Original

# Risk factors for non-union in humeral shaft fractures: a retrospective analysis of intramedullary nailing outcomes

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## Abstract

**Background:** Intramedullary nailing is the primary surgical treatment for many humeral shaft fractures. Non-union in these patients require new surgical treatments, with severe impact on the quality of life; identifying the risk factors associated with non-union is crucial to reduce this evolution. The goal of this retrospective cohort study is to analyze the aspects that can lead to non-union in humeral shaft fractures treated with intra-medullary nailing.

**Methods:** The authors retrospectively analyzed cases of humeral aseptic non-union treated with nail removal and Open Reduction Internal Fixation (ORIF) with a locking compression plate, in a single hospital between November 2013 and June 2024. From 33 identified cases, 20 patients met our inclusion criteria: age over 18 years, humeral shaft fractures (AO/OTA 12-A1 or 12-B2) involving the deltoid tuberosity treated with antegrade intramedullary nailing and failure of healing after 12 months. All the non-unions were not infected and vital normo or hypertrophic. The following exclusion criteria were applied: age under 18 years, pathological fractures, fractures treated non-surgically, or fractures treated with devices other than antegrade intramedullary nails.

**Results:** 20 patients (mean age 49 ± 10.6 years; 13 males, 7 females) underwent revision surgery with plate fixation after failed intramedullary nailing. Left-sided fractures accounted for 45% of cases. AO/OTA 12-A2

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was the most prevalent fracture pattern (55%), followed by 12-B2 (40%). Among the twenty patients, the fracture at the deltoid insertion was involved with a "V" fragment in thirteen cases of nonunion. The mean overall follow-up was 11 ± 3 months. Complete radiographical union was achieved in 19 patients (95%) with a mean time to bony union of 7.1 ± 3.5 months. No deep infections or osteomyelitis occurred.
**Conclusions:** The results of this study contraindicate IM nailing in humerus fractures AO types 12-A1, 12-A2, and 12-B2 with displacement of the "V" fragment. The non-union occurs due to the difficulty in reducing and fixing the "dynamic" gap caused by deltoid traction and the slow healing of that area. The solution for the vital non-union is to reduce the gap and use plate fixation, and this treatment is recommended, especially in an acute setting.

**Keywords**

Shaft humerus fractures; deltoid; non-union; intramedullary nailing; radiographs

## Introduction

Humeral shaft fractures represent about 3% of all bone fractures and usually occur in young people following high-energy trauma or in the older population with low-energy torsional trauma.[1,2] Intramedullary (IM) nailing is a method of fixation considered in the management of humeral shaft fractures due to its capacity for minimally invasive stabilization, allowing early mobilization and providing biomechanical advantages. IM nailing is particularly indicated for segmental fractures, pathologic fractures, fractures in osteopenic bone, and those with long zones of comminution or compromised soft tissues. It also plays a therapeutic role in cases requiring early stabilization with minimal surgical trauma, such as in multi-trauma patients or pathological fractures due to tumors. The technique improves rotational control and axial loading of the fracture site, promoting union while allowing early mobilization.[3-5]

This paper aims to critically discuss the IM nailing of a shaft fracture pattern that involves the proximal area at the insertion of the deltoid.

## Materials and Methods

We retrospectively analyzed all clinical cases of humeral aseptic vital nonunion of the humerus, following IM nailing. The non-union unions were treated by the same surgeon between November 2009 and June 2024. We reviewed the preoperative and postoperative X-rays. In total, we identified 33 clinical cases of humeral aseptic nonunion, of which 13 were excluded based on our criteria or were lost during the follow-up. We analyzed the following data: age, sex, fracture characteristics, type of nonunion (atrophic or hypertrophic), initial surgical treatment, last surgical treatment, presence of radial nerve palsy, duration of the palsy, and clinical and radiological follow-up at 1, 3, 6, and 12 months. We included patients who met the following inclusion criteria: age over 18 years, previous spiral, oblique, or third fragment humeral shaft fractures classified as AO/OTA 12-A1, 12-A2, or 12-B2 involving the deltoid tuberosity, treated with antegrade intramedullary nailing, and failure of fracture healing 6 months after surgery. Among the twenty patients, the fracture at the deltoid insertion with a "V" fragment was involved in fourteen cases of nonunion.

We excluded patients with the following features: age under 18 years, pathological fractures, fractures treated non-surgically, or fractures treated with devices other than antegrade intramedullary nails. All the patients underwent the same treatment: removal of the nail, revision of the non-united site; evaluation of the type of nonunion, and the need for biological or mechanical support. All the non-unions needed a reduction of the fragment and an increase in stability. The reduction was obtained by opening

the site, using pointed clamps because the bone was fragile, and the fixation of a couple of lag screws, if possible, and then a plate. All patients began active and passive physiotherapy on the first postoperative day.

**Surgical technique**

The preoperative plan should consider the type of nail, the entry point, the type of locking screws, and the need for special removal instruments (such as for a broken nail). The condition of the axillary nerve and the cuff should also be examined.

The patient is positioned supine with the arm adducted on a radiolucent board, with the C-arm on the opposite side of the surgical team. The entire upper extremity is prepared and draped in a sterile manner, and a surgical timeout is conducted. The first step involves a lateral approach following the previous scar (Figure 1).

The first step is to identify the nail tip, insert the nail extractor, and locate and remove the distal locking screws. This step is important because removing the screws provides insight into the residual bone stock, especially in the proximal humerus, where the plate will be anchored.

The second step involves proximal dissection while protecting the axillary nerve (approximately 6 cm from the acromion tip), corresponding to the surgical humeral neck. Distally, the deep fascia is incised, and the biceps is retracted anteromedially to reveal the brachialis and brachioradialis muscles. The radial nerve is identified in the interval between these muscles, starting just proximal to where it penetrates the lateral intermuscular septum. The nerve is traced proximally by elevating the distal origin of the lateral head of the triceps. The triceps muscle is retracted from the posterior surface of the humerus. In the spiral groove area, the nerve lies between the lateral and medial heads of the triceps. This exposure reveals the humeral shaft and the non-union site. For vital non-union, the fragments are only minimally decompressed to define the correct reduction edges; for atrophic non-union, more aggressive debridement is recommended, keeping in mind that shortening may be acceptable.

In our cases, all sites were vital (Figure 2). The fracture can then be anatomically reduced and temporarily fixed with pointed clamps (Figure 3). If the fracture line exceeds 5 cm, 2.7 or 3.5 lag screws are used for compression. Compression can be achieved either with free lag screws or through lag screws placed by the plate. The plate should span the entire segment, extending distally to the previous screw holes, and be fixed with at least six cortices, preferably using locking systems (Figure 4).

The limb is then immobilized in a sling for one week for comfort. Postoperative rehabilitation begins the day after surgery, allowing the use of the limb for daily activities. However, any rotational movements are prohibited for 40 days.

**Results**

Among a cohort of 33 patients with non-union V deltoid fractures treated with open reduction and internal fixation (ORIF) with plate and screws, 20 patients with a mean age of 49 ± 10.6 years were included in the study after inclusion and exclusion criteria were applied. The overall mean follow-up was 11 ± 3 months. The flowchart of study population characteristics is available in Table 1.

**Demographic and Injury Characteristics**

The cohort comprised 13 male and 7 female patients, with left-sided fractures accounting for 45% of cases and right-sided fractures 55%. Low-energy trauma mechanisms, particularly falls from standing height, were the leading cause of injury in older patients (mean age > 65 years), whereas high-energy mechanisms such as road traffic accidents predominated in younger individuals (mean age < 40 years). According to the AO/OTA classification system, the distribution of fracture patterns was as follows: AO/OTA 12-A1 comprised 5% of cases, AO/OTA 12-A2 (the most common pattern) at 55%, and AO/OTA 12-B2 (wedge fractures) representing 40% of the cohort. Among the twenty patients, the fracture at the deltoid insertion with a "V" fragment was involved in thirteen cases of nonunion (Table 2).

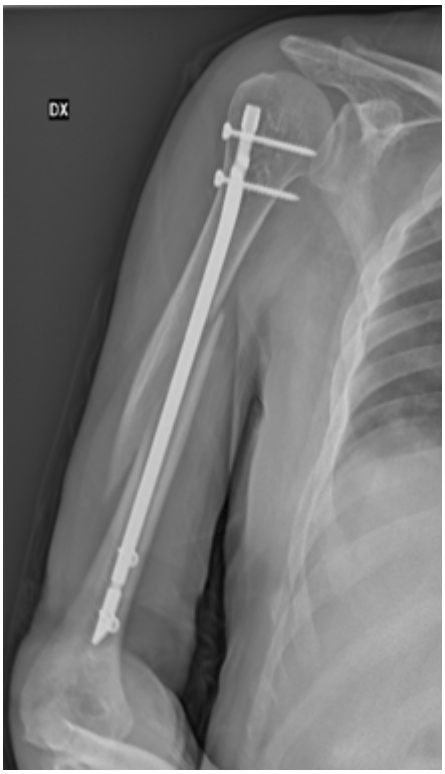


***Figure 1.*** *Screws and nail are removed through the previous surgical incision*

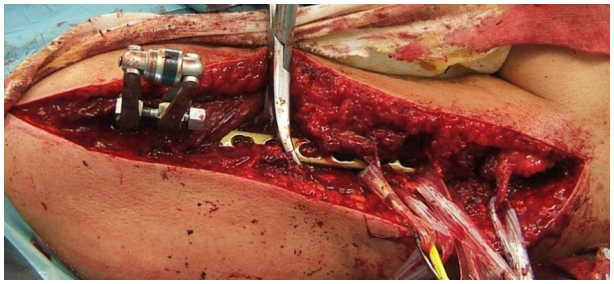

***Figure 3.*** *No graft is needed. Just clamps or tie rod*

**Surgical Management and Clinical Outcomes**

All 20 patients were initially treated with antegrade intramedullary nailing at the first surgery. Subsequently, all cases underwent revision surgery consisting of nail removal followed by open reduction and internal fixation (ORIF) utilizing a locking compression plate (LCP) through a lateral approach. Mean time between initial failed intramedullary nailing and revision plate fixation was 14.5 ± 6.2 months. Radial nerve identification and protection were accomplished in all cases during the lateral surgical approach.

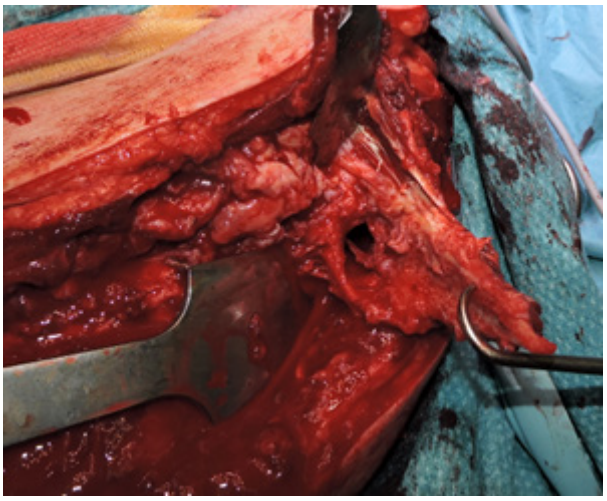

***Figure 2.*** *Debridement of the site of the fracture and evaluation of the length of the V fragment in order to make the compression.*

**Radiographical and Functional Union**

Radiographical evidence of fracture healing was documented sequentially on plain radiographs and additional imaging studies performed at postoperative intervals. The mean time to radiographic bony union, defined as bridging callus visible on anteroposterior and lateral radiographs at the fracture site, was 7.1 ± 3.5 months. Complete radiographical union was achieved in 19 of 20 cases (95%), with one patient experiencing delayed union beyond 12 months without clinical symptoms like pain, swelling or stiffness; this single delayed union case demonstrated progressive callus formation and achieved consolidation by 14 months.

**Complications**

Radial nerve injury occurred in two patients (10%), presenting as transient neurapraxia secondary to iatrogenic injury. It recovered in about six months postoperatively. Hardware-related complications requiring elective implant removal in one case (5%), the patient had symptomatic soft-tissue impingement from distal screw placement, and removal was performed 18 months postoperatively. No deep surgical site infection or osteomyelitis was document-

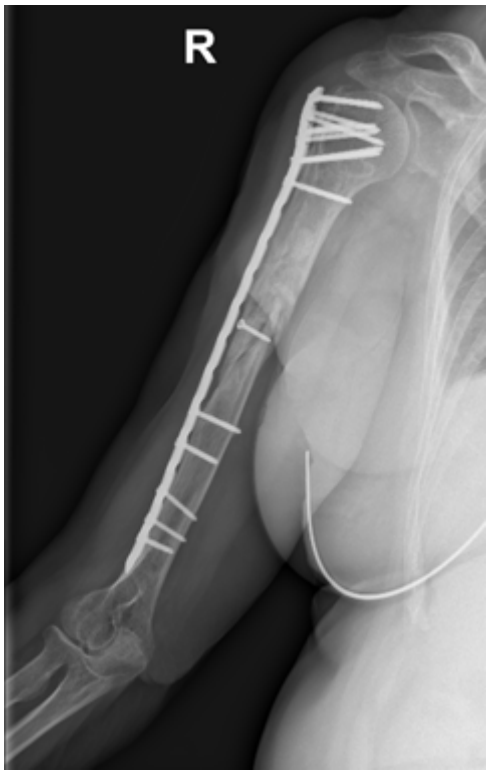


***Figure 4.*** *Radiographic control of the plate position*

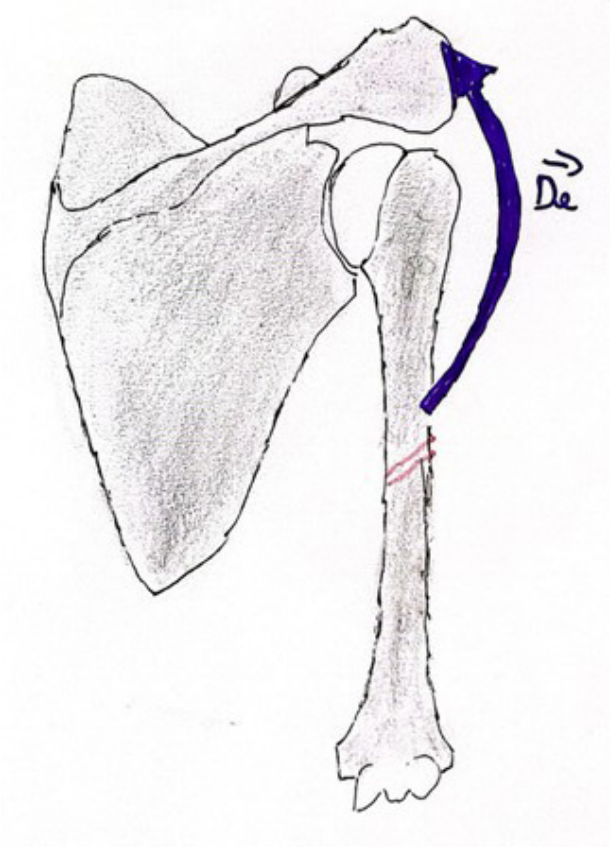


***Figure 5.*** *Biomechanism of the deltoid muscle*

ed throughout the follow-up period. All patients achieved complete functional recovery and resumption of activities of daily living.

**Discussion**

The most important finding of this study is that humeral shaft fractures where the fracture line touches and displaces the insertion point of the deltoid muscle must be fixed with plates and screws, because closed reduction and IM nailing lead to nonunion.

The humeral shaft is predominantly composed of dense cortical bone surrounding a medullary canal, providing structural integrity and serving as a conduit for neurovascular elements. The shaft presents three surfaces (anterolateral, anteromedial, and posterior) and three borders (anterior, lateral, and medial), which serve as attachment sites for various muscles.[6,7] A key anatomical feature is the deltoid tuberosity, a V-shaped prominence located laterally on the midshaft, serving as the insertion point for the deltoid muscle in the area called deltoid insertion (DI).[8] The anterior, middle, and posterior deltoid muscle fibers enter the DI in a V-shaped tendinous confluence with a broad posterior band and a narrow separate anterior band, which accounted for the anterior one-fifth of the DI (0.44 cm).[8] Rispoli et al.[9] noted that after the deltoid insertion release, the interconnections between the deltoid tendon and its fascia were continuous with the brachialis muscle and intermuscular septum. The integrity of these interconnections may contribute to the preserved deltoid function despite the partial release of the deltoid in lateral plate fixation. Biomechanically, the humeral shaft is designed to withstand complex loading patterns, including axial compression, torsion, bending, and shear forces, which occur during various upper limb activities. Its tubular structure and cortical composition confer resistance to these stresses, facilitating effective force transmission between the shoulder and elbow joints (Figure 5). The deltoid muscle, particularly its insertion on the deltoid tuberosity, plays a pivotal role in shoulder

| **Table 1.** Demographics (Data *are expressed as mean ± SD)* | | |
|---|---|---|
| **Patients (no)** | | **20** |
| **Follow-up (months)** | **Mean** | 11 ± 3 |
| **Age at surgery** | **Mean** | 49 ± 10.7 |
| **Gender** | **M** | 13 (65%) |
| | **F** | 7 (35%) |
| **Side** | **Right** | 11 (55%) |
| | **Left** | 9 (45%) |

| **Table 2.** *Fracture characteristics. *Data are expressed as mean ± SD* | | |
|---|---|---|
| **Patients (no)** | | **20** |
| **Type of fracture** | **12 A1** | 1 (5%) |
| | **12 A2** | 11 (55%) |
| | **12 B1** | 8 (40%) |
| **"V" fragment** | | 13 (65%) |
| **Fracture healing (radiographs)** | | 7.1 ± 3.5 months* |
| **Complications** | | 3 (15%) (2 Radial neuroapraxia, 1 Hardware removal) |

biomechanics. It significantly contributes to shoulder abduction and flexion strength, as its fibers exert forces that influence the mechanical environment of the humeral shaft.

To our knowledge, limited literature exists regarding the so-called "V deltoid fractures" area, where forces from the deltoid muscle create maximum stress and where a lack of reduction often results in nonunion. The surgical reference AO guide [10] recommends that for shaft fractures in this area, treatment should aim for stable osteosynthesis to allow early mobilization, prevent joint stiffness, and enhance functional recovery. For AO/OTA type A fractures, open reduction and internal fixation (ORIF) with compression plating remains the gold standard. ORIF enables anatomical reduction, direct visualization of the fracture, interfragmentary compression, and, if necessary, identification and protection of the radial nerve, which closely parallels the humeral shaft in the spiral groove.[11,12]

Minimally invasive plate osteosynthesis (MIPO) has become widely accepted as a less invasive alternative that preserves soft tissues and periosteal blood supply, promoting indirect bone healing through callus formation and potentially reducing nonunion risk. The classical anterior MIPO approach, as well as posterior, anterolateral, and anteromedial approaches, provide circumferential access to the humerus with smaller incisions and less soft tissue dissection.[13,14]

IM nailing has gained popularity due to improvements in implant design and technique, especially for multifragmentary fractures or in polytrauma patients. IM nailing offers rapid stabilization and minimal physiological impact, often associated with shorter union times and less blood loss compared to ORIF. However, concerns remain about shoulder impingement and the difficulty of accessing the radial nerve, which cannot be directly visualized during nailing.[15,16]

**Table 3.** Summary of the most important published studies **comparing IM nailing and plate fixation for humeral shaft fractures and for humeral shaft nonunions.**

| Study | Study design | Population/ Fracture type | Treatment/ Comparison | Outcomes | Key conclusions |
|---|---|---|---|---|---|
| van Bergen et al.[5] | Systematic review (173 studies, 11,868 pts) | Adult OTA/AO 12 humeral shaft fractures treated nonoperatively or with IM nailing / plating | Nonoperative functional bracing vs IM nailing vs plate osteosynthesis (including MIPO) | Healing rate: 89% nonoperative, 94% IM nailing, 96% plating. Secondary radial nerve palsy: 1% nonoperative, 3% IM nailing, 6% plating. Implant failures and intraoperative complications more frequent with IM nailing. | Both IM nailing and plating achieve high union rates; plating (especially MIPO) shows slightly higher healing and better functional scores, at the cost of a higher rate of iatrogenic radial nerve palsy. |
| Hu et al.[33] | Systematic review and metaanalysis (14 studies, 903 pts) | Adult humeral shaft fractures | Intramedullary nail (IMN, 437 pts) vs locking compression plate (LCP, 466 pts) | IMN associated with shorter operative time and less intraoperative blood loss. Postoperative infection lower with IMN (RR 0.32). No significant differences in nonunion, delayed union, radial nerve injury or reoperation rates. ASES scores lower and shoulder/elbow motion limitation more frequent after IMN (RR 1.88). | IMN is biomechanically and surgically less invasive (shorter surgery, less blood loss, fewer infections), but early shoulder and elbow function tends to be better after LCP fixation, with similar union and nonunion rates between techniques. |
| Ouyang et al.[34] | Updated metaanalysis of 10 RCTs (439 pts) | Adult diaphyseal humeral fractures | Plate fixation vs intramedullary nailing | Plating significantly reduced postoperative shoulder impingement and restriction of shoulder motion compared with nailing. No significant differences in nonunion, delayed union, infection, radial nerve palsy, iatrogenic fracture comminution or implant failure between groups. | Both techniques achieve similar union and complication rates; plating appears to better preserve shoulder range of motion and reduce shoulderrelated complications compared with antegrade nailing. |
| Micic et al.[20] | Retrospective cohort (56 pts) | Humeral diaphyseal nonunion after conservative treatment | Dynamic compression plate (36 pts) vs intramedullary nail (20 pts) for nonunion | Union: 100% in the plate group vs 90% in the IM nail group. Mean time to union ≈ 4.2 months (plate) vs 4.5 months (nail) (NS). Complications: 13.8% plate (mostly transient radial nerve palsy) vs 10% IM nail (including distal humeral fracture during nail insertion). CMS and DASH slightly better with plating, not statistically significant. | Both plating and IM nailing provide high union rates for humeral shaft nonunion, with somewhat higher union and functional scores after plating. IM nailing offers shorter surgery, less blood loss and shorter hospital stay, which may benefit elderly or comorbid patients. |

| | | | | | |
|---|---|---|---|---|---|
| Patino et al.[35] | Retrospective comparative study (57 pts) | Acute humeral shaft fractures treated operatively | Plate fixation (27 pts) vs antegrade locked IM nailing (30 pts) | Healing: 100% in plate group vs 93.3% in nail group. Full shoulder ROM: 66.6% plate vs 40.0% nail (p = 0.02). Excellent RodríguezMerchán score: 66% plate vs 40% nail. Complications: 7.4% plate vs 20% nail (including 2 nonunions and subacromial impingement) | Plate fixation resulted in better shoulder ROM and functional scores and fewer complications than antegrade IM nailing, although both techniques achieved good overall clinical results and high union rates. |
| Hudson et al.[36] | Retrospective case series (14 pts) | Complex humeral shaft fractures (AO/OTA B2, B3, C2, C3), many obese and/or polytrauma patients | Percutaneous antegrade IM nailing using a minimally invasive technique | Primary union achieved in 93% (13/14) after index nailing; final union 100% after one secondary plating procedure. No pre or postoperative radial nerve palsy. Mean ASES 78.2, Constant 72.1, Penn Shoulder 82.7, SANE 81.9 at ≥1 year. | Percutaneous IM nailing is an effective option for complex, comminuted humeral shaft fractures in highrisk patients, providing high union rates and satisfactory shoulder function, with low risk of radial nerve injury and limited softtissue morbidity. |

The literature considers IM nailing a viable option for humeral shaft fractures, yet most studies inadequately address the mechanical challenges posed by the V fragment or ignore its unique biomechanical environment.[17] Current nonunion research mainly focuses on technical factors such as nail diameter, locking screw configuration, and entry point, while overlooking the critical role of deltoid muscle forces in fracture stability.[18] Recent systematic reviews of humeral shaft nonunion show variable union rates with IM nailing, ranging from 4% to 23%.[19] However, these studies rarely stratify outcomes based on the deltoid tuberosity. Micic et al. reported a 10% nonunion rate with IM nailing, compared to 0% with plate fixation, but did not specifically analyze fractures involving the deltoid insertion area.[20]

The biomechanical reasoning behind this involves the unique force vectors generated by the deltoid insertion.[21] The deltoid exerts significant distraction forces perpendicular to the humeral shaft, tending to cause angulation and displacement at the V fragment. Unlike plate fixation, which provides direct compression and resists these forces through its position on the tension side of the bone, IM nails rely primarily on interlocking screws to control rotation and length.[22] This disadvantage becomes especially evident when the fracture line involves or passes through the deltoid tuberosity, as the nail cannot sufficiently counteract the muscle's distractive forces.[23] Furthermore, the current literature shows a concerning lack of standardized criteria for assessing the reduction quality of the V fragment during IM nailing procedures.[24]

While overall fracture alignment and rotation are routinely evaluated, specific parameters for restoring the deltoid ridge anatomy are rarely reported.[25,26] This gap may explain the variable union rates seen across different series and underscores the need for more precise anatomical considerations in treatment planning.[27,28]

Our findings indicate that the mechanical environment created by IM nailing is insufficient to maintain reduction stability when deltoid forces are unopposed by sufficient interfragmentary compression. Treating nonunion involving the V fragment after IM nailing suggests that this fragment should

be anatomically reduced and securely fixed to prevent mechanical failure and nonunion.[29]

Our series shows that all nonunion cases occurred where the deltoid ridge was inadequately managed during initial IM nailing, supporting the idea that this region requires specific surgical attention beyond what is used for standard diaphyseal fractures.[30] The conversion from failed IM nailing to plate fixation without bone grafting achieved union in all cases.

In our series, no atrophic nonunions were observed, so bone grafting was not used. This demonstrates the superiority of compression plating in managing the complex forces generated by deltoid muscle contraction. This aligns with biomechanical principles showing that plate constructs better resist bending and distraction compared to intramedullary devices, especially when placed on the tension side of the bone (Table 3).[31,32]

Based on our results, we suggest that fractures involving the deltoid tuberosity should be regarded as a distinct subset of humeral shaft fractures requiring modified treatment strategies. The presence of the V fragment should be an indication for plate fixation rather than IM nailing, regardless of other fracture features. This is especially important because nonunion in this region can severely impair shoulder function and overall upper limb performance due to deltoid muscle dysfunction.

This study has limitations, including its retrospective design that may introduce bias without randomization, the small sample size that could limit the analysis of clinical and radiological outcomes, and the absence of a control group treated primarily with plate fixation for V fragment fractures that precludes definitive conclusions about the best primary treatment. Additionally, long-term functional outcomes and patient-reported measures were not thoroughly assessed, possibly underestimating the full clinical impact. Nonetheless, strict surgical selection criteria may have influenced these limitations. A key strength is the uniform evaluation of patients undergoing the same procedure by the same surgeon, with similar demographic features, sample size, and follow-up. To date, no study has simultaneously assessed clinical and radiological results following plate and screw fixation for nonunion after IM nailing. Future research should aim to develop standardized radiographic criteria to identify V fragment involvement preoperatively, establish biomechanical testing protocols to compare fixation methods in this specific area, and conduct prospective studies to validate our recommendations. Advances in implant design, including locking plates tailored for the deltoid ridge or specialized nails with better proximal locking, could also provide new solutions for these challenging fractures.

## Conclusion

Due to the anatomical and biomechanical features of AO type 12-A1, 12-A2, and 12-B2 fractures involving the "V deltoid fractures" we found that this fragment could not be reduced and fixed in a closed way and intramedullary nailing should not be the surgical choice of fixation. At this anatomical level, the fracture displacement frequently creates a gap that cannot produce sufficient callus formation. Successful healing requires closer contact between the fragments. Additionally, the gap is dynamic because of continuous displacement forces exerted by the deltoid muscle. As a result, the relative stability provided by bridging constructs, such as intramedullary nails, plates, or external fixators, is inadequate to ensure reliable consolidation. Only anatomical reduction combined with absolute stability can guarantee consistent and successful healing in these cases. In these specific patterns, plate fixation with lag screws, when feasible, offers better outcomes by enabling anatomical reduction and providing absolute stability. These types of pseudarthrosis remain biologically active, so achieving an as close as possible anatomical reduction with clamps or lag screws promotes primary healing without the need for bone grafting. Moreover, placing the plate laterally effectively counteracts the deforming force from the deltoid muscle, which is the main cause of displacement in these fractures.

## Conflict of Interest

The authors declared no conflicts of interest.

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**Cite this paper as**

Berlusconi M, Fedele G, Cicio C, Compagnoni R, Mocchi M, Staletti L, Randelli F. Risk Factors for Non-Union in Humeral Shaft Fractures: A Retrospective Analysis of Intramedullary Nailing Outcomes. AOTH. 2026; 77(1):19-30.

**DOI** https://doi.org/10.69133/aoth.v77i1.527