International Journal of Case Reports in Orthopaedics

E-ISSN: 2707-8353
P-ISSN: 2707-8345
Impact Factor (RJIF): 6.09
IJCRO 2025; 7(2): 78-85
www.orthocasereports.com
Received: 02-06-2025
Accepted: 05-07-2025

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Removal of a bent intramedullary nail of the femur: A case report and literature review

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DOI: https://www.doi.org/10.22271/27078345.2025.v7.i2b.266

Abstract
Background: Extraction of a bent intramedullary femur nail is not commonly performed and can be challenging for the trauma surgeon. Few methods have been described in the literature over the years but there is no common consensus on the best way for extraction.
A review of the literature was performed and different techniques for removal of a bent intramedullary nail are summarised here.
Case Presentation: We present a case of 21 year old male who was treated for bilateral femoral fractures with bilateral intramedullary nailing. His post-operative recovery was complicated by hypertrophic delayed union of the right femur. Five months following surgery he sustained another injury to his right femur following a motorcycle accident resulting in a re-fracture to his right femoral shaft, with the forces resulting in bending of his in-situ intramedullary nail.
He proceeded to surgery where the bent femoral nail was weakened by using a carbide drill bit and high speed stainless steel burr removing 50% of the cross sectional diameter of the nail. This allowed for reduction of the nail using an F bender tool followed by nail extraction and exchange of nail. He was allowed to bear weight fully post operatively and was discharged well on post-operative day 7.
Clinical Outcomes: We identified 34 case reports in the literature reporting techniques for removing bent intramedullary nails of the femur. Reported techniques included removal without any reduction (2), closed reduction prior to removal of intramedullary nail (2), and partially burring of nail prior to manual reduction (15). A commonly reported technique is full sectioning of the nail either by high speed burr or jumbo pin cutters prior to removing the nail through fracture site (10). Some have even described creation of longitudinal bone window to expose the nail totally prior to removal followed up fixation with plates and/or cables. Two case reports described using a plate and bone clamps as reduction tools prior to removal of intramedullary nail.
Discussion: There are various ways of removing a bent intramedullary nail. While there is no common consensus on the gold standard, the majority of surgeons preferred either sectioning of the nail and removing it in two separate pieces or partially sectioning the nail followed by manual reduction and removal. Pre-operative planning and knowledge of available resources (eg carbide drill bits, reduction tools, high speed stainless steel burrs) are crucial in the removal of bent intramedullary nail.
We recommend that at least half the cross sectional diameter of the nail should be burred to sufficiently weaken the nail for successful straightening and removal. We caution against breaking the nail as this would complicate removal requiring retrieval through the fracture site.

Keywords: Bent, intramedullary, femoral, nail

Introduction
The use of an intramedullary nail is considered the gold standard technique for treating femoral shaft fractures and remains the preferred method by many surgeons [1] as it has yielded high union rates with few complications [2].
Currently, the most widely used materials for intramedullary metal implants are Titanium or Stainless Steel due to their bio-inert qualities and superior mechanical properties to achieve desired support at femoral shaft fracture sites [3]. Titanium is comparatively stronger, has fewer toxic effects on surrounding tissue, less bacterial adhesion and hence reduced rate of infection. On the other hand, due to the difference in bone-screw interface mechanical binding requirements, stainless steel nails require lesser strength and time and cause less bleeding during removal [4]. Stainless Steel is also considerably cheaper than Titanium.
More than 1 million cases of these femoral shaft fractures occur worldwide due to trauma from traffic collisions alone, with much higher incidence among younger age groups and poorer income status [5]. Subsequent high-energy trauma following a femoral

shaft intramedullary nail fixation can potentially result in a bent nail [6], which is challenging to retrieve through the intramedullary canal [7]. There is currently no consensus within the field on the optimal method to remove a bent intramedullary nail. Our aim was to present a typical case of a bent intramedullary nail of the femur caused by a traffic collision, and to present the results of a systematic review of the literature on techniques to remove a bent intramedullary nail.

Methodology: A literature review on PubMed, Clinical Key/ Elsevier, MD Consult Science Direct, Scopus, Medscape, and Google Scholar electronic was performed. Search terms "bent" "intramedullary nail" "removal techniques" were used in the literature review. Relevant articles were identified, reviewed, and the described techniques were summarized in table form in Annex 1. Articles describing the removal of bent intramedullary nail of the femur were included. Articles or case reports involving the tibia, or cases involving a broken intramedullary nail were excluded. 34 case reports reporting techniques for removing bent intramedullary nails of the femur were identified, with publication years ranging from 1974 to 2018.

Case Report

A 21-year old male presented with bilateral displaced femoral shaft fractures with intact femoral necks, as shown in Figure 1A. Surgical fixation with bilateral intramedullary nail (A2FN Depuy Synthes, Ti-6Al-7Nb) was performed with Figure 1B showing post-operative results.

The patient developed hypertrophic delayed union, as seen in Figure 1C, but was otherwise well clinically and did not complain of any pain. Nail dynamization was proposed, but the patient declined due to cost concerns.

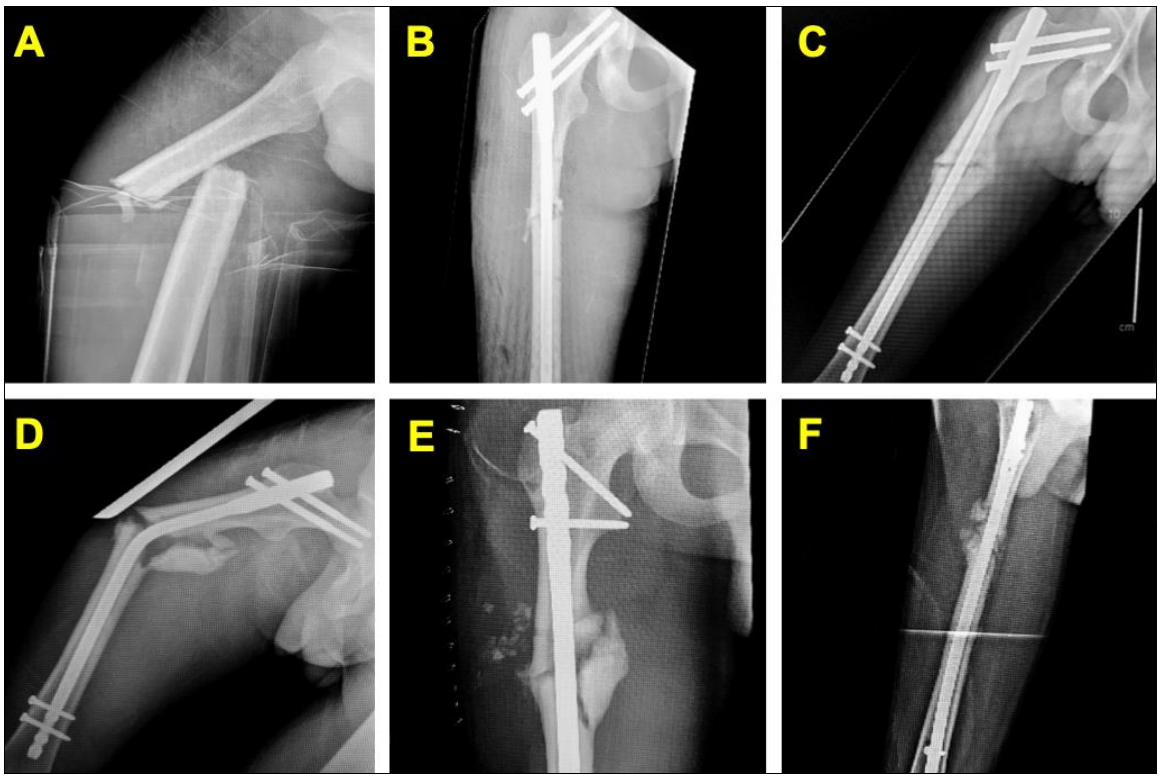

Fig 1: X-Ray images of Right Femur during various stages of treatment in chronological order. A: Initial injury. B: After first operation. C: Post-operative follow-up. D: Subsequent injury. E: After second operation. F: Post-operative follow-up.

Five months following the initial surgery, the patient was involved in another motorcycle accident. This resulted in a comminuted fracture in the right femoral shaft through the region of the old fracture with resultant varus deformity of the intramedullary nail (Figure 1D).

Clinical examination and preoperative blood investigations did not suggest any evidence of infection. At the revision surgery, an initial attempt to bend the nail with an F bender tool was unsuccessful. The fracture site was exposed revealing the underlying intramedullary nail. A drill was used to weaken the nail followed by the use of a high-speed burr to remove approximately half of the nail diameter.

Attachments used are shown in Figure 2, and fluoroscopy images during the operation at various stages are shown in Figure 3. Irrigation was used liberally throughout. Care was taken while sectioning the nail as we wanted to remove the nail intact from the proximal wound without having to retrieve it from the fracture site. Adequate reduction of the fracture and intramedullary nail with the F bender tool was only possible after at least 50% of the cross-sectional diameter of the nail was removed, as shown in the intraoperative photos in Figure 4. This allowed easy nail extraction in its entirety from the proximal wound, and exchange femoral nailing with allograft bone putty augmentation.

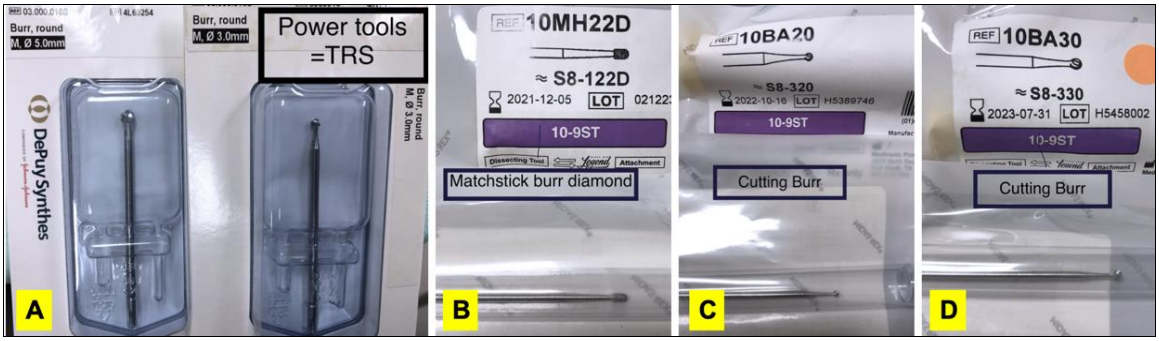

Fig 2: Photos of drilling head attachments. A: 5mm (left) and 3mm (right) size round burr heads. B: Matchstick burr Diamond Head. C and D: Different sized cutting burr heads.

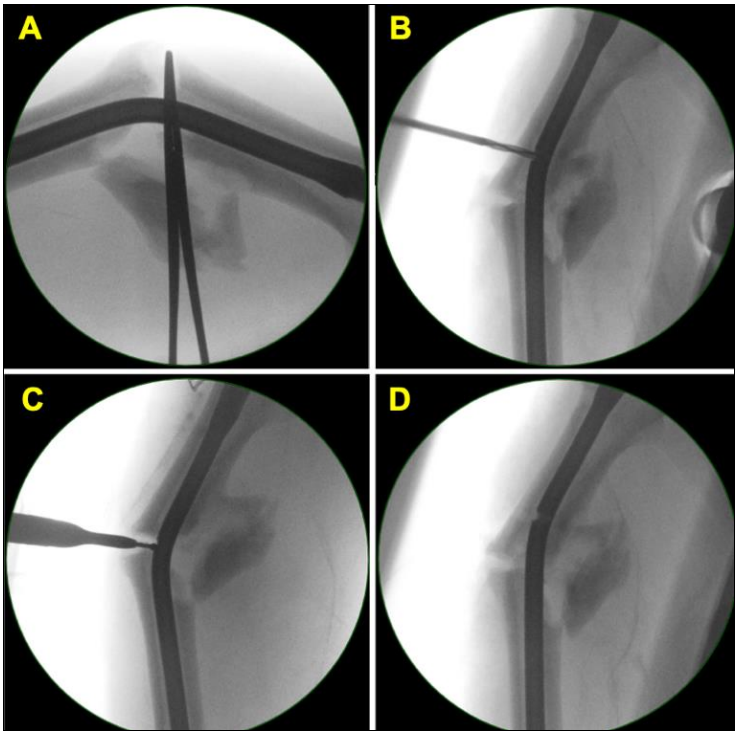

Fig 3: Intraoperative Fluoroscopy at different stages. A: Fracture site identified. B: Weakening of implant with drill bit. C: Weakening of implant with burr. D: Approximately half of nail diameter has been removed.

Fig 4: Intraoperative photographs. Left: Removed bent intramedullary nail. Right: Close-up view of burred site of bent intramedullary nail. Yellow Arrow points to the site of burring in both photos.

Post-operative results are displayed in Figure 1E. The patient was allowed to bear weight fully post-operatively, and was discharged on post-operative Day 7. At 8 weeks following surgery, full mobility was possible with minimal pain, with stable alignment of the right femur as seen in Figure 1F. Further follow-up was held in patient's home country due to cost issues.

Discussion: Of the identified case reports, 19 patients were described to have Stainless Steel intramedullary nails, while 4 patients were recorded to have Titanium intramedullary nails. The other 11 reviewed case reports did not stipulate the type of material used for the intramedullary nail. The most common reported deformity of the bent intramedullary nails from this literature review were that of a Varus nature (20 case reports), followed by apex anterior deformity (9 case reports).

Table 1: Summary of Literature review for intramedullary nails composed of different materials, including number of case reports, different site of removal of intramedullary nail, and technique used during removal. SS: Stainless steel, Ti: Titanium, MNR: Material Not Recorded.

	Material			Total
	SS	Ti	MNR	
Number of Case Reports	19	4	11	34
Site of Nail Removal				
Proximal Entry Point	10	3	9	22
Fracture Site	4	1	-	5
Proximal Entry Point and Fracture Site	1	-	1	2
Proximal Entry point and Partial nail left in-situ	1	-	-	1
Longitudinal Osteotomy Site	-	-	1	1
Whole nail left in-situ	1	-	-	1
Not Recorded	2	-	-	2
Technique Used				
Full section of nail before removal	8	1	1	10
Partial section of nail and Manual Reduction	5	1	5	11
Partial section without Manual Reduction	2	-	2	4
Manual reduction without Partial section	2	-	2	4
Standard Expiration	-	2	-	2
Increase Varus Angle	1	-	-	1
Longitudinal Osteotomy	-	-	1	1
Nail fully left in-situ	1	-	-	1

It was noted that all patients in the case reports of this literature review were male, and the majority (25th to 75th percentile, with reference to Figure 2) of patients were aged between 20 and 37 years old. This age range largely corresponds to the Young-Adult age group definition of 18 to 35 years old [8].

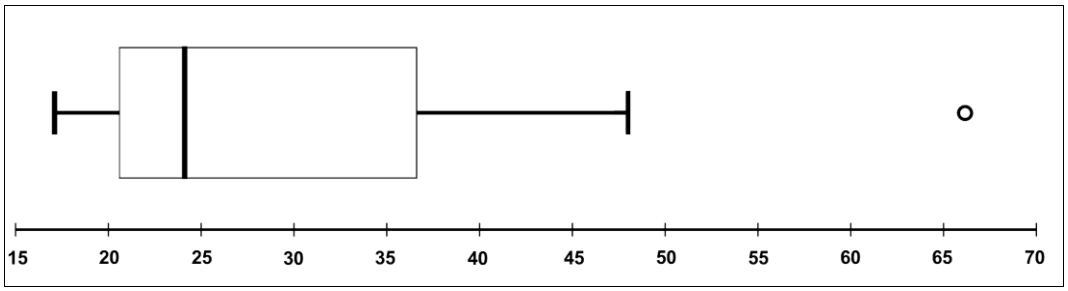

Fig 5: Box-and-whiskers diagram showing age demographics of 33 case reports identified from literature review. Patient age was unrecorded for 1 case report and omitted from this analysis.

The most common observed site of nail removal was from an entry point proximal to that of the fracture site, regardless of material of the nail. Removal of nail from the fracture site and leaving partial or the whole nail in-situ was only seen for case reports where the intramedullary nail was composed of Steel.

A variety of techniques used to remove the intramedullary nail were reported. The two most common techniques were to partially section the nail at the apex of the deformity and then proceeding with manual reduction, or fully section the nail and removing in 2 separate pieces, as seen from Table 1. For the latter, many case reports have described full sectioning of the nail into 2 parts either by high-speed burr or jumbo pin cutters prior to removing the nail. We would advise against fully sectioning the nail as this would require removal through the fracture site. Other techniques that were used included partial sectioning only, or manual reduction only.

Less commonly used techniques include increasing the varus angle of the femur until the nail formed a "V-Shape" then extraction with minimal corticotomy[19] (Recorded as "Increase Varus Angle" technique in Table 1). Another recorded technique that was not used as much was the creation of a longitudinal bone window to fully expose the nail prior to removal[26], followed by fixation with plates and/or cables (recorded as "Longitudinal Osteotomy" technique in Table 1).

In summary, there are various ways of removing a bent intramedullary nail. While there is no established gold standard nor an identifiable statistically significant single common consensus, it has been observed from this literature review that the majority of surgeons preferred either sectioning of the nail and removing it in two separate pieces or partially sectioning the nail followed by manual reduction. Pre-operative planning and knowledge of available resources (e.g. carbide drill bits, reduction tools, high speed stainless steel burrs) are definitely crucial in the removal of bent intramedullary nail. Sectioning of at least half the cross sectional diameter of the nail is recommended to sufficiently weaken the nail for successful removal. It is not advised to break the intramedullary nail, as this would complicate removal.

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Annex 1: Table of Results of Literature Review

No.	Year	First author	Age	Sex	Implant Material	Complication Prior	Presenting Deformity	Technique Used	Equipment Used	Fracture Site Open?	Nail Fully Broken?	Site of Nail Removal	Bone Grafting?
1	1974	LaSalle WB	21	M	Stainless Steel	7 weeks post op	30° anterolateral	Fully section the nail and extraction in two pieces	Dental drill	Yes	Yes	Fracture Site	NR
2	1991	Patterson RH	17	M	Stainless Steel	22 months post op	30° varus	Close straightening using perineal post as fulcrum	Perineal post of the traction table	No	No	Proximal	NR
3	1994	Burzynski N	19	M	Stainless Steel	Delayed union	NR	Partially section the nail, manual reduction	Midas rex high-speed burr	Yes	No	Proximal	NR
4	1998	Al Maleh AA	24	M	NR	Non union	25° apex anterior	Drill to weaken the nail, no straightening	Ansbach high-speed drill	Yes	No	Proximal	NR
5	1998	Al Maleh AA	17	M	NR	6 months post op	25° apex anterior	Drill to weaken the nail, no straightening	Ansbach high-speed drill	Yes	No	Proximal	NR
6	1998	Nicholson P	18	M	Stainless Steel	6 months post op	42° varus	Fully section the nail and extraction in two pieces	Midas rex high-speed burr	Yes	Yes	Proximal and Fracture site	NR
7	2001	Apivatthakakul T	21	M	NR	2 years post op	35° varus	Percutaneous, drill to partially section the nail (single drill hole), manual reduction	Trochar sleeve, metal cutting drill bit, fluoroscopy	Percutaneous	No	Proximal	NR
8	2001	Ohtsuka H	19	M	NR	NR	28° varus	Partially section the nail, manual reduction	Metal drill bit	Yes	No	Proximal	NR
9	2002	Kockesen TC	37	M	Stainless Steel	NR	42° varus	Fully section the nail and extraction in two pieces	Metal cutting saw	Yes	Yes	NR	NR
10	2004	Nicolaides V	20	M	Stainless Steel	9 months post op	85° varus	Fully section the nail and extraction in two pieces	Metal cutting saw	Yes	Yes	Fracture Site	NR
11	2004	Nicolaides V	22	M	Stainless Steel	10 weeks post op	32° varus	Fully section the nail and extraction in two pieces	Metal cutting saw	Yes	No	Proximal	NR
12	2004	Singh R	45	M	Stainless Steel	Non union	35° varus	Fully section the nail and extraction in two pieces	Jumbo pin cutter	Yes	Yes	Fracture Site	NR
13	2006	Neimpoog S	21	M	Stainless Steel	NR	30° varus	Increasing the varus angle of	Hook	Yes	Yes	Fracture Site	NR

								the femur, until the nail formed a V-shape, then extraction with minimal corticotomy					
14	2007	Sonanis SV	23	M	NR	Non union	30° varus	Partially section the nail, manual reduction	Conical side cutting burr	Yes	No	Proximal	NR
15	2008	Bek D	23	M	Inflatable femoral nail	2 months	32° varus	Partially section the nail, manual reduction	Metal saw	Yes	No	Proximal	NR
16	2009	Banerjee R	34	M	Stainless Steel	15 years post op	30° apex anterior	High speed burr to partially section off nail, perineal post	High-speed metal-cutting burr	Yes	No	Proximal	NR
17	2009	Biert J	21	M	Titanium	NR	33° varus	Standard extirpation without any additional intervention		No	No	Proximal	NR
18	2009	Bissonnette G	48	M	Stainless Steel	Distal femur articular non-union	35° apex anterior	Drill to partially section the nail, no straightening	Ansbach high-speed drill	Yes	No	NIL, nail left in-situ	No
19	2010	Stahel PF	42	M	Stainless Steel		60° apex anterior	Fully section the nail and removal of proximal part and leaving the distal part in situ, followed by plating	Ansbach metal-cutting, oscillating circular saw	Yes	Yes	Proximal, distal nail left in-situ	NR

Cont… Annex 1: Table of Results of Literature Review

20	2011	Shen PC	32	M	Stainless Steel	1 year post op	35° varus	Straightening with a broad plate and two bone forceps	4.5-mm broad dynamic compression plate, two bone-holding forceps	Yes	No	Proximal	NR
21	2011	Sakellariou VI	40	M	NR	Non union 13 months post op	50° varus	Creation of a longitudinal bone window along the anterolateral side of the proximal part of the femoral shaft	NR	Yes	No	Osteotomy site	DBM
22	2012	Kritsaneephaiboon A	19	M	NR	1 month post op	30° apex anterior	Straightening with a broad plate and two bone forceps	Locking plate and a collinear reduction clamp	No	No	Proximal	No
23	2012	Heffeman MJ	36	M	Titanium	4 months post op	33° apex anterior	Drill to partially section the nail, manual reduction with F tool	Midas rex high-speed burr and F tool	Yes	No	Proximal	NR
24	2012	Park J	66	M	Stainless Steel	NR	35° apex anterior	Partially section the nail, manual reduction	high-speed burr	Yes	No	Proximal	Yes
25	2013	Pesciallo C	22	M	Stainless Steel	NR	24° varus	Partially section the nail, manual reduction	High-speed metal cutter	Yes	No	Proximal	NR
26	2013	Bicici V	35	M	Stainless Steel	NR	23° varus, 30° apex anterior	High speed burr to fully section the nail. Cortical osteotomy to remove the proximal part	Midas rex high-speed burr	Yes	Yes	NR	NR

27	2015	Dhanda MS	26	M	NR	1 month post op	42° varus	Fully section the nail and extraction in two pieces	Jumbo pin cutter	Yes	Yes	Proximal and Fracture site	Yes
28	2015	Amit B	25	M	Stainless Steel (K nail)	5 days post op	Varus	Without extraction but add another plate for fixation	Post	No	No	Proximal	No
29	2015	Shishir SM	33	M	NR	5 weeks post op	30° varus	Manual reduction (patient supine on floor, with assistant standing on thigh with sandbag under # site) - 3 point manoeuvre	NIL	No	No	Proximal	NR
30	2016	Kose O	39	M	NR	Chronic OM at 23 months post op	32° valgus	Partially section the nail, manual reduction	3mm metal cutting drill	Yes	No	Proximal	NR
31	2016	Kose O	29	M	Titanium (10mm)	Delayed union at 15 months post op	18° varus	Standard nail extirpation	No	No	No	Proximal	NR
32	2017	Odendaal J	43	M	Stainless Steel	7 weeks post op	20° varus	Partial resection of nail and removal from proximal entry point	Diamond tip cutting disc	Yes	No	Proximal	Yes
33	2018	Yap WK	NR	M	Stainless Steel	NR	38° varus	Partially section the nail, manual reduction	II, jumbo pin cutter	Yes	No	Proximal	NR
34	2019	Canton G	19	M	Titanium	Hypertrophic non-union at 18 months post op	145° varus, with distal locking screw bending	Fully section the nail and extraction in two pieces	Diamond burr	Yes	Yes	Lateral approach for proximal part, fracture site for distal part	NR

NR: Not Recorded

How to Cite This Article
Mohan R, Tan CH, Chng E, Premchand RXA, Park DH. Removal of a bent intramedullary nail of the femur: A case report and literature review. International Journal of Case Reports in Orthopaedics. 2025;7(2):78-85