thus, the optimal surgical treatment for PDFFs, particularly very distal fractures, remains controversial [10-12].

RIMN has been shown to have better outcomes when compared to ORIF in some studies. [13, 14] However, contrasting reports have shown that patients treated with RIMN demonstrated lower levels of ambulation and experienced higher complication rates such as nonunion and malunion compared to patients treated with plate fixation. [14 5] Addi nally, some studies utilizing locking plate constructs have demonstrated less perativ lood lo better alignment and greater knee motion when compared to RIM . [16]

Periprosthetic fractures can occur either immediat y adjacent r f proximal to the prosthesis, presenting very different challenges for fixation. F distal PDFFs raise increasing concern for adequate distal fixation. Many su eons o for plate fixation in this scenario, as opposed to RIMN, due to concerns that ails ca get adequate fixation in far distal segments. [17] To our knowledge, no study s speci ally ex mined outcomes of very distal PDFFs utilizing RIMN.

This investigatio sought to mpare outcomes of very distal PDFFs, defined by a fracture at or di o the a ior nge of the TKA prosthesis, treated by RIMN versus ORIF with locking late/screw We hypothesized that adequate fixation can be achieved in short distal segments of PD wit both RIMN and plates and there would be no difference in clinical out mes n the two groups.

Metho s:

Following institutional review board approval, we performed a retrospective review of patients 50 years or older who underwent fracture fixation of PDFFs between March 2013 through December 2016. Patients were identified by surgical billing records, and then verified by evaluation of radiographs. All PDFFs were radiographically examined for type of knee implant;

cruciate retaining (CR) or posterior stabilized (PS), and classified by plain radiographs and/or sagittal or coronal CT scans utilizing the Su classification[18] as: 1) 'above the flange' in which no extension of the fracture line extends to the flange (Su I)(Figure 1a); 2) 'at the flange' in which the fracture extends to the level of the flange (Su II)(Figure 1b; and 3) below th ange' in which the fracture line extends distal to the flange (Su III) (Figure 1 . Patie with fr tures 'at the flange' or 'below the flange' were included in the analysi Su II a d III), and those with PDFFs 'above the flange' were excluded (Su I). Anyone w h less th welv months follow up was excluded from the study.

Patients were treated by RIMN or ORI based n treatment determined by surgeon preference. Distal femoral replacement as only ized in the setting of loose TKA components, which was only obse ed in o patien At the beginning of the study period, the orthopaedic trauma surgeons in our gr p had f m, but differing opinions as to whether far fractures distal could be dequately stabiliz d by a RIMN (i.e., some felt that the additional screws afforded by an OR would e additional stability and decrease construct failure). This was in part t genesis of this retrospective review. Similarly, postoperative weightbearing status was assigned ed on th surgeon assessment of postoperative fracture fixation stability. Over the our f the study, our group had an increasingly aggressive approach to early weig aring in these and other lower extremity fractures, especially for intramedually nail constru s and non-articular injuries. All procedures were performed by a fellowship trained orthopaedic trauma surgeon. Individual surgeon experience and preference based on fracture location influenced implant selection. All RIMN cases utilized modern nails with distal multiplanar fixation (Stryker SCN nail, Allendale, NJ), which allows four locking screws within 32 millimeters of the distal end of the nail. All had at least three of four distal locking screws

(three when the TKA interfered with placement of one screw). ORIF cases utilized modern distal femur locking plate constructs (Stryker Axsos Distal Femur Plate, Allendale, NJ- 8, Synthes Locking Condylar Plate, Paoli, PA- 2, Synthes Variable Angle Locking Condylar Plate, Paoli, PA- 1, Synthes Less Invasive Stabilization System (LISS), Paoli, PA). One si le fracture was treated with lag screws and a neutralization plate. All oth fractu were t ated with a bridge plate construct with locking metaphyseal screws an hybrid mix of lo king and non-locking shaft screws). The working length of the plat ranged f m thre o six holes.

The electronic medical record s review d for patient demographics, comorbidities (obesity, smoking, Char on Comorbidity I dex (CCI)), injury characteristics, operative data (estimated blood loss, su cal durat n), resource utilization (length of stay), post-operative weight beari g status, and complications.

The pri ry out me was unplanned reoperation. Secondary outcomes assessed included alig men on infection, and patient-reported outcomes (PROs). PROs were obtained using Visua nalog Scale (VAS, 0-10 for pain), and Patient-Reported Outcome Measurement Information System (PROMIS) Physical Function (PF) and Pain Interference (PI) domains. Outcomes were obtained prospectively at follow up office visits, or via phone interview. For patients contacted by phone, VAS and data regarding any additional surgeries was obtained in addition to PROMIS.

Radiographs were reviewed for location of fracture, method of fixation, initial post-operative alignment, final alignment, and union. Radiographs were measured by two trauma-trained surgeons for determination of final alignment and change of alignment. Malunion was defined by: 1) greater than 5 degrees of coronal plane malalignment compar to a norm anatomic lateral distal femoral angle of 81+/-2 degrees; 2) greater than 0 degr of sag al plane malalignment based on the alignment of the anterior flang f the T A and th anterior femoral cortex.[19] Loss of alignment from intraoperative final ra graph was defined as a change of alignment of more than five degrees in eith plan Union was defined as bridging callus across one cortex of the fracture with min ma no pain.[2 Nonunion was defined by lack of bridging bone six months postoperati y an arrest of healing on sequential radiographs, with or without reoperation or catas phic f ilure o ixation.

Student's t-test and Fisher's ex t test (l w cell counts) were utilized in the analyses to compare continuous and ategorical variables, respectively, between the groups.

Results

One ndred and e patients with PDFFs were screened. Thirty-one patients with fr s proximal he prosthesis were not included in the analysis. Eighteen patients were dece ed ior data collection. One patient was treated with a distal femoral replacement. Of 56 elig le patients, 48 met inclusion/exclusion criteria. Eight patients with less than 12 months follow up and were excluded. Mean follow up was 27 months (range: 12-55 months). In the RIMN group, 18 fractures extended distal to the TKA flange, and 18 were at the flange. In the ORIF group, 9 of 12 fractures extended distal to the flange and 3 were at the flange. There were 22 CR and 14 PS knee implants in retrograde nailing group, and six CR and six PS knee implants

in the ORIF group. There was no difference between the RIMN group (n=36) and ORIF group (n=12) with respect to demographics, comorbidities, and hospital length of stay. (Table 1)

There was no difference detected between RIMN and ORIF with respect peration, deep infection, nonunion, coronal plane malunion, sagittal plane malunion, stoperative hange in fracture alignment, discharge disposition, VAS pain score, and PR MIS pain erfe nce score. (Table 2) PROMIS physical function scores were higher in IMN ompared to ORIF (33.9 vs 27.7; p=0.04). (Table 2)

Five patients in the RIMN group had a rep t surgery: th conversions to a distal femoral replacement (one each for infection alunio and nonunion), one nonunion repair via exchange nailing with plate applicatio and bone aft, and one prophylactic plate application for pain at the junction of a RIMN an THA m. There were three repeat operations in the ORIF group: one distal femoral ement inf tion, and two nonunions (including one early fixation failure) conver to RIMN

There ere five malun in the RIMN group, two in the coronal plane and three in the sagittal plan Two of th e shifted post operatively and three were malaligned at surgery. All th lunions occ d in fractures distal the flange of the TKA. Both nonunions/fixation fail s in he ORIF group occurred in fractures distal to the flange of the TKA.

ere was a significant difference in surgical time favoring RIMN (75 vs 110 mins, p=0.02). (Table 3) Half of the patients in RIMN group were initially made weight bearing as tolerated as opposed to only 14% in ORIF group (p<0.01).

Discussion

Far distal PDFFs (fractures at the flange or below the flange) pose unique challenges for fixation due to limited bone stock. Few reports comment on a small number of far distal PDFFs as a subset of all distal femur fractures or PDFFs. [17,22] Opposing commentary exists expressing concern for both nails and plates for very low fractures.[17, 21] This analys attempts to specifically address outcomes in a more homogeneous inju patter defined s low PDFFs, frequently associated with a higher rate of complication Our inv tigation f 48 patients with low PDFFs found no difference in reoperatio and mos her cl ical outcomes between nail and plate fixation, supporting the idea th t RIM is a viable treatment option in these cases. Furthermore, the overall reoperatio at 7%) was s ilar to other studies reporting on all PDFFs. [9]

PDFFs are more becoming ncreasi gly preva nt as the population ages, more TKAs are performed annually, and the elderly p lation remaining active. Numerous studies have reported similar results th both plate and nail fixation methods. [11,12,16,17] However, nearly all investigations report o heterog neous injury population that includes a wide range of fracture patt ns from the level of the TKA flange proximal to the shaft of the femur. Three systematic rev ws have ported pooled results of PDFFs. [11,23,24] Ristevski, et al. observed a tre to d an increased rate of nonunion in ORIF via locked plating compared to RIMN and a highe idence of malunion in the RIMN group.[23] Ebraheim, et al. found that locked plating and RIMN had similar union rates, but the complication rate for locked plating was lower.[11] A third review by Li, et al. found no significant difference in union rate, operation time, or complication rate between fractures fixed with RIMN versus locked plates.[22]

Few studies comment specifically on very distal fractures [17, 23], and to our knowledge, no other studies directly compare nail and plate fixation for fractures at or distal to the TKA

flange. Matlovich, et al. reported on 57 patients treated with either locking plates (n=38) or RIMN (n=19).[17] Groups were further broken down into fractures at or below the flange and proximal to the flange, leading to small numbers in each group. They found comparable clinical results in all both groups, but recommended caution in using RIMN in fractu s distal t he flange, based on two nonunions from a small group. Streubel et al. rep rted on e resul of 61 patients with PDFFs treated with a lateral locking plate, 33 of wh h wer istal to th TKA flange.[23] They reported a nonunion rate of 15% of the m re distal cture nd a 9% fixation failure rate.[22] This retrospective comparative study f 48 p ents focuses on fractures at or below the flange of the knee prosthesis with at l st months fol w-up. The relatively low rate of unplanned reoperation (14% in RIMN gro nd 5% in ORIF group) is similar to studies examining all periprosthetic distal f mur fra tures i uding fractures proximal to the prosthesis with presumably more bone stock.

Meneghini, et al eported on 91 pa ents treated with locked plates (n=66) or RIMN (n=29).[14] Despite a hig numbe of screws in the distal segment, the failure rate of locked plates was tw ce as high as the rate in the RIMN group. There was a high rate of coronal plane malalignment eater th n five degrees) in both groups: 56% of RIMN cases and 46% of locked pla ca Advancements in periarticular nailing techniques, improved implant designs inclu distal multiplanar nail locking, and anatomically contoured plates may contribute to the low rates of malunion (14% in RIMN group, 8% in ORIF group) observed in the current study. Tornetta, el al. reported a low rate of revision surgery in a multicenter, randomized study comparing RIMN (5%) to locked plating (8%) in 126 patients with distal femur fractures.[24] There was a higher rate of valgus deformity (>5 degrees) in the ORIF group (20%) compared to the RIMN group (12%).

Most of the operative results were equivalent for both groups in the current study. We showed a significant difference in the surgical time, with the RIMN group being significantly shorter (75 vs. 110 minutes; p=0.02). Despite the ORIF cases being almost 50% longer, there was not a significant difference in the rates of deep infection or need for tran usion.

There were two nonunions/fixation failures in each group. O patient in RIF roup failed to adhere to weight-bearing restrictions and had early (two ek) mplant failure evidenced by bending of the plate and15 degrees varus m lignment. is w s revised with an IMN and healed uneventfully. A second patient in the ORIF g p was diagnosed with nonunion after the plate broke four months postoperativ y and ent on to heal after exchange nailing and bone grafting. One patient that develope nonu in the IMN group was treated with a distal femoral replacement and a second atient u derwent teral plate supplemental fixation and bone grafting.

We attempted to measure fin fracture malalignment and identify cases that shifted postoperatively (6%) the l cases had a clinically significant change of alignment postoperativ y. One pat t underwent conversion to a hinged TKA, and another case resulted in 10 degrees of es e valgus that was tolerated by a 91-year-old patient. Malalignment in the IMN was 14% with three deformities in the sagittal plane and two in the coronal plane xtension deformity has been found to be well tolerated.[19] The ORIF group had one malunion in the sagittal plane. We noted the frequent need for reconciliation of the sagittal plane measurements between the surgeons due to difficulties in accurately measuring residual sagittal plane alignment. Each also noted a significant number of alignment disparities related to poor femoral component positing despite near anatomic alignment of the fracture.

Alternatives to plate or nail constructs include hybrid reconstructions and distal femoral replacement arthroplasty. Distal femoral hybrid reconstructions use a combination of RIMN and ORIF for distal femur fractures.[25] It is hypothesized that these hybrid constructs maximize construct stability with minimal biologic insult, and thus can allow patients earlier weight bearing to facilitate rehabilitation. Distal femoral arthroplasty is a treatment option that has the benefits of immediate weightbearing as well as avoiding the outcomes of malunion and nonunion. Disadvantages of this treatment approach include significant morbidity should infection occur, as well as a very high cost of treatment due to the prosthesis. This option is more complicated in periprosthetic fractures that native distal femur fractures, as often the tibial components are well fixed. Rahman et al. reported on the results of 17 patients treated with this approach.[26] Range of motion and patient reported outcome scores were overall good, but there were six complications, two requiring revision of the prosthesis. Girgis et al. reported on prosthetic replacement in 14 patients.[27] Overall clinical outcomes were good, but only 64% returned to their pre-injury level of function, and there were two complications.

We feel there are a few important RIMN technique details which evolved during the study, and while low numbers prevent definitive recommendations, we feel these add to the successful procedure.[28] This is includes maximizing distal screw placement even for fractures in which one of the interlocking screws only gains purchase in one distal cortex. Additionally, we place the nail in the distal segment as far distal as possible, such that the most distal interlocking screw is resting against the proximal aspect of the TKA or its associated pegs or cement (Figure 2). Additionally, use of an implant or technique that provides “locked” screws in the distal aspect of the nail may prevent toggling of the distal segment in the nail. Lastly, in cases with a capacious femoral canal, anterior to posterior screws placed in the metaphysis

proximal to the fracture abutting the nail may minimize medial-lateral movement of the nail in the canal.[29]

This study has a number of limitations. As with any retrospective study sults are subject to selection bias with the potential that more distal fractures were m e likely to treated with ORIF which is advocated by most surgeons. However rgeon pref nce n our team was somewhat split at the beginning of the study period A ur p tice has evolved, most PDFFs are currently treated with RIMN at our institution Additionally os operative weight bearing status also evolved during the study period, initially w RIMN cases, and eventually ORIF cases being allowed to weight bear as t rated almost all circumstances. We had a somewhat liberal definition of union. B sed on tudy by Strotman et al., we felt union was adequately predicted with one cort x of bri ging call and a low pain score.[18] The small sample size may result in a type 2 err nd lar r, prospective studies may more accurately characterize complicati risks in this unique population. Although there was no published data on 'far distal' femur perip sthetic f ctures to conduct an a priori power analysis, we conducted a post-hoc p wer analysis The power to detect a difference between groups with an alpha set at 0.1 and reoper on incid nce of 14% and 25%, respectively is 25%. Lastly, we acknowledge tha radi phic assessment of malalignment in this injury, particular sagittal plane alignment whic n only be based off a TKA component (which may not have been optimally positioned), is fraug with a degree of error.

In summary, in this cohort of high-risk fractures, we observed a relatively low rate of reoperation and complications following treatment of very distal PDFFs via contemporary methods of RIMN or ORIF with no difference between groups. Additionally, malalignment and

patient reported outcomes were similar between groups in this difficult fracture pattern. The data demonstrate that very low PDFFs can be treated with either RIMN or ORIF effectively.

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Table 1. Demographics, injury characteristics, and comorbidities

	RIMN	**ORIF**	
	n=36	n=12	*P*-Value
Age, mean (SD)†	73.3 (9.9)	75.9 (11.4)	0.48
Gender, female/male§	33/3	11/1	99
BMI, mean (SD)†	33.9 (6.7)	34.9 (8.3)	0 2
CCI, mean (SD)†	1.8 (2.2)	2.3 (2)	0.48
Fracture, Closed/Open§	33/3	12	0.56
LOS in days, mean (SD)†	6.8 (3.8)	5.3 (4.0)	0.28
ASA, mean (SD)†	3.1 (0.5)	(0.4)	0.46
Smoking, Yes/No§	8/28	2/	>0.99
F/U in months, mean (SD)†	28.7 (12	39.9 (12.1)	**0.01**

Legend: RIMN, retrograde intramedullary nail; OR , open reduc and internal fixation; SD, standard deviation; † Student's t-test; § Fisher's exact test; BMI, body mass ind ; CCI, C rlson co rbidity index; LOS, length of stay; ASA, American Society of Anesthesia score; F/U, follow-up.

Table 2. Clinical outcomes

	RIMN	**ORIF**	
	n=36	n=12	*P*-Value
Reoperation (%) §	5 (14)	3 (25)	0.39
Deep infection (%) §	1 (3)	1 (8)	0.44
Nonunion, Fixation failure (%) §	2 (6)	2 (17)	0.26
Malunion in Coronal plane >5 degrees from LDFA (%) §	2 (6)	(0)	>0.99
Malunion in Sagittal plane >10 degrees from PDFA/Sag (%) §	3 (8)	(8	>0.99
VAS, mean (SD)†	2.7 (2.8)	3.1 (2.8)	0.67
PROMIS physical function, mean (SD)†	3.9 0.9)	27.7 (7.5)	**0.04**
PROMIS pain interference, mean (SD)†	53.1 11.9)	52.7 (12.5)	0.92
Postop change in fracture alignment (%) §	(14)	1 (8)	>0.99
Location of discharge, Home/Rehab a d nursing facility§	6/30	1/11	0.66

RIMN, retrograde intramedullary l; ORIF, open reduc on and internal fixation; SD, standard deviation; † Student's t-test; § Fisher's exact test; LDFA, lateral tal femoral a le; PDFA, posterior distal femoral angle; VAS, visual analog scale; PROMIS, the patient-reported outc es measure nt information system.

Table 3. Perioperative variables			
	RIMN	**ORIF**	
	n=36	n=12	*P*-Value
Weight bearing status, TTWB/WBAT§	18/18	11/1	**0.02**
Transfusion, Yes/No§	18/17	4/8	0.28
Units of transfusion, mean (SD)†	1.2 (1.4)	1 3 (2.2)	0.91
Surgery time in minutes, mean (SD)†	75 (26.4)	10 (39 0)	**0.02**

RIMN, retrograde intramedullary nail; ORIF, open reduction and internal fixa n; SD, standa ev on; † Student's t-test; § Chi-square test; TTWB, toe-touch weight-bearing; WBAT, weight bearing to ted.

A

B

C

- Figure 1. Representative lateral imaging of A- fracture proximal to the flange (Su I), B- fracture at the flange (Su II), and C- distal to the flange (Su III) Only fractures at and distal to the flange were included in this study (Su II and III).

A

B

C

D

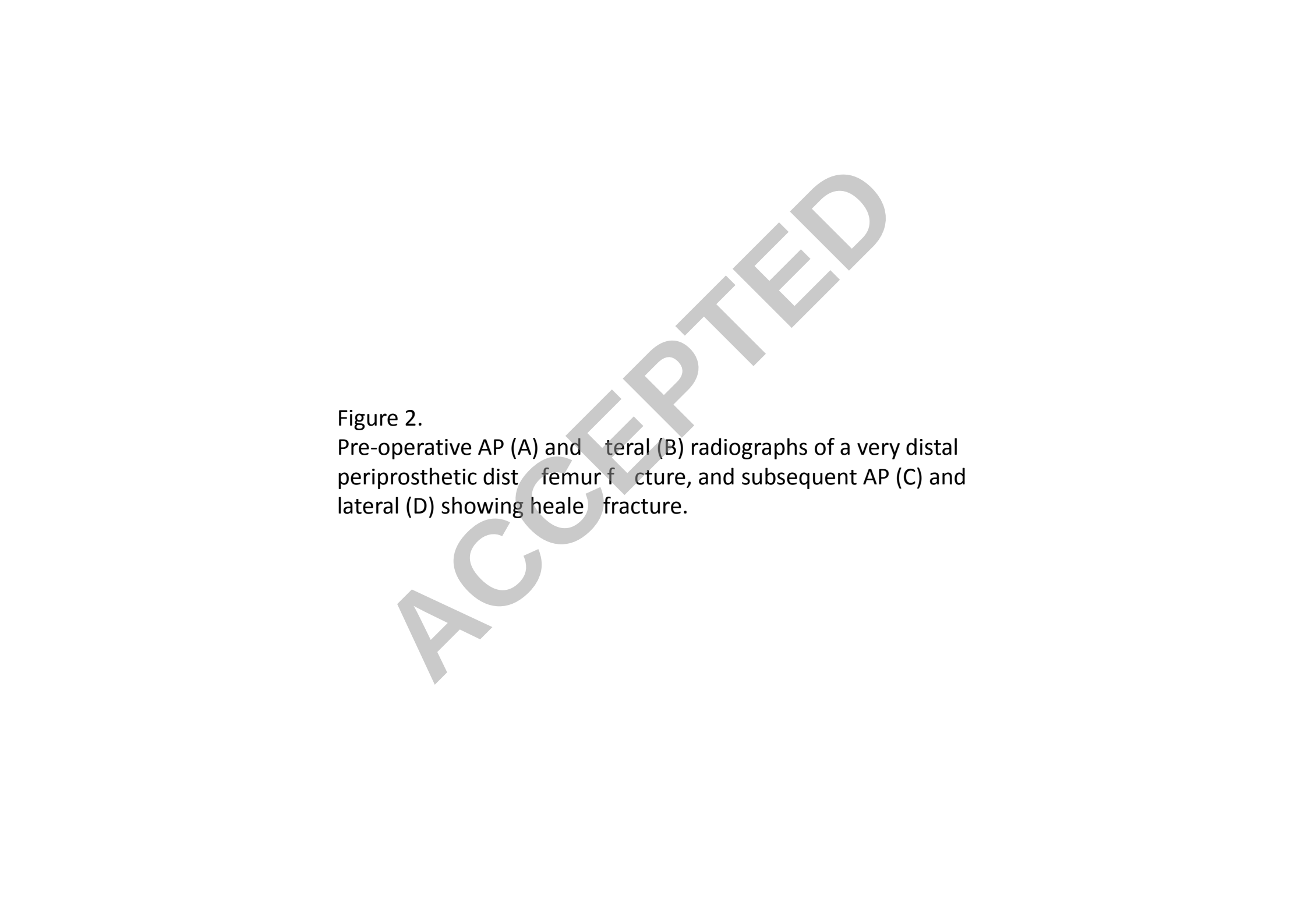

Figure 2.
Pre-operative AP (A) and lateral (B) radiographs of a very distal periprosthetic distal femur fracture, and subsequent AP (C) and lateral (D) showing healed fracture.