European Journal of Orthopaedic Surgery & Traumatology (2024) 34:2073–2079
https://doi.org/10.1007/s00590-024-03899-6

ORIGINAL ARTICLE

Retrograde intramedullary nailing of AO/OTA 33C femur fractures in patients with below-knee amputations: technical note and case series

Mitchel R. Obey[1] · Jack W. Weick[2] · Christian G. Falgons[3] · Timothy S. Achor[3] · Stephen J. Warner[3]

Received: 25 November 2023 / Accepted: 28 February 2024 / Published online: 26 March 2024

Abstract

Purpose Intra-articular distal femur fractures in patients with a lower extremity amputation can present a technical challenge for the treating surgeon in what may be otherwise considered a routine procedure in non-amputees. Difficulties with positioning, fracture reduction, limb contractures, and stump osteoporosis can present challenges with treatment. Here, we describe the surgical technique and outcome of a case series of amputee patients with AO/OTA 33C femur fractures.

Methods Retrospective case series of five patients with a comminuted supracondylar distal femur fracture with intercondylar extension proximal to a below-knee amputation treated with retrograde intramedullary nail at a single Level 1 trauma center from January 1, 2021, to January 1, 2023. Baseline demographic and clinical data were recorded. Rate of bony union and complications were documented.

Results Five patients (three females and two males) with a mean age of 48 years who were treated for a comminuted supracondylar distal femur fracture with intercondylar extension proximal to a below-knee amputation were identified. At the time of final follow-up (mean 109.3 days, range 29–183 days), all patients had healed their incisions and were progressing to return of function with their prosthesis. All patients were treated with the surgical technique described in this article, and no postoperative complications were reported.

Conclusion This is an effective and safe technique for surgical treatment of comminuted intra-articular distal femur fractures in patients with an ipsilateral below-knee amputation. We believe that this technique can be utilized by any orthopedic surgeon taking trauma call and can avoid unnecessary transfers or delays to care.

Keywords Femur Fracture · Amputee · Below-Knee Amputation · Retrograde Intramedullary Nail

Introduction

The rate of major lower extremity amputation, either below knee (BKA) or above knee (AKA), has overall slowly decreased in the past three decades [1]. However, the amputation rate in the US remains higher than other nations, in both diabetic and non-diabetic patients, and an estimated 185,000 new lower extremity amputations are performed each year [2–4]. By the year 2050, it is projected that the amputee population will grow to 3.6 million in the US. As a result, orthopedic surgeons will inevitably be faced with treating musculoskeletal injuries in patients with ipsilateral amputations. These patients are susceptible to falls secondary to altered gait mechanics, and in the setting of osteoporosis, patients are at increased risk of fracture.

The previous authors have reported on treatment of an intertrochanteric femur fracture above a BKA [5], a femoral

Investigation performed at McGovern Medical School at UTHealth Houston.

✉ Mitchel R. Obey
Mitchel.obey@gmail.com

[1] Department of Orthopaedic Surgery, Orthopaedic Trauma Service, Washington University in St. Louis, 660 S. Euclid, Campus, Box 8233, St. Louis, MO 63110, USA

[2] Department of Orthopaedic Surgery, Grant Medical Center, Columbus, OH, USA

[3] Department of Orthopaedic Surgery, University of Texas Health Science Center at Houston, Houston, TX, USA

neck fracture above an AKA [6] or BKA [7], and arthroplasty above bilateral lower extremity amputations [8, 9]. A recent review of orthopedic procedures in lower extremity amputees outlined many of the challenges treating surgeons may be faced with, and how to surmount them to appropriately treat these patients [2]. However, there is a paucity of the literature specifically pertaining to treating lower extremity amputees with comminuted femur fractures. These injuries are seen not uncommonly at our institution, and, in many cases, these patients are referred and/or transferred for "higher level care" due to surgeon unfamiliarity in treating this particular injury. At our institution, amputees with diaphyseal and intra-articular distal femur fractures are treated with an effective surgical technique that has led to favorable results. As such, we present our surgical technique for these injuries and case series of patient examples and their outcomes.

Materials and methods

The institutional board review (IRB) approval was obtained prior to initiation of this study. Patients with a comminuted supracondylar distal femur fracture with intercondylar extension proximal to a below-knee amputation treated with retrograde intramedullary nail at a single Level 1 trauma center from January 1, 2021, to January 1, 2023, were identified. Patient electronic medical records were reviewed to confirm fracture pattern, and mechanism as well as verify treatment was performed with a retrograde intramedullary nail. Demographic information, comorbidities, injury mechanism, and the details of surgical technique were collected. Patient records were further reviewed to assess for rates of postoperative complications, reoperations, infections, and osseous union. In this study, the authors defined osseous union as bridging bone or callus on at least three cortices in combination with supportive clinical findings (i.e., resolution of pain).

Description of operative technique

This is a 51-year-old female with a history of poorly controlled diabetes resulting in the right BKA who was transferred to our institution after a ground-level fall sustaining a right intra-articular distal femur fracture. Radiographs and CT scan demonstrated a comminuted distal femur fracture with intra-articular extension (Fig. 1).

After appropriate preoperative evaluation and clearance by the internal medicine and anesthesia teams, the patient was indicated for surgical fixation, and informed consent was obtained. She was positioned supine on a radiolucent table with a bump under the ipsilateral hip. The entire right lower extremity was prepped and draped (Fig. 2). The leg was placed over a radiolucent triangle to allow for flexion through the knee. To assist with intraoperative traction and regain appropriate length, alignment, and rotation, a 2-mm Steinmann pin was placed percutaneously from lateral to medial in the proximal tibia. A sterile traction bow was

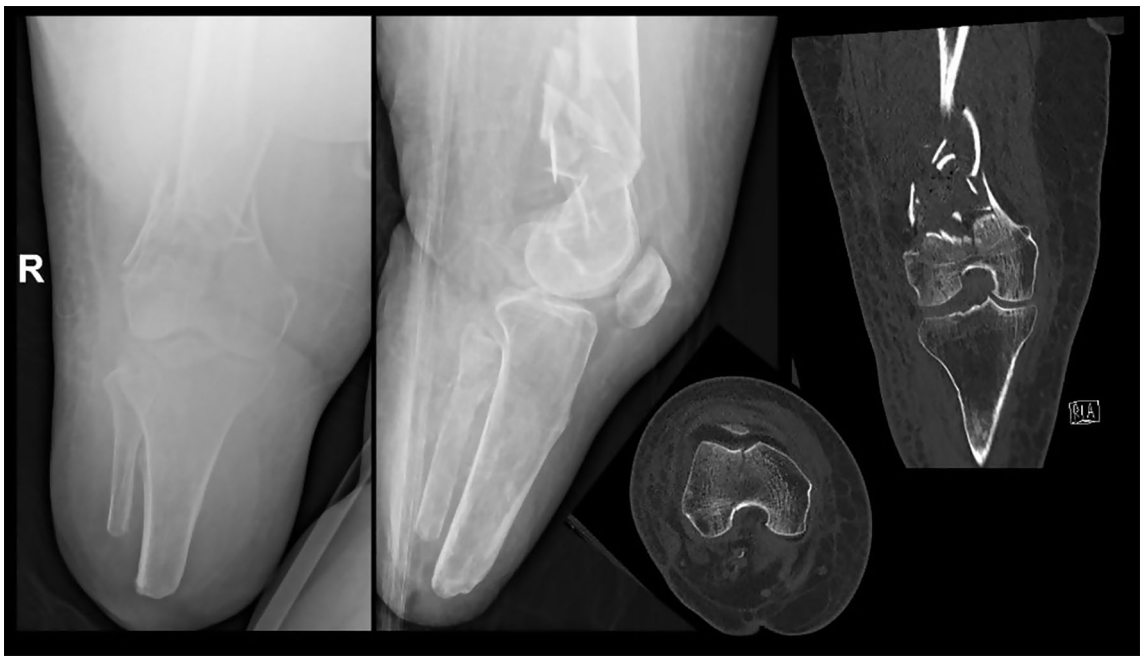

Fig. 1 The right knee and femur radiographs with representative CT scan images showing a comminuted distal femur fracture with simple intra-articular extension in the setting of a prior BKA

Fig. 2 Intraoperative patient positioning

then attached to the Steinmann pin to serve as a handle for manipulation of the distal femur (Fig. 3).

Given the intra-articular split in this fracture, a periarticular clamp was applied percutaneously to compress the articular surface. This was then provisionally held in place with 2-mm Steinmann pins under fluoroscopic guidance out of the way of the planned trajectory for the retrograde intramedullary nail (Fig. 4a and b).

A 3-cm incision was made centered over the patellar tendon with the knee flexed over the triangle. The starting point for the retrograde intramedullary nail was located under fluoroscopy with the starting guidewire and was followed with reaming over the guidewire. The ball-tipped guidewire was then advanced proximally. We utilized the traction bow with manual manipulation to ensure the distal femur fracture was appropriately aligned. The femur was then sequentially reamed, and the retrograde intramedullary nail was placed. The placement of the traction pin and bow allowed for easy passage of the nail and nail out-rigger while still holding the reduction (Fig. 4c and d).

Four distal interlocking bolts were placed to maximize distal fixation. After confirming appropriate rotational

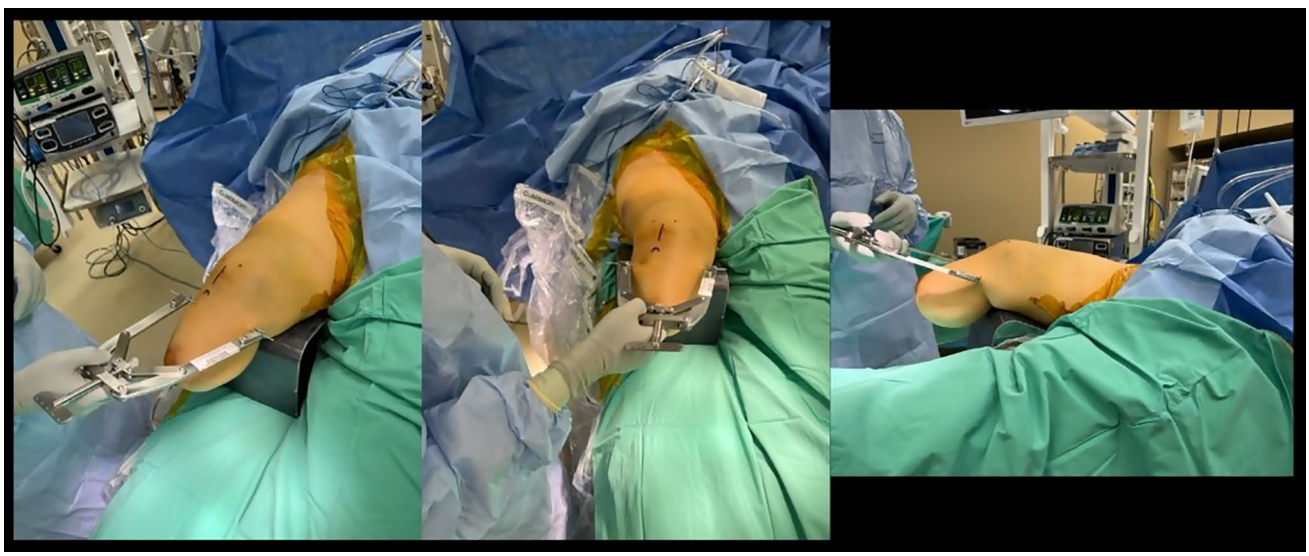

Fig. 3 Proximal tibia skeletal traction for manipulation of the distal femur fracture over a sterile triangle

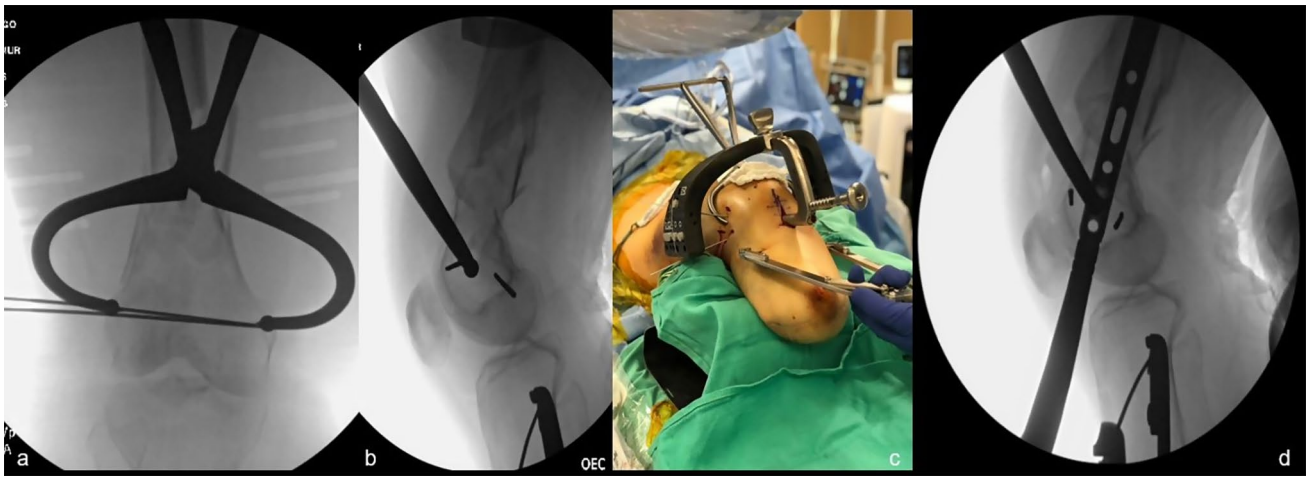

Fig. 4 Intraoperative fluoroscopy images illustrating: **a**,**b** The periarticular clamp placed across the medial and lateral femoral condyles to compress the articular surface with 2-mm Steinmann pins provisionally stabilizing the reduction and **c**,**d** the retrograde intramedullary nail insertion and fluoroscopic images demonstrating safe passage of the nail between Steinmann pins

alignment with comparison to the contra-lateral extremity alignment films taking prior to draping. Two proximal interlocking bolts were placed using perfect circle technique. The 2.0-mm Steinmann pins were used to place two 5.0-mm cannulated headless compression screws to further stabilize the intra-articular split. The proximal tibia traction pin was then removed. Figure 5 demonstrates immediate postoperative radiographs of the final construct.

Postoperatively, the patient was made non-weight-bearing to her right lower extremity to allow for wound healing prior to resuming ambulation through her prosthesis.

Results

Five patients (three females and two males) with a mean age of 48 years who were treated for a comminuted supracondylar distal femur fracture with intercondylar extension proximal to a below-knee amputation at a single Level 1 trauma center from January 1, 2021, to January 1, 2023, were identified (Table 1). Three patients sustained a femur fracture from low-energy falls and two from motor vehicle/motorcycle crashes. Four patients were transferred to our institution for higher level of care, and one was referred to our outpatient clinic. The mean time from injury to

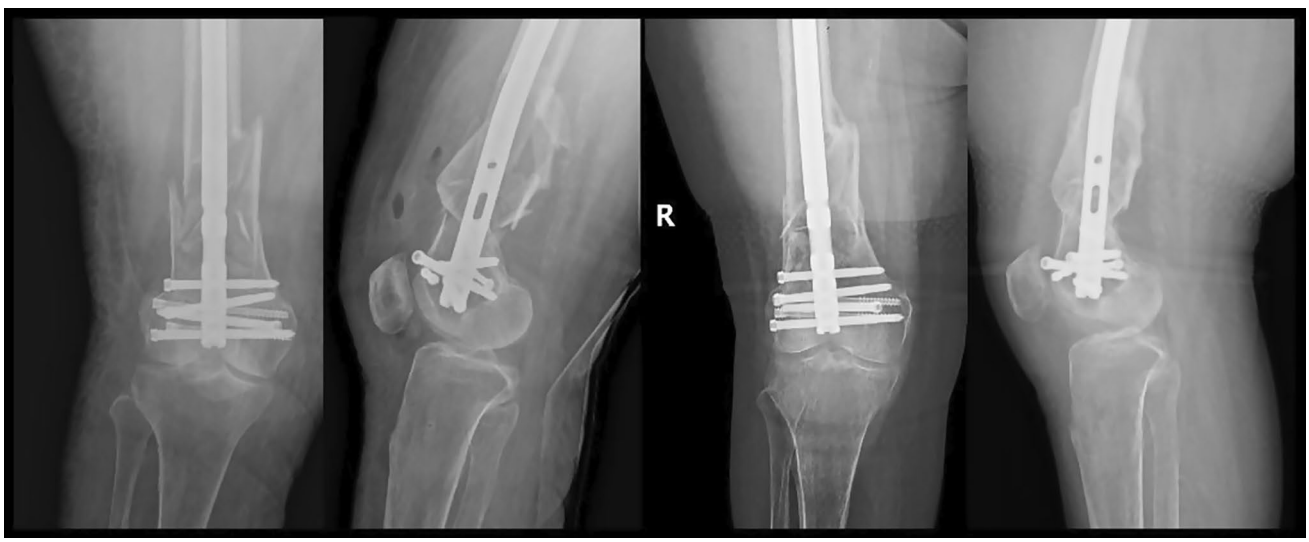

Fig. 5 Final immediate postoperative (left) and 6-month follow-up (right) radiographs

Table 1 Patient demographics and fixation characteristics

	Age	Gender	Mechanism	OTA classification	Time from amputation to fracture surgery	*Length of tibia stump (cm)	Fixation
Patient 1	54	F	Ground-Level Fall	33C	> 1 year	14.99	Retrograde IMN, Headless Compression Screws
Patient 2	51	F	Ground-Level Fall	33C	3 years	15.79	Retrograde IMN, Headless Compression Screws
Patient 3	38	F	Ground-Level Fall	33C	4 years	8.85	Retrograde IMN
Patient 4	51	M	Motor Vehicle Crash	33C	15 months	10.57	Retrograde IMN, Headless Compression Screws
Patient 5	45	M	Motorcycle Crash	33C	15 days	19.95	Retrograde IMN, Headless Compression Screws

*Length of tibia stump: length of tibia bone as measured from joint line to most distal extent of bone

transfer to our institution for surgery was 1.36 days (range, 0.02–6.6 days), and all patients arrived in either a splint or knee immobilizer. The mean tibia bone stump length was 14.03 cm (range, 8.85–19.95 cm). All patients underwent surgical fixation of their femur fracture with the technique described above. At the time of final follow-up (mean 109.3 days, range 29–183 days), all patients had healed their incisions and were progressing to return of function with their prosthesis. Two patients were lost to follow-up and were not able to be contacted to a return to clinic visit. Two patients reached at least 3 months of follow-up, progressed to bony union, and maintained good length, alignment, and rotation of their extremity.

Discussion

As the amputee population continues to grow, orthopedic surgeons will inevitably be faced with treating fractures in these patients. Many community and non-trauma fellowship trained surgeons may feel uncomfortable treating these patients, resulting in patient referrals and hospital transfers, delaying patient care. Here, we present an effective surgical technique for the treatment of midshaft and intra-articular distal femur fractures in patients with a below-knee amputation.

Fractures of the femoral diaphysis and distal femur are common in the general population; however, their incidence is considerably less in amputees with a reported incidence of less than 3% [10, 11]. There are several effective approaches and techniques for surgical management of femur fractures, but special challenges may present themselves when attempting to reduce and stabilize similar fractures with standard techniques in patients with ipsilateral lower extremity amputations. There is a paucity of the literature on the topic, and the majority of articles are limited to case reports. A recent review article summarized a small number of case reports in amputee patients with proximal femur fractures (including intertrochanteric and femoral neck) and a periprosthetic distal femur fracture [2]. Overall, good outcomes were reported across all studies included in the review with detailed examples of intraoperative positioning and reduction techniques. Irrespectively, not all surgeons may feel comfortable attempting surgical management of these fractures in amputees, which often leads to increased rates of patient transfers and delays to care.

Patients with lower extremity amputations may pose a problem when considering positioning on a fracture table due to the absence of a foot to secure into the traction boot. However, in some specific fracture patterns, it is very beneficial to somehow obtain axial traction to achieve an adequate reduction for fixation. In these cases, a previously described technique is to fit an inverted traction boot onto the stump, but, this technique requires at least 12 cm of limb distal to the knee joint [12, 13]. Similarly, when a patient's anatomy is not amenable to standard traction techniques, skin or cutaneous traction may be utilized and secured to the stump [14, 15]. In this study, we recommend use of sterile fine wire skeletal traction placed through the proximal tibia with weight suspended from the end of the bed. We have found this approach to be highly effective and can be done with a standard traction bow set-up. Though we typically perform this with an assistant holding manual traction through the traction bow to allow for easy manipulation of alignment and rotation in real-time while the surgeon is performing the retrograde nail, this could also be performed utilizing off-table traction hung from the end of the bed connected to the traction bow with sterile rope. A similar technique has been described with a Steinmann pin in a patient with bilateral amputations and a left femoral neck fracture [16]. It is important to take care when placing skeletal traction, as it is not without risks to the soft tissues of the residual limb such as scar formation,

infection, and pull-out from osteoporotic bone [12, 14, 15, 17]. We have not experienced any of these complications in our patients.

There are two previous reports in amputees with similar fractures to the patients presented in this study. One is the case of a 24-year-old patient with bilateral diaphyseal femur fractures and a previous right BKA, who was treated with skeletal traction and antegrade intramedullary nailing [17]. The second was a 81-year-old patient with bilateral short BKAs and a left total knee arthroplasty (TKA) who sustained a comminuted periprosthetic supracondylar distal femur fracture, and underwent revision TKA to a hinged implant. In both cases, the authors reported good outcomes.

When evaluating a patient's candidacy for fixation of their fracture with this surgical technique, it is important to take a few things into consideration. The first of which is assessment of tibial bone stump length. Although the authors have not yet found this to be a barrier to utilization of this technique, it is important to verify that each patient has a long enough tibial stump so that a traction pin can be placed safely be standard techniques. Techniques may differ slightly by institution, but we would recommend having at least 2 cm of intact tibia distal to the tibial tubercle to ensure the traction pin can be placed far enough distally to avoid violation of the joint capsule and/or iatrogenic injury to the common peroneal nerve. Finally, it is not uncommon for amputees to have knee flexion contractures or contracted patellar tendons that may inhibit obtaining an appropriate start point for a retrograde intramedullary nail. It is important to determine if the patient's knee can be flexed enough to accommodate placement of a retrograde intramedullary nail. This can be completed with a lateral radiograph of the knee in flexion, or if necessary, intraoperatively with fluoroscopy. In rare cases, it may not be possible to insert a retrograde intramedullary nail between the tibia and patella, and in such instances, the authors would advocate performing a knee arthrotomy to allow for subluxation of the patella medially or laterally so that the appropriate start point can be obtained for safe insertion of the retrograde intramedullary nail.

Here, we present a series of amputees with comminuted intra-articular distal femur fractures and one with a comminuted femoral shaft fracture who were treated with the surgical technique described above. All patients did well throughout surgery and their postoperative course, and radiographs at final follow-up demonstrated osseous union of their fractures in appropriate length, alignment, and rotation. We believe that this technique can be utilized by any orthopedic surgeon taking trauma call and can avoid unnecessary transfers or delays to care.

Funding No funds, grants, or other support was received to assist with the preparation of this manuscript.

Declarations

Conflicts of interest The authors have no relevant financial or non-financial interests to disclose.

Human and animal participants This article does not contain any studies involving animals performed by any of the authors. This article does not contain any new studies involving human participants performed by any of the authors.

Informed consent The institutional board review (IRB) approval was obtained prior to initiation of this study. No informed consent was necessary as there were no subjects in this manuscript.

References

1. Moxey PW, Gogalniceanu P, Hinchliffe RJ et al (2011) Lower extremity amputations–a review of global variability in incidence. Diabet Med 28(10):1144–1153. https://doi.org/10.1111/J.1464-5491.2011.03279.X
2. Lindsey RW, Resnick L (2019) Orthopaedic procedures in amputees. JBJS case Connect. 9(1):e17. https://doi.org/10.2106/JBJS.CC.19.00114
3. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, Travison TG, Brookmeyer R (2008) Estimating the prevalence of limb loss in the United States: 2005 to 2050. Arch Phys Med Rehabil 89(3):422–429. https://doi.org/10.1016/J.APMR.2007.11.005
4. Renzi R, Unwin N, Jubelirer R, Haag L (2006) An international comparison of lower extremity amputation rates. Ann Vasc Surg 20(3):346–350. https://doi.org/10.1007/S10016-006-9044-9
5. Curley AJ, Chang ES (2019) Operative positioning technique for an intertrochanteric fracture in a patient with an ipsilateral below-the-knee amputation: a case report. JBJS case Connect. 9(1):e1. https://doi.org/10.2106/JBJS.CC.18.00106
6. Freitas A, Souto DRM, Da Silva JF, Dantas BR, De Paula AP (2015) Treatment of an acute fracture of the femoral neck in a young female adult with a transfemoral amputation: a case report. JBJS case Connect. 5(3):e58. https://doi.org/10.2106/JBJS.CC.N.00119
7. Jain A, Bansal H, Mittal S, Kumar A, Trikha V (2022) Intracapsular fracture of the proximal femur in a bilateral above-knee amputee: a case report with technical tips for intraoperative positioning and literature review. Chinese J Traumatol = Zhonghua chuang shang za zhi. 25(5):306–310. https://doi.org/10.1016/J.CJTEE.2021.09.003
8. Arango D, Tiedeken NC, Gershkovich G, Shaffer G (2016) Bilateral hemiarthroplasty in a patient with below-knee and above-knee amputations. JBJS Case Connect. 6(1):e3. https://doi.org/10.2106/JBJS.CC.O.00114
9. Williams MG, Phillips J (2015) Revision total knee arthroplasty in a patient with bilateral below-the-knee amputation. JBJS Case Connect. 5(4):e107. https://doi.org/10.2106/JBJS.CC.N.00238
10. Gonzalez EG, Mathews MM (1980) Femoral fractures in patients with lower extremity amputations. Arch Phys Med Rehabil 61(6):276–280
11. Denton JR, McClelland SJ (1985) Stump fractures in lower extremity amputees. J Trauma 25(11):1074–1078
12. Rethnam U, Yesupalan RS, Shoaib A, Ratnam TK (2008) Hip fracture fixation in a patient with below-knee amputation presents a surgical dilemma: a case report. J Med Case Rep 2:1–3. https://doi.org/10.1186/1752-1947-2-296

13. Al-Harthy A, Abed R, Campbell AC (1997) Manipulation of hip fracture in the below-knee amputee. Injury 28(8):570. https://doi.org/10.1016/S0020-1383(97)00118-6
14. Anjum SN, McNicholas MJ (2006) Innovative method of traction on fracture table in femoral neck fracture fixation in a below knee amputee. Inj Extra 37(8):277–278. https://doi.org/10.1016/J.INJURY.2006.02.005
15. Davarinos N, Ellanti P, McCoy G (2013) A simple technique for the positioning of a patient with an above knee amputation for an ipsilateral extracapsular hip fracture fixation. Case Rep Orthop 2013:1–3. https://doi.org/10.1155/2013/875656
16. Berg AJ, Bhatia C (2014) Neck of femur fracture fixation in a bilateral amputee: an uncommon condition requiring an improvised fracture table positioning technique. BMJ Case Rep 2014:bcr2013203504. https://doi.org/10.1136/BCR-2013-203504
17. Mitrasinovic S, Kiziridis G, Wellekens S, Roslee C, Anjum SN (2019) Innovative method of traction in a bilateral diaphyseal femur fracture in a polytrauma below-knee amputee. Case Rep Orthop 2019:1–6. https://doi.org/10.1155/2019/8691398