International Journal of Research in Orthopaedics
Aggarwal S et al. Int J Res Orthop. 2026 Jul;12(4):994-1001
https://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20262029

Reconstruction of aseptic humerus non-union with compression plating and cortico-cancellous bone grafting

Sameer Aggarwal[1], Aman Hooda[2]*, Deepak Negi[1], Harsh Mander[2], Mehar Dhillon[2], Mandeep Singh Dhillon[2]

[1]Department of Orthopaedics, PGIMER, Chandigarh, India
[2]Department of Orthopaedics, Fortis, Mohali, Punjab, India

Received: 23 February 2026
Revised: 04 April 2026
Accepted: 22 May 2026

***Correspondence:**
Dr. Aman Hooda,
E-mail: amanhooda_10@yahoo.co.in

Copyright: © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT

Background: Managing humeral shaft nonunion requires a comprehensive approach. Key factors include infection, prior surgeries, and severe bone loss. Treatment is challenging due to various surgical options, a lack of clear protocols, and limited evidence-based guidelines.
Methods: Forty-four adults with humeral shaft nonunion (not caused by infection) were treated over 8 years from January 2012 to December 2020. Seven cases were particularly stubborn. Cases were excluded if they involved open fractures, infections, breaks with big gaps, bone disease, or other upper limb injuries. Treatment included removing unhealthy bone and tissue, correcting bone shape, using the patient's own bone to help healing, and fixing the bone with a strong plate. Outcomes were assessed using the DASH (Disabilities of the Arm, Shoulder, and Hand) score at baseline and at least 24 months later.
Results: Patients were followed for an average of 75 months. All patients healed. On average, healing took about 6 months (ranging from 4 to 12 months). Four patients (11.1%) had temporary nerve problems that fully recovered within 6 months. Two patients (5.5%) had mild wound infections. Arm function scores improved from an average of 76 before treatment to 7 at the end, showing excellent recovery.
Conclusions: Our study shows that open surgery with a locking plate, supplemented with additional bone when needed, is very effective for healing stubborn humeral shaft fractures. Careful steps, such as gentle tissue handling, maintaining a healthy blood supply, and fully removing the bad tissue, are key to success.

Keywords: Humeral shaft non-union, Non-union, Aseptic non-union, Bone grafting, Locking compression plate

INTRODUCTION

Humerus shaft fractures are frequently encountered injuries, due to high-impact trauma like road traffic accidents, injury from heights, or direct trauma.[1] The humerus plays a pivotal role in the smooth functioning of the shoulder and elbow joints, and any disruption to its structural integrity can substantially hinder an individual's ability to carry out everyday tasks. The medical literature reports an incidence range of 0.3%-13% for nonunion following humerus shaft fractures, with 8-13% incidence after surgical intervention.[2] Nonunion can be due to inadequate reduction and fixation, devitalization of soft tissues, or multiple patient-associated factors leading to compromised fracture healing, such as tobacco intake, chronic alcohol abuse, inadequate immobilisation, immunocompromised patient status, and infection.[2,3] This condition poses a complex clinical challenge that may lead to persistent discomfort, compromised function, and diminished overall quality of life.[4] Multiple surgical procedures may lead to chronic pain and disability not only around the affected arm but also lead to stiffness around the neighboring joints. The management of humeral shaft nonunion often requires an integrated plan. Important considerations are infection, prior surgeries, and significant bone loss.[2] Conservative methods include casting, bracing, splinting, electrical stimulation, and shock wave therapy. These approaches are effective only in select cases.[5]

Operative treatments include compression plating, intramedullary nailing, bone grafting, and Ilizarov external fixation. No consensus exists for the optimal treatment, especially in recalcitrant cases. The management goals are deformity correction, bone union, and full arm function. An effective approach involves open reduction and internal fixation with a locking plate for stable, rigid fixation, along with bone grafting.[6]

However, this strategy is supported mainly by limited follow-up from small case series.[6-8] This large case series describes the institution's experience treating 44 cases of humeral shaft nonunion, each with at least 2 years of follow-up. The main objective is to add to the evidence supporting open reduction and internal fixation with a stable, rigid compression plate and bone grafting, especially for recalcitrant cases. By presenting findings and outcomes, the study aims to offer perspectives to inform clinical decision-making and encourage further research in this specialised field.

METHODS

This prospective case series included 44 patients with aseptic humeral shaft nonunions treated in the Department of Orthopaedics at the Post Graduate Institute of Education and Research (PGIMER), Chandigarh between January 2012 and December 2020. Each patient was followed for at least 2 years or until union. All steps, from patient selection to follow-up, were performed prospectively as part of the study protocol.

Patient selection, settings and ethics

Inclusion criteria: adults over 18 years with aseptic humeral shaft nonunion, adequate radiographic and clinical follow-up, and treatment with or without surgery. For each patient, demographics (age, gender, medical history) were recorded. All included patients underwent surgery for aseptic humeral nonunion as per protocol.

Exclusion criteria: children under 18, nonunions with bone gap >6 cm, open fractures, infections, other upper-limb injuries, or nonunions due to bone disease.

Nonunion was defined as ongoing pain or movement at the fracture site with no radiographic healing. The study included hypertrophic, oligotrophic, and atrophic nonunions. Institutional Ethical Committee approval was obtained (DRB/Ortho/2023/48).

Surgical procedure

All patients underwent open reduction and internal fixation with a locking compression plate, supplemented by a minimum of eight cortical purchase screws on either side of the fracture to achieve rigid fixation. This technique is the standard of care for humeral shaft nonunions, supported by a high union rate and good functional outcomes.[9] The surgical approach was determined by the surgeon based on the fracture configuration, previous approach used, and the presence of radial nerve palsy requiring exploration.

Any previous failed hardware was removed. Priority was placed on complete thorough debridement of the nonunion region by removal of interposed fibrous and necrotic tissue, along with excision of devitalized tissue. The fracture ends were freshened, and deformity was addressed to restore proper alignment. Rigid fixation was attained by optimising cortical contact and compression with the plate, along with augmented healing at the previous fracture site due to the placement of adequate bone graft. The sclerotic cap on either side of the medullary canal was opened by using a drill, and the fibrous tissue was removed using a nibbler or a curette. Opening the canal and roughening the area around the fracture leads to active bleeding and subsequently stimulates a healing response. "Shingling" was performed to stimulate osteogenesis around the nonunion site without considerable loss of vascularisation.[10] This was performed by carefully decorticating the bone on either side of the fracture site with the use of a sharp osteotome along a length of 2 cm. Shortening osteotomy of the fracture ends was performed if needed, thus changing the configuration to a transverse configuration, ensuring maximal cortical opposition, compression, and stability of the construct. A plate of adequate length (at least a 9-hole plate or longer) was supported by at least 4 bi-cortical screw purchases on either side to increase stability.

Bone graft

All patients also had bone taken from their hip (iliac crest) or, if needed, the lower leg (fibula) to fill any gaps or weak spots. The bone used depended on the situation and the doctor's choice.

The donor bone helped join and support the fixed bone. In particularly tough cases, a piece of fibula bone inside the arm acted as a strong support for healing and screw placement. The hip bone graft was also used over the fixed area after the bone was prepared using the shingling technique.

Post-operative care

Postoperatively, patients were given a shoulder-arm pouch. Shoulder pendulum and elbow motion exercises began as soon as possible. Resistance exercises were started only after the fracture fully united on radiographs.

Follow-up and outcome measures

The patients were followed up at 6-weekly intervals until radiographic union, and then at 6-monthly intervals for 2 years. The primary outcome measures were union status and time to union after final surgery, determined by radiological assessments. A fracture was considered united when there were no pain and mobility at the fracture site, and a bridging callus was present across three cortices with obliteration of the fracture line on radiographs by two senior consultants. The Disabilities of the Arm, Shoulder, and Hand (DASH) Score at the presentation and at final follow-up was used to assess functional outcomes. DASH scoring is a self-rated questionnaire that measures upper-extremity disability and symptoms. The DASH is scored in two components: the disability/symptom questions (30 items, scored 1-5) and the optional module, which includes a high-performance sport/music/work section (4 items, scored 1-5). The scoring varies from 0 to 100.

A higher score indicates increased disability. Postoperative radial nerve status and other complications, such as delayed wound healing and deep or superficial infection, were also recorded.

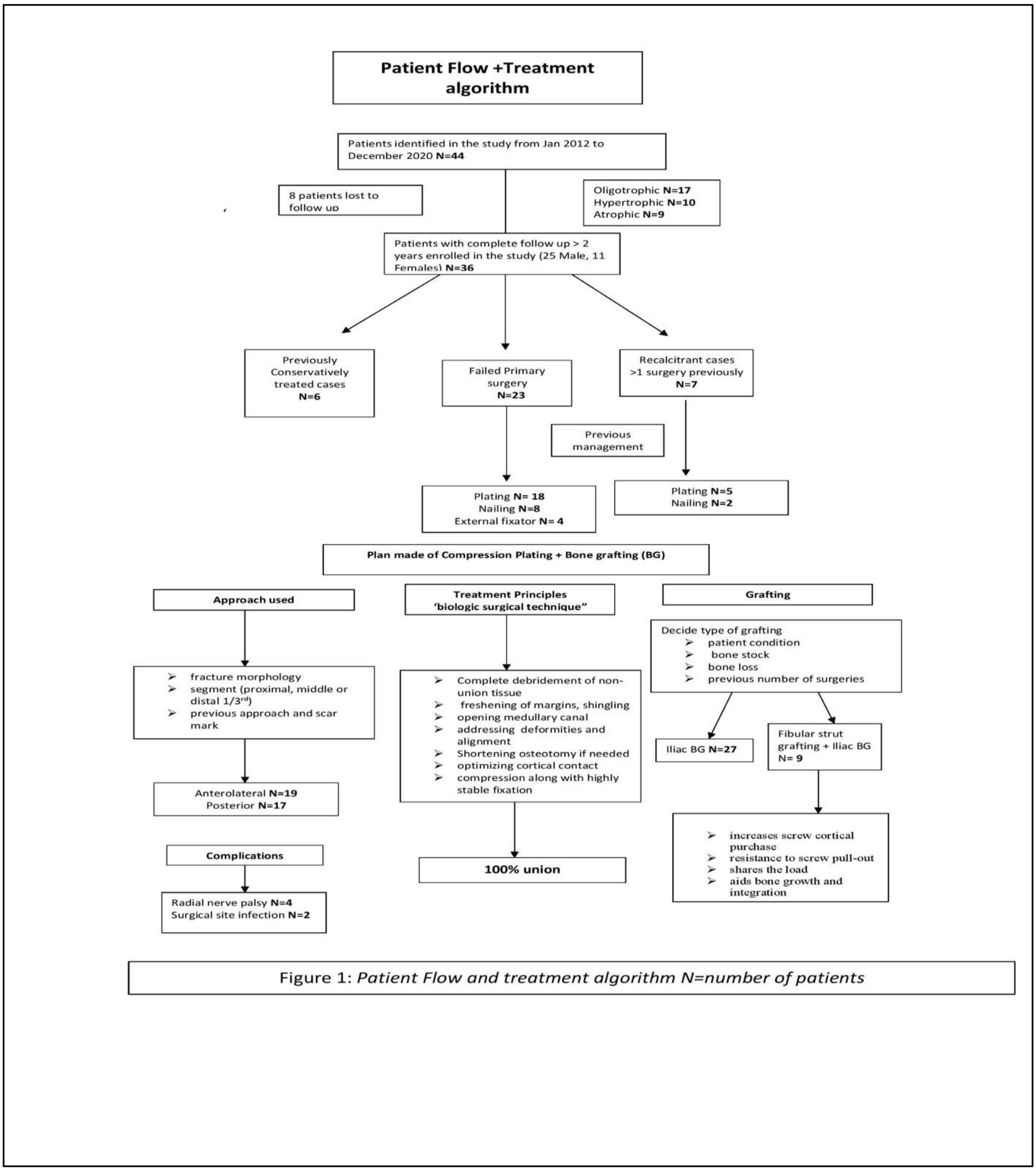

Figure 1: *Patient Flow and treatment algorithm N=number of patients*

Figure 1: Patient flow and treatment algorithm (n=number of patients).

Statistical analysis

Data were entered in Microsoft Excel and analysed. Categorical data were presented as frequencies and proportions. Continuous data were represented as means and standard deviations.

The Fisher's exact test was used to assess differences between qualitative variables, given the small sample sizes, and a p value<0.05 was considered statistically significant.

Data collection

Data were collected on the patients' age, sex, side of injury, type of nonunion, mechanism of primary injury, treatment history, total number of surgeries, time from injury to last surgery, surgical approach, graft used, co-morbidities, time from final surgery to radiological union, follow-up duration, union status, DASH Score at presentation and final follow-up, and complications were noted (Figure 1).

RESULTS

A total of 44 patients underwent surgery for humeral nonunions at our institute during the study period from January 2012 to December 2020.

Table 1: Patient demographics, fracture characteristics and surgical details (n=36).

Variables	Value
Number of patients	36
mean age (years)	44.2±10.9
Males/females ratio (%)	25/11 (69.4/30.6)
Atrophic non-union	9 (25%)
Oligotrophic non-union	17 (47.2%)
Hypertrophic non-union	10 (27.7%)
Underwent single surgical procedure before union (failed conservative treatment)	6 (16.7%)
Underwent 2 surgical procedure before union (failed primary surgery)	23 (63.8%)
Underwent 3 surgical procedure before union (recalcitrant)	7 (19.4%)
Mean time from injury to final surgery (months)	19.4±22.1
Cases operated anterolateral approach to humerus	19 (52.8%)
Cases operated by posterior approach to humerus	17 (47.2%)
Bone graft used- iliac crest only	27 (75%)
Bone graft used- iliac crest + fibula	09 (25%)

Table 2: Outcome parameters (n=36).

Outcome parameters	Value
Mean time from surgery to union (range)	6.25±1.57 months (4-12 months)
Overall union rate	100 %
Mean follow-up duration	74.8±32.2 months
Radial nerve palsy (post-injury)	4 (11.1%)
Radial nerve palsy (post-surgical intervention by authors)	4 (11.1%)
Superficial infections (post-surgical intervention by authors)	2 (5.5%)
Mean DASH score at presentation	76
Mean DASH score at final follow up	7

Eight patients were lost to follow-up, including one patient who expired after six months of surgery due to unrelated causes. 36 patients, including 25 males and 11 females, with a mean age of 44.2±10.9 years, were included in this study. The left arm was involved in 20 patients, and 16 patients had a nonunion in their right humerus. 9 (25%) of the patients had an associated co-morbidity, with hypertension and diabetes being most commonly associated in 5 (13.8 %) and 3 (8.3%) of the patients, respectively (Table 1).

Nonunion types and treatment history

The nonunion were classified into hypertrophic, oligotrophic, and atrophic types. The majority of the patients had oligotrophic nonunion (n=17, 47.2%), followed by hypertrophic (n=10, 27.7%) and atrophic nonunion (n=9, 25%) (Figure 2). The principal cause of injury was road traffic accidents (RTA) in most cases (n=28, 77.8%), followed by falls from height (n=5, 13.9%). There was one case each with a history of assault, machine cut injury, and animal bite, leading to the fractured limb. Most patients had a history of prior to surgical management, including the plating and nailing, resulting in nonunion (n=30, 83.3%) (Figure 2.) 7 patients (19.4%) had persistent nonunion following the second surgery with bone grafting and required a third revision, which finally led to union.

Surgical management and follow-up

We performed anterolateral plating in 19 (52.8%) cases, and posterior plating in 17 (47.2%) patients. All patients underwent open reduction and internal fixation with a locking plate, using a graft harvested from either the fibula or the iliac crest after removal of any previous implant. The average time from injury to the last surgery was 19 months. The average follow-up duration was 75 months. (Table 1) (Figure 1) (Figure 2-3). Bony union was achieved in all 36 patients at final follow-up, as confirmed by radiographic assessment. The Mean Disabilities of the Arm, Shoulder, and Hand (DASH) Score improved significantly from 76 at the presentation to 7 at the final follow-up. There was no pain or tenderness over the previous nonunion site and no pain with motion.

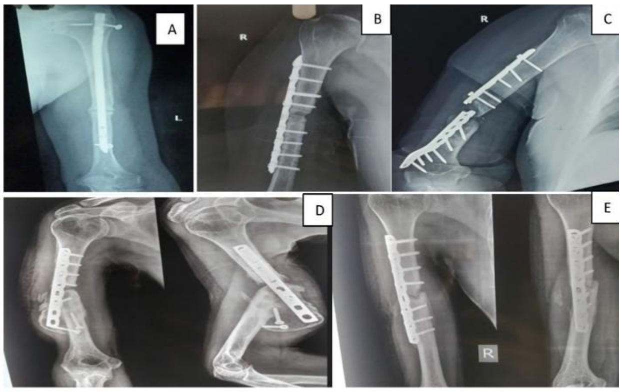

Figure 2: X-rays depicting different non-union cases: (A) X-ray depicting non-union in nail at 9 months, (B) X-ray showing no signs of union at 6 months, (C) broken implant after 5 months due to non -union, (D) broken implant after 4 months after gap non - union and (E) non-union at 6 months after reoperation with bone grafting and compression planting.

Of the 6 patients initially managed conservatively, union was achieved after a single surgery, and the remaining 30 patients underwent 1 or 2 additional surgical procedures after the index surgery. These 30 patients underwent multiple surgeries due to nonunion after primary surgery (using an external fixator/intramedullary nail/plate), persistent nonunion after a second nonunion surgery, or implant failure (Breakage), but all 30 subsequently achieved union.

The average time interval from final surgery to radiological union was 6.25 months (range 4-12 months). (Figure 3). 4 (11.1%) had a history of radial nerve palsy (RNP) immediately after index injury, but had a complete recovery by the time of the nonunion surgery. 4 (11.1%) developed an iatrogenic RNP following nonunion surgery in our institute. Complete recovery was seen within 6 months in all four patients.

There were 2 (5.5%) postoperative superficial surgical site infections (SSIs), which settled with a short course of antibiotics and aseptic dr. On comparing the cases based on prior management, they were divided into conservative, failed primary surgery, and recalcitrant cases with a history of prior failed nonunion surgery.

4/7 recalcitrant cases required iliac grafting along with fibula strut grafting in view of previous bone loss and poor bone quality. Among recalcitrant cases, time to union was higher, at a mean of 7.28 months, compared with failed primary management cases (Figure 4). The pre- and post-surgery DASH scores were also higher in recalcitrant cases than in cases with failed primary treatment.

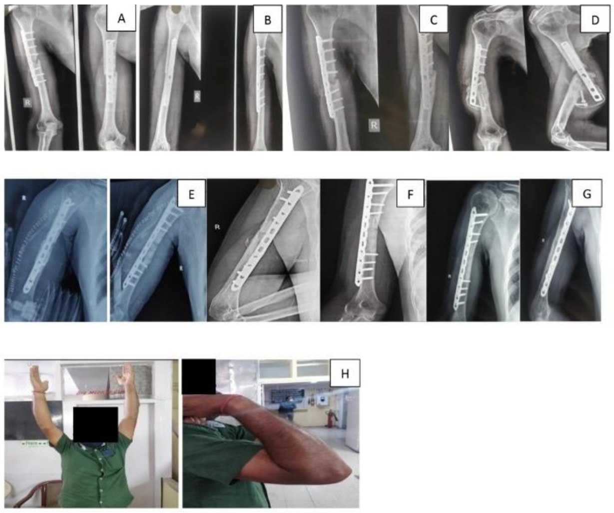

Figure 3: 33 male with implant failure managed compression plating and iliac bone grafting: (A) X-ray on day 14 of fixation of midshaft fracture humerus, (B) X-ray at 3 months depicting no callus, (C) X-ray at 6 months showing signs of non-union, (D) X-ray at 9 months showing implant failure, (E) immediate post- operative after compression plating and iliac bone grafting, (F) 3 months post operative depicting good radiological union, (G) 10 month X-ray showing union, and (H) 10 month follow up depicting good comparable functional outcome.

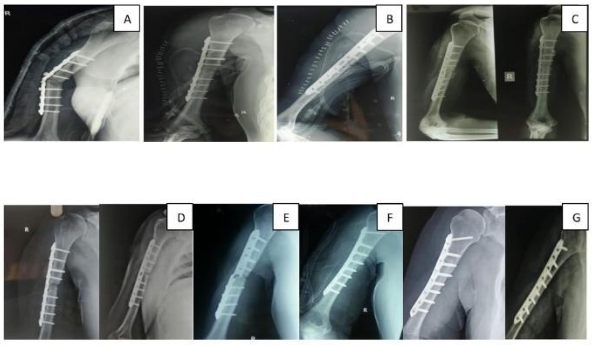

Figure 4: Recalcitrant case managed with compression plating with fibular strut grafting and iliac bone grafting: (A) X-ray showing implant failure of midshaft fracture humerus, (B) immediate post-operative X-ray after compression plating and iliac bone grafting, (C) X-ray at 1 month follow up, (D) X-ray at 3 months showing no signs of union, (E) X-ray at 4 months follow up depicting broken plate, (F) post operative day 1 after revision plating with fibular strut and iliac graft (G) 5 month X-ray showing adequate radiological union and (H) 11 month follow up depicting good outcome.

Table 3: Post-operative outcomes comparison based on previous management strategy.

Parameter	Conservatively managed cases	Non-union after failed primary surgery	Recalcitrant cases (failed non-union surgery)
Number of cases (n)	6	23	7
Previous fixation method– nailing	0	6	2
Previous fixation method – plating	0	13	5
Previous fixation method–ex-fix	0	4	0
Anterolateral surgical approach used by authors	3	12	4
Posterior surgical approach used by authors	3	11	3
BG used – iliac crest	6	18	3
BG used– iliac+fibula	0	5	4
Mean duration from surgery-to-union (months)	6.5	6.73	7.28
DASH score on presentation	75.0	75.08	79.85
DASH score (post-surgery performed by authors)	7.0	6.9	7.85
Post operative complications encountered-RNP	1	1	2

Abbreviations- RNP: Radial nerve palsy, EX-FIX: External fixator, BG: Bone grafting.

DISCUSSION

The management of non-union humeral shaft fractures poses a multifactorial challenge in orthopaedic surgery, specifically in zones with limited access to the latest advances in fracture care. Humeral shaft nonunions can cause significant morbidity from multiple operations, associated complications and functional disability. Currently, there is limited evidence-based consensus on the management of humeral shaft nonunions, and the treatment protocol is not clearly defined, as multiple modalities are available. A thorough preoperative evaluation is imperative to identify any metabolic or infectious factors that may have contributed to the nonunion.[4]

Therapeutic principles in non-union are emphasised by Giannoudis et al's "diamond concept," which aims to achieve mechanical stability through internal fixation, along with appropriate contributions of osteogenic mediators for effective vascularisation.[11] The strategy is to adhere to the principle of "biological surgical technique," preserving soft tissue attachments while maintaining mechanical stability. The gold-standard treatment is surgery, with thorough debridement of the nonunion site, rigid internal fixation with a locking plate, and augmentation with cancellous bone graft.[12] Although most patients achieve union with standard surgical intervention, some may require specialised techniques, such as cortical struts or vascularised fibular grafts. In this comprehensive study, we sought to illustrate the outcomes of 36 patients who underwent surgical intervention for humeral shaft non-union at our institution. We achieved a 100% union rate (all 36 patients) for aseptic non-union of humeral shaft of fractures. The mean time to the union was 6.25 months, slightly higher than reported in the literature. Our findings corroborate the 100 per cent union achieved by Babhulkar et al in 64 patients with locking plates and appropriate bone grafting over 120 weeks. Babhulkar et al used multiple treatment techniques, including compression plating, bridge plating, fibular grafting, and interfragmentary screw application with neutralisation plating.[12] However, we propose the use of compression plating along with or without fibular grafting to maintain a rigid and stable construct with more emphasis on recalcitrant cases.

A systematic review by Peters et al reported a 98% union rate in patients treated with plate fixation and autologous bone graft, concluding that the complication rate was relatively low at 12%.[4] Dheenadhayalan et al in their large case series on Consistent Protocol-Based Management of Humerus Shaft non-union, achieved complete union in 97% of patients and concluded that stable fixation with compression plating, supported by intramedullary cancellous autologous grafts, achieves a high union rate with minimal complications.[12,13-19] Our results correspond harmoniously with the existing scientific literature, which has consistently reported favourable outcomes associated with this treatment modality (Table 3). The key factor in achieving excellent results in this study is achieving cortex-to-cortex contact with adequate compression after excising the de-vascularised bone via osteotomy at both fracture ends. A transverse shortening osteotomy was done in the majority of cases as it maximises the surface area of contact between the two bone ends. Maintaining maximum length in nonunions is advisable; shortening after nonunion excision can be tolerated in the upper limb, as several studies have reported minimal functional impairment with up to 4 cm shortening.[21] It is worth noting that some researchers and medical practitioners have also advocated the use of locked intramedullary nailing as an alternative for the management of humeral shaft nonunions.[20-22] However, it's important to note that the adoption of intramedullary nails has been somewhat constrained by inherent limitations. These include excessive fluoroscopy during the procedure, increased surgical skill demands, postoperative complications such as persistent shoulder pain, and a substantial diminution in shoulder range of motion post-surgery.[23,24] Exchange nailing has been advocated by some authors for nonunion humeral fractures; however, healing rates range from 40% to 95.6%. This poor outcome may be due to a lack of cyclical loading along with higher distractive and torsional loads in the arm.[22]

Wiss et al reported that 16% of cases required revision nonunion surgery, with a strong correlation between recalcitrant cases and a history of prior plating as the initial procedure, infection, and more than one surgical procedure.[19] Konda et al also demonstrated that fracture plating was a positive predictor of a recalcitrant nonunion.[25] We had 7 recalcitrant nonunion cases, of which 5 had undergone plating, and 2 had undergone nailing as prior treatment. In our study, the 7 recalcitrant nonunions required longer union times, with a mean of 7.28 months, compared with 6.5-6.73 months in previously managed cases. Feng et al reported 100 per cent union in 15 consecutive aseptic recalcitrant cases over 6.4±1.8 months with double plating and autologous bone grafting, with complications ranging from radial and ulnar nerve palsy to superficial infection or discomfort over the iliac crest.[15] Two cases of radial nerve palsy which recovered over 6 weeks were reported in our recalcitrant cases. The authors reported the concept of dual plating in these cases to restore intact compressive and torsional stiffness of the humeral shaft.[15]

The majority of cases required fibula and iliac crest grafting due to increased bone loss and poor bone quality. The pre-operative and post-operative DASH scores were also comparatively higher than those of the previously managed cases. It is important to understand that recalcitrant cases may require more complex management, taking into account bone loss, skin condition, and the previously used approach, but 100% union can be achieved with adequate management. Mukhopadhaya et al. conducted a retrospective study spanning 12 years that included 132 patients with aseptic humeral shaft nonunion. The study reported improvement in Quick DASH scores from 77 to 5 on average, with an average union achieved at 21 weeks with minimal complications. Good results were achieved, as measured by the DASH score, with the average preoperative score improving from 76 to 7 at follow-up, confirming excellent functional outcomes.[26] A large case series analysis by Massin et al concluded that the lack of graft use is associated with a higher failure rate in the management of nonunion.[27] Surgery-associated complications are found to be rare; however, radial nerve palsy is the most common occurrence, which subsides spontaneously. Predictive factors for failure of spontaneous resolution include increased age and iatrogenic nerve injury during exploration, with an incidence of 7-8%, similar to that reported in a multicentre study by Koh et al following surgical management of such cases.[28] The incidence of postoperative radial nerve palsy in our case series was 11.1%, with 100% successful recovery within 6 months. The strengths of this study include a large sample size, a very long follow-up duration, and the evaluation of the outcome using functional scores in addition to radiographic assessment. Our surgical methodology achieved a high union rate, thus underlining the reproducibility of a consistent management strategy. The drawbacks include the absence of a control group and the single-centre design.

In essence, our study not only contributes to the broadening base of expertise surrounding the management of humerus shaft nonunions but also emphasises the importance of meticulously choosing and tailoring treatment approaches to the individual patient, factoring in their unique clinical presentation and the available resources within the healthcare setting, with special attention given to recalcitrant cases. It is important to note that the proposed treatment of complex humeral nonunion cases can be performed in any primary setting, provided the principles are followed, and may not require referral to a higher centre. Further prospective studies reporting the union and complication rates after operative treatment strategies for humeral shaft nonunion should provide clear guidance for future guidelines.

CONCLUSION

Our study strongly indicates that the approach involving open reduction and internal fixation with a locking plate, combined with judicious bone grafting, is a highly effective therapeutic strategy for treating humeral shaft nonunion. Stepwise, careful dissection, preservation of soft-tissue attachments, prevention of loss of blood supply to the osseous fragments, and complete resection of the nonunion and fibrous tissue by debridement are the stepping stones for a successful outcome. It is also important to understand that recalcitrant cases may require more time for union, but with adequate pre-operative planning, surgical technique and proper graft selection, 100% union and adequate functional outcome can be achieved.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee (DRB/Ortho/2023/48)

REFERENCES

1. Ekholm R, Adami J, Tidermark J, Hansson K, Törnkvist H, Ponzer S. Fractures of the shaft of the humerus. An epidemiological study of 401 fractures. J Bone Joint Surg Br. 2006;88(11):1469-73.

2. Peters RM, Claessen FM, Doornberg JN, Kolovich GP, Diercks RL, Van den Bekerom MP. Union rate after operative treatment of humeral shaft nonunion: a systematic review. Injury. 2015;46(12):2314-24.
3. Sarmiento A. Functional bracing of fractures of the shaft of the humerus. Orthop Trauma Dir. 2008;6(1):33.
4. King AR, Moran SL, Steinmann SP. Humeral nonunion. Hand Clin. 2007;23(4):449-63.
5. Singh AK, Arun GR, Narsaria N, Srivastava A. Treatment of nonunion of humerus diaphyseal fractures: a prospective study comparing interlocking nail and locking compression plate. Arch Orthop Trauma Surg. 2014;134(7):947-53.
6. Van Houwelingen AP, McKee MD. Treatment of osteopenic humeral shaft nonunion with compression plating, humeral cortical allograft struts, and bone grafting. J Orthop Trauma. 2005;19(1):36-42.
7. Hsu TL, Chiu FY, Chen CM, Chen TH. Treatment of nonunion of humeral shaft fracture with dynamic compression plate and cancellous bone graft. J Chin Med Assoc. 2005;68(2):73-6.
8. Sitati F, Kingori J. Outcome of management of humerus diaphysis nonunion. East Cent Afr J Surg. 2009;14(2):13-8.
9. Cadet ER, Yin B, Schulz B, Ahmad CS, Rosenwasser MP. Proximal humerus and humeral shaft nonunions. J Am Acad Orthop Surg. 2013;21(9):538-47.
10. Bernard de Dompsure R, Peter R, Hoffmeyer P. Uninfected nonunion of the humeral diaphysis: review of 21 patients treated with shingling, compression plate, and autologous bone graft. Orthop Traumatol Surg Res. 2010;96(2):139-46.
11. Giannoudis PV, Einhorn TA, Marsh D. Fracture healing: the diamond concept. Injury. 2007;38(4):S3-6.
12. Babhulkar S, Babhulkar S, Vasudev A. Recalcitrant aseptic atrophic nonunion of the shaft of the humerus after failure of surgical treatment: management by excision of nonunion, bone grafting and stabilization by LCP in different modes. Injury. 2017;48(2):S33-43.
13. Dheenadhayalan J, Vembanan K, Devendra A, Perumal R, Nagashree V, Kumar AH, et al. Consistent protocol-based management of humerus shaft nonunion: an analysis of 100 cases. Indian J Orthop. 2023;57(4):552-64.
14. Ozdemir G, Bingol O, Inci F, Ceyhan E, Karahan N, Deveci A. Treatment of the refractory atrophic humeral nonunion with autogenous block iliac crest graft and spongioplasty: a retrospective study. Acta Chir Orthop Traumatol Cech. 2022;89(3):208-12.
15. Feng D, Wang X, Sun L, Cai X, Zhang K, Wang Z, et al. Double plating with autogenous bone grafting as a salvage procedure for recalcitrant humeral shaft nonunion. BMC Musculoskelet Disord. 2020;21(1):769.
16. Pollon T, Reina N, Delclaux S, Bonnevialle P, Mansat P, Bonnevialle N. Persistent nonunion of the humeral shaft treated by plating and autologous bone grafting. Int Orthop. 2017;41(2):367-73.
17. Rollo G, Prkić A, Pichierri P, Eygendaal D, Bisaccia M, Filipponi M, et al. Plate-and-bone-strut fixation of distal third humeral shaft aseptic nonunions: a consecutive case series. J Clin Orthop Trauma. 2019;10(1):S127-32.
18. Zalavras CG, Yasmeh S, Bougioukli S. Surgical management of humeral shaft nonunions: success of a consistent protocol over 17 years. Injury. 2021;52(12):3580-7.
19. Wiss DA, Garlich JM. Healing the index humeral shaft nonunion: risk factors for the development of a recalcitrant nonunion in 125 patients. J Bone Joint Surg Am. 2020;102(5):375-80.
20. Kontakis GM, Papadokostakis GM, Alpantaki K, Chlouverakis G, Hadjipavlou AG, Giannoudis PV. Intramedullary nailing for nonunion of the humeral diaphysis: a review. Injury. 2006;37(10):953-60.
21. Kusnezov N, Dunn JC, Stewart J, Mitchell JS, Pirela-Cruz M. Acute limb shortening for major near and complete upper extremity amputations with associated neurovascular injury: a review of the literature. Orthop Surg. 2015;7(4):306-16.
22. Lin J, Chiang H, Hou SM. Open exchange locked nailing in humeral nonunions after intramedullary nailing. Clin Orthop Relat Res. 2003;(411):260-8.
23. Crolla R, De Vries L, Clevers G. Locked intramedullary nailing of humeral fractures. Injury 1993;24(6):403.
24. Lin J, Hou SM, Hang YS, Chao EY. Treatment of humeral shaft fractures by retrograde locked nailing. Clin Orthop Relat Res. 1997;(342):147-55.
25. Konda SR, Davidovitch RI, Egol KA. Initial surgical treatment of humeral shaft fracture predicts difficulty healing when humeral shaft nonunion occurs. HSS J. 2016;12(1):13-7.
26. Mukhopadhaya J, Bhadani JS, Ranjan R, Kushwaha SR. Operative management of aseptic humeral shaft nonunion: a retrospective study from Eastern India. Indian J Orthop. 2024;58(12):1793-805.
27. Massin V, Laumonerie P, Bonnevialle N, Le Baron M, Ollivier M, Flecher X, et al. What treatment for humeral shaft nonunion? Case-series assessment of a strategy. Orthop Traumatol Surg Res. 2023;109(5):103532.
28. Koh J, Tornetta P, Walker B, Jones C, Sharma T, Sems S, et al. What is the real rate of radial nerve injury after humeral nonunion surgery?. J Orthop Trauma. 2020;34(8):441-6.

Cite this article as: Aggarwal S, Hooda A, Negi D, Mander H, Dhillon M, Dhillon MS. Reconstruction of aseptic humerus non-union with compression plating and cortico-cancellous bone grafting. Int J Res Orthop 2026;12:994-1001.