Bent or Broken? Methods of Removing a Deformed Tibial Intramedullary Nail: A Systematic Review

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Purpose: Our objective was to analyze the indications and risks and benefits of various techniques for the removal of bent and broken tibial intramedullary nails (IMNs) described in the current literature.

Methods: English-language articles in PubMed, Embase, and Scopus databases were queried for full-text studies of methods for extraction of a bent or broken IMN from the tibia using the Preferred Reporting Items for Systematic Reviews guidelines on December 31, 2022. Two authors independently extracted data from the selected studies. Subsequently, each extracted data set was consolidated on the agreement of the authors.

Results: After reviewing a total of 25 patient cases and 7 surgical techniques, 10 overall methods to remove bent and broken tibial IMNs were identified: the use of hook extractors with commercial or custom devices (8), standard extraction with or without external manipulation (5), grasping of broken segments with the use of forceps (5), press fit / tapping into the hollow of the nail (4), interference fit guidewires (3), retrograde pushout (3), partial sectioning (3), complete sectioning (2), capture from the outside (2), and corticotomy flap and retrograde extraction (1). The creation of a corticotomy flap with a retrograde extraction method was associated with the greatest degree of concomitant soft-tissue damage followed by complete and partial sectioning of the IMN. Stainless steel hollow IMN was the most common type of deformed nail in the included studies. IMN fracture at the upper distal locking hole was the most common type of deformity. Of the 25 patient cases, 24 described male patients. The average patient age was 32 years.

Conclusion: Factors to consider during preoperative planning of IMN extraction include the type and material of IMN, the degree and direction of angulation, and the location of IMN deformity. Stainless steel IMNs have greater stiffness and are more difficult to manually straighten, consequently requiring innovative ways to extract them from the medullary canal. A greater likelihood of failed closed surgical extraction is associated with rigid, stainless steel nails, an angulation of greater than 20°, an angulation with apex anterior, and proximally located deformities. The presence of an open wound or comminuted fracture allows for greater degree of mobility and easier removal.

TABLE I: List of Previously Published Cases with Deformed Tibial Nail and Removal Techniques

Year	Author	Age Sex	Type of Nail	Nature of Deformity	Surgical Approach	Method of extraction	Equipment
1988	Dugdale et al	33 M	-	Break at Distal Locking Screw	Closed	Hooks at the Distal End	Custom hook extraction device ; Synthes universal chuck ; Plastic Gross-Kempf sleeve
		33 M	-	Break at Distal Locking Screw	Closed	Hooks at the Distal End	
1995	Kelley et al	26 M	Stainless Steel	Break at Distal Locking Screw	Closed	Hooks at the Distal End	T-handler starter reamer
		43 M	Titanium	Break at Middle of IMN	Closed	Retrograde Pushout Technique ; Grasping and Manual Extraction	Rush rod
1996	Yip et al	23 M	Stainless Steel	Anterior Bend	Closed	Standard Extraction	-
		34 M	Stainless Steel	Anterior Bend	Closed	Standard Extraction	-
1997	Khan et al	23 M	-	Break at Distal Locking Screw	Closed	Press Fitting in the Hollow of the Nail	8 mm hand-held rigid reamer
1998	Charnley et al	30 M	Stainless Steel	Break at Distal Locking Screw	Closed	Grasping and Manual Extraction	Petelin laparoscopic grasping and dissection forceps
2001	Giannoudis et al	26 M	Stainless Steel	Break at Distal Locking Screw	Closed	Capture of IMN from Outside	Commercially available extraction device
2002	Lerner et al	-	-	-	Closed	Hooks at the Distal End	-
2004	Levine et al	26 M	Titanium	Break at Distal Locking Screw	Closed	Retrograde Pushout Technique ; Interference Fit Guide Wires	4.5 mm metal drill bit ; Steinmann pin
2005	Gosling et al	19 M	Stainless Steel	Break at Distal Locking Screw	Closed	Capture of IMN from Outside	Custom extraction device
2011	Aggerwal et al	30 M	Stainless Steel	Anterior Bend	Open	Partial Sectioning	Metal cutting drill bit
2012	Buunaaim et al	28 F	Stainless Steel	Posterior Bend	Closed	Standard Extraction	-
2013	Abdelgawad et al	28 M	Titanium	Break at Distal Locking Screw	Closed	Hooks at the Distal End	Small piece of flexible nail
2015	Kim et al	23 M	-	Break at Middle of IMN	Closed	Press Fitting in the Hollow of the Nail	Nancy nail ; Diamond burr
2016	Pullen et al	23 M	Titanium	Break at Distal Locking Screw	Closed	Retrograde Pushout Technique ; Grasping and Manual Extraction	Steinmann pin ; Kocher forceps
2016	Kose et al	39 M	Stainless Steel	Coronal Bend	Open	Partial Sectioning	3 mm metal cutting drill
2017	Gil et al	34 M	-	Break at Distal Locking Screw	Closed	Hooks at the Distal End	Standard T2 Tibial Nailing System ; Implant Extraction System
2018	Loeb et al	36 M	Carbon Fiber Composite	Break at Distal Locking Screw	Closed	Tapping in the Hollow of the Nail	-
2019	McChesney et al	65 M	Titanium	Sagittal and Coronal Bend	Closed	Standard Extraction	Winquist Universal Nail Extractor
2019	Pathak et al	45 M	Stainless Steel	Sagittal and Coronal Bend	Open	Complete Sectioning	Industrial metal cutting drill bit
2019	Gaubert et al	25 M	-	Anteriolateral Bend	Open	Corticotomy and Retrograde Extraction	-
2021	Garg et al	43 M	-	Break at Distal Locking Screw	Closed	Hooks at the Distal End	Custom hook extraction device ; Mosquito forceps
2022	Zhou et al	48 M	-	Break at Distal Locking Screw	Closed	Hooks at the Distal End	Custom hook extraction device