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Successful Union After Revision Plating for Non-Union of Humeral Shaft Fracture Initially Treated with Intramedullary Nailing: A Clinical Case Report

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ABSTRACT

Introduction: The optimal fixation method for humeral shaft fractures remains debated, particularly between intramedullary nailing and plate fixation. Although intramedullary nailing is minimally invasive, its mechanical stability may be insufficient for simple transverse fractures requiring interfragmentary compression, potentially increasing the risk of non-union.

Case Presentation: A 15-year-old female sustained a proximal humeral shaft fracture following a low-energy fall and underwent antegrade intramedullary nailing. Persistent pain and restricted shoulder motion were noted during follow-up. At six months, radiographs demonstrated a persistent fracture gap with sclerotic margins and no bridging callus, consistent with atrophic non-union. Revision surgery included nail removal, debridement of the fibrous interface, and compression plate fixation. Complete cortical union and full functional recovery were achieved within twelve weeks.

Clinical Discussion: This case demonstrates the mechanical limitations of intramedullary nailing in simple transverse humeral shaft fractures. Limited interfragmentary compression and persistent micromotion may impair fracture healing. Compression plating provides greater control of fracture reduction, enables direct compression, and facilitates debridement of the non-union site.

Conclusion: Implant selection for adolescent humeral shaft fractures should consider fracture biomechanics rather than surgical invasiveness alone. In transverse fractures requiring absolute stability, inadequate fixation with intramedullary nailing may contribute to non-union. Early recognition and conversion to compression plate fixation can restore mechanical stability, promote union, and achieve satisfactory functional recovery.

Keywords: bone plate, humeral fracture, intramedullary nailing, non-union fracture.

INTRODUCTION

Humeral shaft fractures constitute approximately 3% of all skeletal injuries in adults and represent a substantial proportion of traumatic injuries in the adolescent population. [1,2] Historically, most of these fractures have been treated conservatively using functional bracing, a method that has consistently demonstrated union rates exceeding 90% in long-term follow-up studies.[2] Nevertheless, over the past two

decades, there has been a gradual shift toward operative management. This change has been largely driven by the expectations of younger and physically active patients, for whom early mobilization, faster functional recovery, and avoidance of the physical and psychological burden of prolonged immobilization are particularly important. [3,4]

Despite the increasing frequency of surgical intervention, the optimal method of internal fixation for humeral shaft fractures remains controversial. Intramedullary nailing (IMN) and open reduction with internal fixation (ORIF) using plates are the two most commonly employed techniques, each grounded in distinct biomechanical and biological principles.[5] Intramedullary nailing functions as a load-sharing device, providing relative stability while preserving the fracture hematoma and periosteal blood supply, which theoretically promotes secondary bone healing.[6,7] However, growing clinical evidence has questioned these theoretical advantages. Several meta-analyses have demonstrated that IMN is associated with higher rates of complications, most notably non-union and iatrogenic radial nerve palsy, when compared with plate fixation. [3,4,6]

The limitations of intramedullary fixation become more apparent in simple transverse humeral shaft fractures, where successful healing depends heavily on rigid stability and effective axial compression. In these fracture patterns, the elastic nature of the nail, combined with limited control over interfragmentary compression, may allow persistent micromotion at the fracture site. Even minimal distraction during the interlocking process has been shown to disrupt the mechanical environment required for primary bone healing, thereby increasing the risk of delayed union or non-union. [8,9] Furthermore, the antegrade approach necessary for nail insertion requires violation of the rotator cuff, a factor that has been consistently associated with postoperative shoulder pain and restricted range of motion.

Several comparative studies have reported superior functional outcomes following plate fixation, particularly with respect to shoulder function. A study demonstrated significantly higher Constant–Murley scores and a greater proportion of excellent functional results in patients treated with plates compared with those managed using antegrade IMN.[10] This advantage is commonly attributed to preservation of the shoulder soft tissue envelope and the ability of plate fixation to generate absolute stability through controlled compression across the fracture site. [9,11]

Non-union following intramedullary nailing of the humeral shaft remains one of the most challenging scenarios in orthopedic trauma surgery. These cases are often characterized by mechanical insufficiency, fibrous tissue interposition, and a compromised biological environment. [8,12] Revision surgery must therefore address both mechanical and biological factors. Conversion from IMN to plate fixation allows direct visualization of the non-union site, thorough debridement of inhibitory fibrous tissue, and restoration of axial compression. When combined with autologous bone grafting, this strategy re-establishes mechanical integrity also enhances the local osteogenic milieu.[13]

This case report presents the clinical course of a 15-year-old female who developed atrophic non-union after primary antegrade intramedullary nailing of a simple transverse humeral shaft fracture. This case highlights the mechanical limitations of intramedullary fixation in specific fracture patterns and emphasizes the role of compression plating as a reliable revision strategy for solid union and full functional recovery.

CASE PRESENTATION

Clinical Assessment and Management

A 15-year-old female student, right-hand dominant, was admitted to the emergency department following trauma. Upon arrival, the primary survey confirmed the patient was alert and hemodynamic stable. Localized physical examination of the right

arm revealed significant swelling, evident deformity, and acute tenderness over the proximal diaphysis. Despite the structural compromise, the distal neurovascular status remained entirely intact, with a palpable radial pulse and normal capillary refill time of less than two seconds. Initial pain management involved intravenous metamizole (1 gr) and ranitidine (50 mg).

Radiographic evaluation confirmed a closed, simple transverse fracture of the proximal humeral shaft (Figure 1A). Following the diagnosis, the limb was temporarily stabilized with a coaptation splint, with post-reduction radiographs demonstrating satisfactory alignment (Figure 1B), in preparation for definitive internal fixation using intramedullary nailing.



Figure 1. Radiographs at initial presentation showing (A) a closed, simple transverse fracture of the proximal humeral shaft and (B) post-reduction alignment after application of a coaptation splint

Primary Intervention and Clinical Failure

Considering the patient's age and the objective of facilitating an early return to academic activities, the surgical team initially opted for antegrade locked IMN. The procedure aimed to provide biological fixation; however, the postoperative trajectory was suboptimal. In the months following the index surgery, the patient reported persistent, localized pain at the fracture site. Clinical assessment during serial follow-ups further identified a concerning limitation in shoulder kinematics, with abduction significantly restricted to less than 60 degrees.

By the 24-week mark, radiographic monitoring demonstrated a clear failure of the biological healing process. The radiograph demonstrated atrophic non-union with a persistent fracture gap, consistent with failure of fracture healing (Figure 2). The X-ray revealed sclerotic bone ends and a notable absence of bridging callus. This failure was likely exacerbated by the mechanical limitations of the nail in a transverse fracture pattern. Specifically, the potential for inadvertent distraction and the lack of axial compression necessary for primary bone healing.

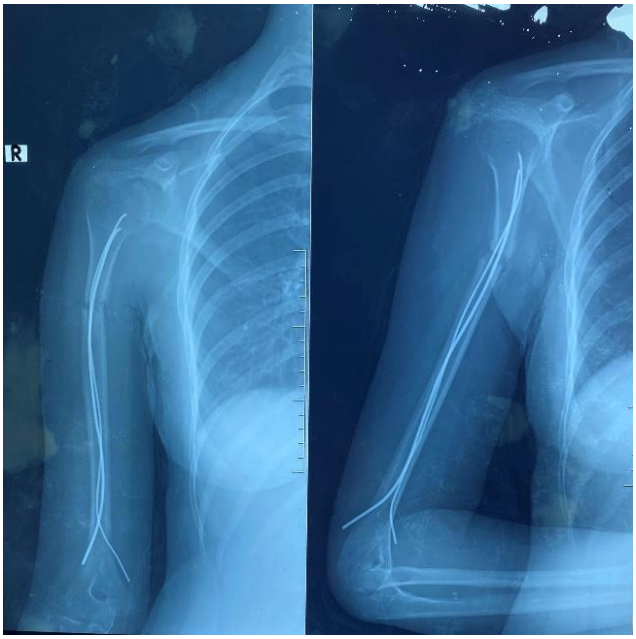


Figure 2. Plain radiograph at 24 weeks postoperatively demonstrating non-union of the humeral shaft with a persistent fracture gap.

Revision Strategy: Transition to Absolute Stability

A structured revision was executed to address both the biological and mechanical deficiencies of the primary fixation. The revision procedure commenced with the extraction of the existing intramedullary hardware. Upon surgical exposure of the non-union site through a lateral approach, dense fibrous tissue was found interposed between the bone ends, physically shielding the fragments from osteoblastic activity. Meticulous debridement of this inhibitory tissue was performed until punctate bleeding of the cortical bone, the "paprika sign" was achieved, effectively refreshing the biological environment.[8] Following removal of the intramedullary nail, the fixation strategy was converted to compression plate fixation, as demonstrated on the postoperative radiograph (Figure 3).

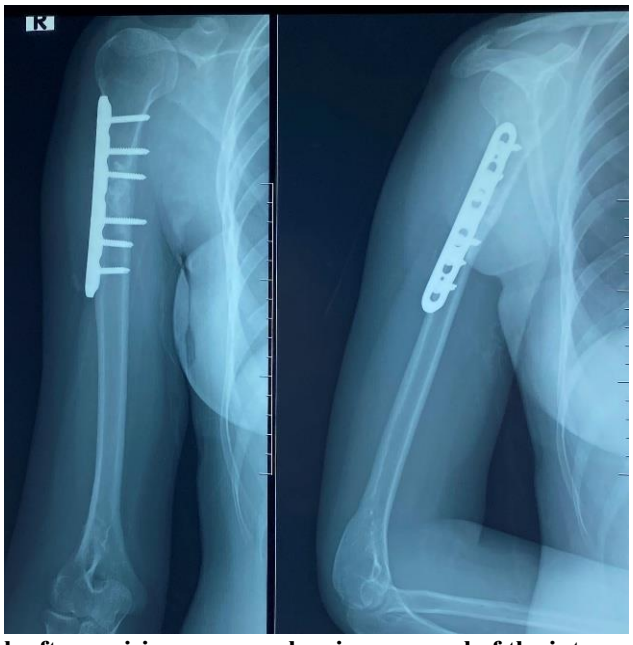


Figure 3. Plain radiograph after revision surgery showing removal of the intramedullary nail and conversion to compression plate fixation.

To correct the mechanical environment, the fixation was transitioned from the relative stability of a nail to the absolute stability provided by a compression fixation plate. Utilizing a dynamic compression principle, the plate allowed for active axial compression across the fracture line, neutralizing the shear forces that had led to the initial IMN failure.[9] To further maximize the osteogenic potential, autologous bone graft harvested from the iliac crest was packed circumferentially around the site.

Outcome and Follow-up

The post-revision recovery was unremarkable, allowing for early range-of-motion exercises. Radiographic evidence of solid cortical bridging and successful union was documented within 12 weeks of the second procedure. At the final follow-up, the patient exhibited near-full restoration of shoulder and elbow function, achieving a near-perfect Constant-Murley score and returning to her daily school routines without residual pain.

CLINICAL DISCUSSION

This case highlights the importance of aligning implant choice with fracture biology and biomechanics, particularly in simple transverse humeral shaft fractures. Although intramedullary nailing is often selected for its minimally invasive nature and theoretical biological advantages, the development of atrophic non-union in this patient underscores that biological preservation alone is insufficient in the absence of adequate mechanical stability. In fractures characterized by a simple transverse configuration, successful healing relies primarily on direct cortical contact and axial compression. When these conditions are not met, the fracture environment may remain mechanically unfavorable, predisposing the patient to delayed union or non-union despite appropriate surgical technique.

Mechanical Considerations and Implant Stability

The outcome observed in this case underscores the decisive influence of mechanical stability on fracture healing, particularly in simple transverse humeral shaft fractures. Intramedullary nailing provides relative stability through a load-sharing mechanism, which is advantageous in comminuted fractures where secondary bone healing is expected. However, in simple transverse patterns, primary bone healing requires rigid fixation with effective axial compression. The elastic behavior of the nail, combined with limited capacity to control interfragmentary compression, may allow persistent micromotion at the fracture site. Even minor degrees of distraction introduced during nail insertion or interlocking can disrupt cortical contact, creating a mechanical environment that is unfavorable for direct bone union. [5,14] This mechanical mismatch likely played a central role in the development of atrophic non-union in the present patient.

Non-Union Risk Associated with Intramedullary Nailing

Several meta-analyses have examined union rates following intramedullary nailing and plate fixation for humeral shaft fractures. Although the overall differences in non-union rates are sometimes modest, reported values consistently show a higher tendency toward non-union with IMN, particularly in simple fracture configurations.[15] A study reported a non-union rate of approximately 8.7% following IMN, compared with 6.3% for plate fixation, emphasizing that fracture morphology should guide implant selection rather than a uniform surgical preference.[5] In the current case, the absence of bridging callus and the presence of sclerotic fracture ends suggest a predominantly mechanical failure rather than an isolated biological deficiency. The relative instability provided by the nail was insufficient to stimulate either primary or robust secondary healing, ultimately resulting in an atrophic non-union.[16]

Functional Implications and Shoulder Morbidity

Beyond fracture union, functional outcome remains a critical consideration, particularly in adolescent patients with high functional demands. Antegrade intramedullary nailing necessitates entry through the rotator cuff, an approach that has been repeatedly associated with postoperative shoulder pain, weakness, and restricted range of motion. [7,10] Several comparative studies have demonstrated inferior shoulder function following IMN when assessed using validated outcome measures, including the Constant–Murley score. In this patient, persistent shoulder stiffness and pain were evident during follow-up, further supporting the notion that rotator cuff violation may compromise functional recovery even when fracture alignment is maintained. These functional drawbacks must be carefully balanced against the perioperative advantages of IMN, such as shorter operative time and reduced blood loss. [11,17]

Revision Strategy and the Role of Plate Fixation

The management of non-union following failed intramedullary nailing requires a strategy that addresses both mechanical insufficiency and biological exhaustion. Conversion to plate fixation allows direct visualization of the non-union site, facilitating meticulous debridement of fibrous tissue and restoration of axial compression across the fracture line. Although plate fixation carries an increased risk of radial nerve injury due to wider surgical exposure, this risk can be mitigated through careful surgical technique and direct nerve identification. [3,5] In the present case, the application of a compression plate transformed the mechanical environment from relative to absolute stability, while autologous bone grafting enhanced the local biological milieu. This combined approach resulted in timely union and meaningful functional recovery, illustrating the effectiveness of compression plating as a salvage procedure in selected cases. [8,9,12]

CONCLUSION

Successful healing of humeral shaft fractures depends on matching implant biomechanics to the fracture pattern. In simple transverse fractures, intramedullary nailing may provide insufficient stability and contribute to non-union when persistent micromotion or distraction is present. When non-union occurs, revision with debridement and compression plate fixation can restore absolute stability, promote fracture union, and achieve satisfactory functional recovery.

Declaration by Authors

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