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Case Report

Humeral Shaft Nonunion Following Reamed Intramedullary Nailing: A Case Report

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Abstract

Introduction: Intramedullary nailing is an established treatment for humeral shaft fractures and is commonly performed using an unreamed technique. Inadvertent reaming during a procedure intended to be unreamed may affect the local biological environment, although its clinical significance remains uncertain. We present a case of humeral shaft nonunion and subsequent mechanical complications following inadvertent reaming during antegrade intramedullary nailing.

Case presentation: A 39-year-old man sustained a closed, approximately mid-shaft, non-comminuted humeral fracture following a motor vehicle accident. The patient was a non-smoker with a BMI of 28 kg/m² and no significant metabolic or systemic comorbidities. The planned procedure was antegrade intramedullary fixation with a 9-mm nail and two proximal and two distal locking screws, without reaming. However, inadvertent reaming of the humeral canal was performed; the reamer diameter was not documented. Fracture reduction was satisfactory, and no intraoperative soft-tissue interposition was identified. Postoperatively, the patient developed radial nerve dysfunction, with EMG/NCS approximately one month later reportedly demonstrating injury at the mid-shaft/arm level. Radial nerve function recovered completely within approximately three months. At approximately six months, persistent nonunion was associated with a distal periprosthetic fracture at the nail tip. During revision surgery, the nail was loose, and the bone surrounding the nonunion was markedly soft and poorly bleeding. Approximately 4 cm of abnormal-appearing bone was resected until viable bleeding bone was encountered. The nail was removed, followed by compression plate fixation and autologous iliac crest bone grafting. Complete union was subsequently achieved.

Conclusion : This case highlights potential clinical consequences following inadvertent reaming during intended unreamed humeral nailing. Although the intraoperative findings raised suspicion of compromised bone viability, the absence of histopathological confirmation and undocumented reaming parameters preclude establishing a direct causal relationship between reaming, thermal injury, and nonunion. Strict adherence to the planned surgical technique and close postoperative surveillance are warranted.

Keywords: Humeral shaft nonunion; intramedullary nailing; Reaming; Thermal osteonecrosis; Periprosthetic fracture. Inadvertent reaming.

Introduction

Intramedullary nailing (IMN) is an established treatment option for humeral shaft fractures. Unlike some long-bone nailing techniques in which reaming is routinely incorporated into the procedure, humeral intramedullary nailing is commonly performed using an unreamed technique. Clinical studies have specifically described antegrade unreamed humeral nailing as an established technique for humeral shaft fractures [1]. In our clinical practice, we therefore use an unreamed technique for humeral shaft intramedullary nailing.

Delayed union and nonunion remain important complications following treatment of humeral shaft fractures. Complications after humeral IMN may include fracture-related, hardware-related, and neurovascular complications [2,3]. When nonunion occurs following intramedullary fixation, revision treatment

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can be challenging. Exchange nailing alone has demonstrated limited success in humeral shaft nonunion, whereas compression plating and biological augmentation have been used successfully in revision procedures.[4-7]

Although reaming is not routinely intended in the humeral nailing technique used in our practice, inadvertent reaming may occur. Reaming can generate intramedullary heat and may potentially affect the local biological environment. Experimental studies have demonstrated that sufficient thermal exposure can cause bone injury and impair bone regeneration [8]. Nevertheless, the clinical contribution of inadvertent reaming to subsequent nonunion in an individual patient remains difficult to establish because nonunion may result from multiple interacting mechanical and biological factors.

We report a case in which unreamed antegrade intramedullary nailing was intended for a closed, non-comminuted, approximately mid-shaft humeral fracture. Still, inadvertent reaming was performed during the index procedure. The patient subsequently developed postoperative radial nerve dysfunction, persistent nonunion, and, approximately six months later, a distal periprosthetic fracture in the setting of persistent nonunion. During revision surgery, the bone surrounding the nonunion was markedly soft and poorly bleeding, raising clinical suspicion of compromised bone viability. The patient ultimately achieved union following removal of the loose nail, resection of the abnormal-appearing bone, compression plating, and autologous iliac crest bone grafting.

The distinctive aspect of this case is the clinical sequence observed after inadvertent reaming during a humeral intramedullary nailing procedure planned as unreamed, including transient radial nerve dysfunction, persistent nonunion, a distal periprosthetic fracture, and markedly soft, poorly bleeding bone encountered during revision surgery.

This case report does not aim to establish a definitive causal relationship between inadvertent reaming and nonunion, but to highlight the clinical consequences observed after unintended reaming during a procedure planned as unreamed humeral intramedullary nailing and to emphasize the importance of strict adherence to the intended surgical technique and careful postoperative surveillance.

Case Presentation

A 39-year-old man sustained an approximately mid-shaft humeral fracture following a motor vehicle accident. The fracture was closed, with no associated open wound, and there was no significant comminution. On initial examination, the affected extremity's neurovascular status was intact.

The patient had a body mass index (BMI) of 28 kg/m². He was a non-smoker and had no history of diabetes mellitus, hypertension, renal disease, osteoporosis, or hypothyroidism. There was no known history of other systemic, metabolic, or endocrine disease. Available laboratory evaluation did not demonstrate vitamin D deficiency or abnormalities involving parathyroid hormone (PTH), thyroid-stimulating hormone (TSH), or phosphorus.

Antegrade intramedullary nailing was selected for fixation. According to the intended surgical plan, the procedure was to be performed without reaming. A 9-mm intramedullary nail was inserted with two proximal and two distal locking screws. Fracture reduction was satisfactory. Intraoperative assessment revealed no evidence of soft-tissue interposition at the fracture site.

During the index procedure, however, the surgeon inadvertently reamed the humeral canal. The procedure had not been planned as a reamed nailing procedure, and the inadvertent reaming was subsequently recognized. The exact diameter of the reamer used was not documented in the available operative records.

The patient's radial nerve function was intact before surgery. Postoperatively, radial nerve dysfunction was identified. Approximately one month after the index operation, electromyography/nerve conduction study (EMG/NCS) reportedly demonstrated radial nerve injury at the mid-shaft/arm level. The original EMG/NCS report was not available for detailed electrophysiological interpretation. Radial nerve function subsequently improved progressively, with complete clinical recovery within approximately three months.

Follow-up radiographs showed persistently inadequate fracture healing. At approximately six months after the index operation, the patient developed pain and tenderness in the distal humerus without a new traumatic event. Radiographic assessment demonstrated a distal fracture at the tip of the intramedullary nail, consistent with a periprosthetic fracture, in the setting of persistent nonunion at the original fracture site.

Revision surgery was subsequently performed. The previously inserted intramedullary nail was loose. At the original nonunion site, the bone was markedly soft rather than sclerotic. The abnormal softness extended approximately 2 cm distal and 3–4 cm proximal to the nonunion region. The involved bone demonstrated poor bleeding and an abnormal intraoperative appearance suggestive of compromised bone viability.

Because no histopathological specimen was obtained during the revision procedure, the presence and precise mechanism of bone necrosis could not be confirmed histologically. No intraoperative photographs of the abnormal bone were available.

The abnormal-appearing bone was debrided and resected until viable, bleeding bone was encountered. Approximately 4 cm of the humeral shaft was ultimately resected to obtain viable bone ends and facilitate fracture union. The loose intramedullary nail was removed, followed by open reduction and compression plate fixation with autologous iliac crest bone grafting. The revision procedure was intended to address both the mechanical instability associated with the loose nail and the compromised biological environment at the nonunion site.

Following revision surgery, serial radiographs demonstrated progressive fracture healing, ultimately resulting in complete union. Radial nerve function remained fully recovered during follow-up.

A standardized DASH or Constant-Murley functional score was not recorded, and a specific time to return to work or unrestricted activity was not available in the clinical records.



Figure 1. Anteroposterior radiograph of the right humerus at initial presentation, demonstrating an approximately mid-shaft humeral fracture following a motor vehicle accident.

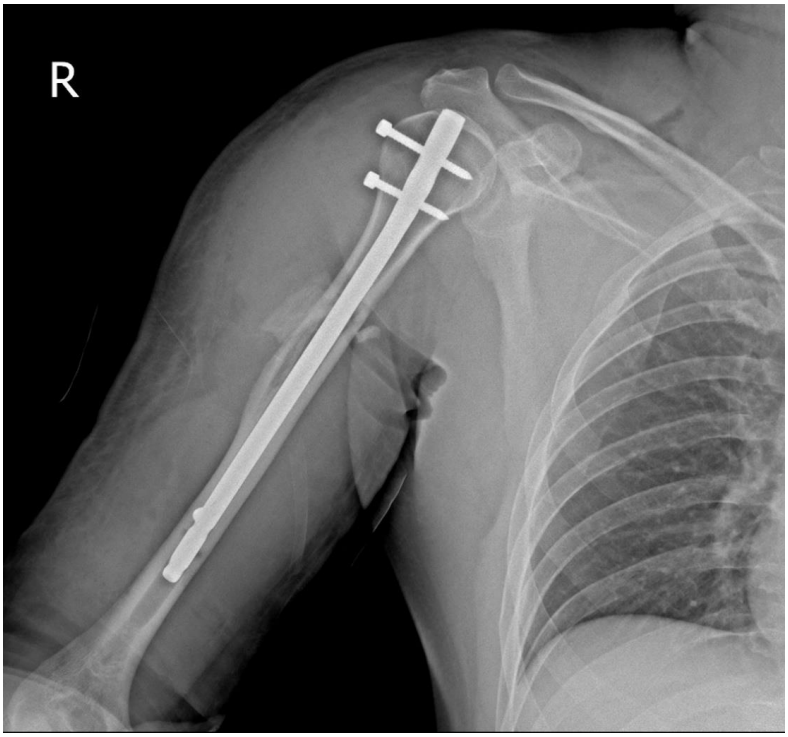


Figure 2. Postoperative anteroposterior radiographs of the right humerus following antegrade intramedullary nailing of the humeral shaft fracture.

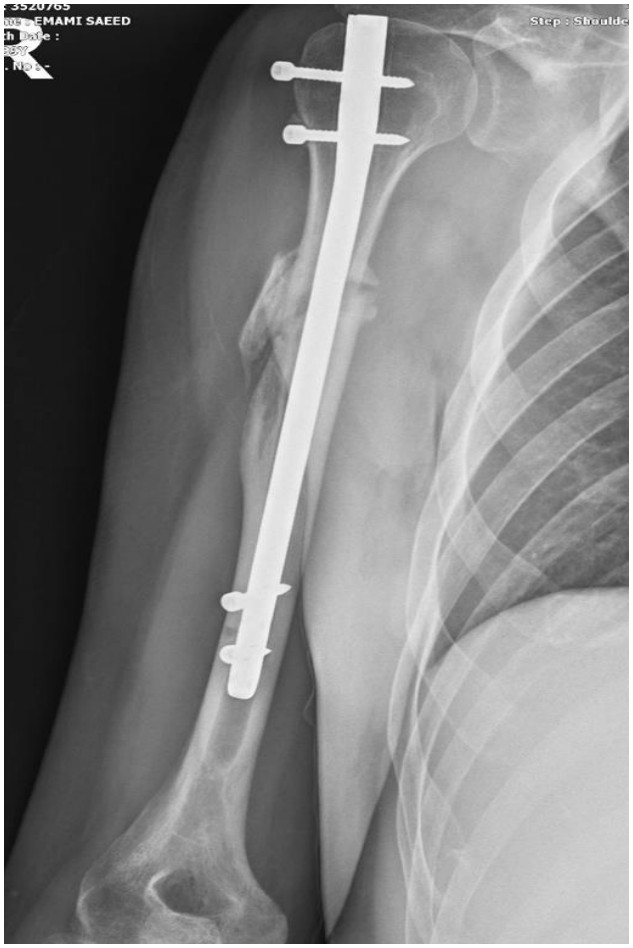


Figure 3. Anteroposterior radiographs obtained approximately six months after intramedullary nailing, demonstrating persistent nonunion of the humeral shaft without radiographic evidence of fracture healing.

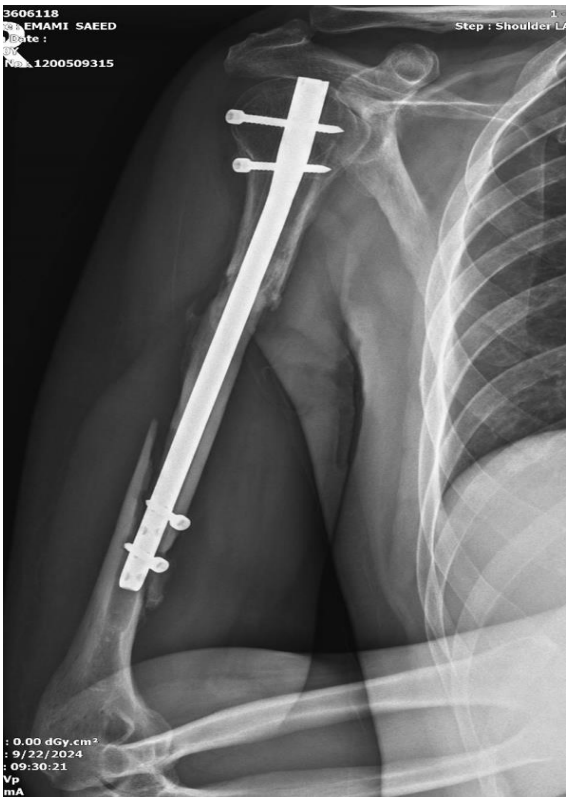


Figure 4. Anteroposterior radiograph demonstrating a distal periprosthetic fracture occurring at the tip of the intramedullary nail approximately six months after the index operation.



Figure 5. One-year postoperative anteroposterior radiograph demonstrating successful fracture union following revision fixation with compression plating and autologous iliac crest bone grafting.

Discussion

Humeral shaft nonunion following intramedullary nailing is a multifactorial complication. Although intramedullary fixation can preserve the surrounding soft tissues and periosteal blood supply, inadequate mechanical stability, fracture characteristics, and local biological impairment may all contribute to delayed union or nonunion .[2-4,7]

The present case has several features relevant to potential causes of nonunion. The initial fracture was closed, approximately mid-shaft, and without significant comminution. Initial fracture reduction was satisfactory, and no intraoperative evidence of soft-tissue interposition was identified at the fracture site. In addition, the patient had a BMI of 28 kg/m² and was a non-smoker, with no history of diabetes mellitus, renal disease, hypertension, osteoporosis, or hypothyroidism. No vitamin D deficiency or abnormality in PTH, TSH, or phosphorus was reported. Thus, no major patient-related or obvious fracture-pattern-related risk factor for impaired healing was identified from the available clinical information.

The most distinctive feature of this case was inadvertent reaming of the humeral canal during a procedure that was specifically planned as an unreamed intramedullary nailing procedure. This is clinically relevant because our practice does not routinely involve reaming with humeral nailing. Reaming of the medullary canal can generate heat, and excessive thermal exposure may potentially impair local bone viability and healing. Experimental work by Eriksson and Albrektsson demonstrated that thermal exposure can adversely affect bone tissue and regeneration, providing a biological rationale for concern regarding excessive heat during bone preparation[8].

However, the exact extent of thermal exposure in the present patient cannot be determined. The diameter of the reamer used during the inadvertent reaming was not documented, and no intraoperative temperature measurement was available. Therefore, although thermal injury represents a possible mechanism, the available information does not permit confirmation of the magnitude of any thermal insult.

The intraoperative findings at revision were notable. The bone surrounding the nonunion was markedly soft rather than sclerotic, and this abnormal softness extended approximately 2 cm distally and 3–4 cm proximally from the nonunion region. The bone also demonstrated poor bleeding. These findings raised clinical suspicion of compromised bone viability and prompted resection until viable, bleeding bone was encountered.

Nevertheless, these findings should not be interpreted as histologically confirmed bone necrosis. No pathological specimen was obtained; therefore, histopathological confirmation was not available. The description of compromised or nonviable bone in this case therefore refers to the clinical intraoperative impression rather than a pathologically established diagnosis. Other mechanisms, including vascular compromise, local biological impairment, or mechanical factors, cannot be completely excluded.

The temporal association between inadvertent reaming and subsequent clinical events is noteworthy. The patient developed postoperative radial nerve dysfunction, and EMG/NCS performed approximately one month after surgery reportedly demonstrated radial nerve injury at the mid-shaft/arm level. Radial nerve function subsequently recovered completely within approximately three months. This clinical course is compatible with a transient nerve injury rather than permanent structural disruption. Although the temporal association with inadvertent reaming raises the possibility of a thermal mechanism, the available clinical and electrophysiological information does not establish that the nerve injury was caused by thermal exposure.

The subsequent distal periprosthetic fracture occurred at approximately six months after the index procedure without a new traumatic event. The persistent nonunion and the loose intramedullary nail may have altered load transmission through the humeral shaft and increased stress concentration at the distal nail tip. Similar implant-related complications have been described in patients with persistent humeral shaft nonunion [6].

Once humeral nonunion develops following intramedullary fixation, revision treatment should address both mechanical stability and the biological environment. Flinkkilä et al. reported a poor union rate following exchange nailing for humeral shaft nonunion after intramedullary fixation, supporting consideration of alternative revision strategies [4]. Subsequent studies have described favorable results with augmentation plating, compression plating, and biological augmentation using bone grafting.[5,7,9-13]

In the present case, the loose intramedullary nail was

removed, clinically abnormal bone was resected until viable bleeding bone was encountered, and approximately 4 cm of the humeral shaft was removed. Compression plate fixation and autologous iliac crest bone grafting were then performed. This combined mechanical and biological approach was followed by progressive radiographic healing and eventual complete union.

The case has several limitations. First, histopathological examination of the abnormal bone was not performed, preventing confirmation of bone necrosis or its underlying mechanism. Second, the exact reamer diameter and other technical parameters of the inadvertent reaming were not documented, preventing assessment of the magnitude of possible thermal exposure. Third, intraoperative photographs were not obtained. Finally, standardized functional outcome scores such as the DASH or Constant-Murley score were not recorded, and the precise time to return to work or unrestricted activities was unavailable.

Despite these limitations, the case emphasizes the importance of preventing inadvertent deviation from the intended unreamed technique during humeral intramedullary nailing. When unexpected postoperative neurological dysfunction or delayed fracture healing occurs, careful clinical and radiographic surveillance may help identify complications earlier and enable appropriate intervention.

Conclusion

This case illustrates a clinically important sequence of complications following inadvertent reaming during a humeral intramedullary nailing procedure that was intended to be unreamed. The patient subsequently developed transient radial nerve dysfunction, persistent nonunion, and a distal periprosthetic fracture at approximately six months after the index procedure.

The markedly soft and poorly bleeding bone observed at revision raised clinical suspicion of compromised local bone viability. However, because histopathological confirmation was not available and the exact parameters of the inadvertent reaming were undocumented, a direct causal relationship between reaming, bone necrosis, and nonunion cannot be established.

The case highlights the importance of strict adherence to the planned unreamed technique during humeral intramedullary nailing. It emphasizes the need for close postoperative neurological and radiographic follow-up after inadvertent reaming. Once nonunion and mechanical failure develop, revision strategies combining removal of failed fixation, resection of clinically compromised bone, rigid compression plating, and autologous bone grafting may successfully restore mechanical stability and provide an appropriate biological environment for union.

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Conflict of Interest Disclosures

The authors declare that they have no competing interests.

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Authors' Contributions

Yousef Fallah: Investigation; Data curation; Writing – review & editing; Supervision; Surgery.

Farhad Mahdavi: Conceptualization; Investigation; Methodology; Project administration; Writing – original draft; Writing – review & editing.

Both authors reviewed and approved the final version of the manuscript.

Ethical Statement

Written informed consent was obtained from the patient for publication of this case report. All patient-related information was handled confidentially.

Declaration of Generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing and improving the clarity of the manuscript. The authors reviewed and revised the suggested content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

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