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Aseptic Humeral Shaft Nonunion Treated with Plate Fixation and Bone Grafting: A Retrospective Study of 50 Cases

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Abstract **Original Research Article**

Background: Aseptic nonunion is a challenging complication of humeral shaft fractures, with reported rates ranging from 1% to 10% depending on the initial treatment method. Surgical management aims to restore stability and promote biological healing. ***Objective:*** To analyze the epidemiological, clinical, radiological, therapeutic, and functional outcomes of aseptic humeral shaft nonunion treated with plate fixation and bone grafting. ***Methods:*** We conducted a retrospective single-center study including 50 patients treated surgically for aseptic humeral shaft nonunion between February 2011 and February 2021. All patients underwent plate osteosynthesis combined with autologous bone grafting. Clinical, radiological, and functional outcomes were evaluated. ***Results:*** The prevalence of aseptic nonunion was 11.9%. The mean patient age was 42 years. Road traffic accidents were the most common cause of injury. Union was achieved in all patients, after the initial procedure in 48 cases and after revision surgery in two cases. The mean time to union was 5 months. Functional outcomes were excellent or good in most patients. Complications were limited to transient radial nerve palsy and minor donor-site morbidity. ***Conclusion:*** Plate fixation combined with autologous bone grafting remains a reliable and effective treatment for aseptic humeral shaft nonunion, providing a high union rate and satisfactory functional outcomes.

Keywords: humerus, non-union, Bone graft, Morocco.

INTRODUCTION

Aseptic nonunion is one of the most frequent late complications of humeral shaft fractures [1-2]. It is defined as a definitive absence of union after a period of six months and can be secondary to all treatment methods. The treatment of aseptic nonunion of the humerus is inspired by the surgical treatment of fresh fractures. Thus, three forms of osteosynthesis are currently practiced, each with its own specificities and complications: the screwed plate, which is the subject of our study, the locked intramedullary nail, and the external fixator. These proposed treatments will tend to block the torsion and distraction forces that are mainly exerted [2,3]. This surgical stabilization should be associated with compression of the site and stimulation of osteogenesis by bone grafting and/or osteomuscular decortication according to Judet *et al* [2,4]. In this retrospective monocentric study, we aim to analyze the etiologies of aseptic nonunion of the humeral shaft and emphasize the results of their treatment with screwed plate associated with bone graft (technique adopted in our department), comparing through a literature review the results of the different treatment methods.

PATIENTS AND METHODS

This retrospective single-center study included 50 patients who underwent surgical treatment for aseptic humeral shaft nonunion between 2011 and 2021. Inclusion criteria comprised patients older than 15 years presenting with aseptic nonunion following a humeral shaft fracture. Patients with septic nonunion, metaphyseal or metaphyseal–epiphyseal nonunion, and nonunion secondary to pathological fractures were excluded.

Preoperative clinical evaluation included pain assessment using an analogue scale, assessment of abnormal mobility at the nonunion site, and neurological examination of the radial nerve. Shoulder and elbow range of motion were recorded bilaterally, and functional impairment was quantified by comparing the angular deficit of the affected limb with that of the contralateral side.

Initial fractures were classified according to the AO classification system. Standard radiographs were reviewed to assess fracture characteristics, nonunion location, nonunion type, and previous treatment modality. Delayed union was defined as the absence of radiographic progression toward healing between three and six months after fracture treatment, whereas nonunion was defined as the absence of bone healing beyond six months. Radiographic analysis also focused on identifying technical errors and other factors potentially contributing to the development of nonunion.

Surgical treatment was indicated in patients presenting with persistent clinical symptoms, including pain and/or abnormal motion at the fracture site, associated with radiographic evidence of failed bone healing. All patients were treated using compression plate osteosynthesis combined with autologous bone grafting.

Patients were positioned supine, allowing simultaneous access to the affected upper limb and the ipsilateral iliac crest. An anterolateral approach was used in all cases. In previously operated patients, existing hardware was removed after identification and neurolysis of the radial nerve. The nonunion site was then exposed and debrided, with complete excision of fibrous tissue and reopening of the medullary canal. Systematic bacteriological samples were obtained intraoperatively. Limited bone resection and shortening were performed when necessary to remove nonviable bone and correct associated deformities.

Fixation was achieved using an anterolateral dynamic compression plate (DCP) applied under direct compression of the nonunion site. Whenever possible, fixation included a minimum of four screws on each side of the lesion. Autologous cancellous bone graft harvested from the anterior iliac crest was subsequently placed around the nonunion site to enhance biological healing.

Postoperatively, the arm was immobilized in a sling with the elbow secured to the body for 45 days. Antibiotic prophylaxis was administered for 24–48 hours. A structured rehabilitation program was initiated in all patients.

Patients were reviewed regularly for clinical and radiographic follow-up. Clinical assessment included pain evaluation, shoulder and elbow mobility, neurological status, and donor-site morbidity related to iliac crest harvesting.

Treatment outcomes were assessed according to the Stewart and Hundley criteria (Table 1), as reported by Martinez *et al.,*[5]. These criteria incorporate pain, elbow mobility, alignment, and bone union. Although initially developed for humeral shaft fractures, they have been widely extrapolated to the evaluation of humeral shaft nonunion.

Figure 1: Per-operative photo of the final assembly

RESULTS

During the study period (February 2011 to February 2021), a total of 420 humeral shaft fractures were managed in our department. Among these patients, 50 developed aseptic nonunion, corresponding to a prevalence of 11.9%, with an average incidence of three to four cases per year.

At the time of diagnosis, the study population consisted of 30 men and 20 women, with a mean age of 42 years (range, 28–69 years). Nonunion involved the left side in 32 patients and the right side in 18 patients. The dominant limb was affected in 34 cases. Regarding occupational status, 10 patients performed manual labor, 30 had non-manual occupations, and 10 were unemployed or without professional activity.

Road traffic accidents represented the leading cause of the initial fracture, accounting for 50% of cases, followed by falls and occupational injuries, each representing 25% of cases.

At presentation, the mean pain intensity was 7/10 (range, 5–10) on the visual analogue scale. Radial nerve palsy was present in five patients at the time of nonunion diagnosis. The mean elbow flexion was 100° (range, 60°–140°), with a mean extension deficit of 10°. Average forearm pronation and supination were 60° and 50°, respectively. Mean active shoulder forward elevation was 110° (range, 80°–150°).

According to the AO classification of humeral shaft fractures [6], the initial fracture pattern consisted of ten type A1 (spiral) fractures, thirteen type A2 (oblique) fractures, seventeen type A3 (transverse) fractures, seven type B1 (spiral wedge) fractures, and three type C3 (complex comminuted) fractures.

The presence of an open fracture at the time of injury is recognized as a potential prognostic factor. In our series, thirteen patients sustained an associated open fracture, including six classified as Gustilo-Anderson type I.

Table 1: Stewart and Hundley score

Score	Pain	Limitation of shoulder and elbow mobility	Angulation
Very good or excellent	No pain	Normal mobility	Good alignment
Good	No pain or pain when changing weather	Stiffness < 20°	< 10°
Average or fair	Pain with exertion or fatigue	Stiffness between 20 and 40°	> 10°
Bad	Permanent pain	Stiffness > 40°	nonunion

Analysis of nonunion location revealed 31 cases involving the middle third of the humeral shaft, 11 involving the proximal third, and 8 involving the distal third. According to the biological classification of nonunion, 12 cases were classified as eutrophic, 29 as atrophic, and 9 as hypertrophic.

Initial fracture management consisted of conservative treatment in nine patients, intramedullary nailing in fourteen, plate osteosynthesis in twenty, and external fixation in seven. Technical shortcomings potentially contributing to nonunion were identified in ten cases. These included five cases in which a screw was positioned within the fracture site, two cases with an insufficient number of bicortical screws, and three intramedullary nail fixations without distal locking, resulting in persistent distraction at the fracture site.

The mean interval between the initial fracture treatment and surgical management of nonunion was seven months (range, 4–24 months). Six patients underwent surgery before the conventional six-month threshold generally used to define established nonunion.

Following an anterolateral approach to the humerus, systematic bacteriological samples were obtained and were negative in all cases. After identification and protection of the radial nerve, the nonunion site was refreshed and stabilized using plate osteosynthesis. Treatment consisted of plate fixation associated with corticocancellous iliac crest bone grafting in eleven patients (22%), osteomuscular decortication alone in eight patients (16%), and a combination of both techniques in thirty one patients (62%).

Procedure-related complications were limited. Three postoperative hematomas were observed and resolved with local treatment. Five patients developed transient radial nerve palsy, with complete spontaneous recovery occurring within four to six weeks. No cases of deep infection, implant-related sepsis, or deltoid and arm muscle atrophy were recorded. Morbidity at the iliac crest donor site was minimal and consisted of mild pain in two patients, not requiring analgesic treatment, and one aesthetically unsatisfactory scar.

At final follow-up (Fig. 2A-B), mean elbow flexion improved to 110° (range, 80°–140°), compared with the preoperative assessment. The mean extension deficit was 15°, while average forearm pronation and supination were 70° and 50°, respectively. Mean active shoulder elevation improved to 120° (range, 80°–170°). Overall, postoperative functional evaluation demonstrated a clear improvement in upper-limb mobility compared with the preoperative status.

Radiographic assessment on anteroposterior and lateral views (Fig. 3) demonstrated two residual malunions that were clinically asymptomatic and did not result in functional impairment. One patient presented a 10° varus deformity, while another exhibited a 10° recurvatum deformity.

Figure 2a: Functional result: shoulder elevation, elbow flexion and extension

Figure 2b: Good functional evolution after a 24-month follow-up

Figure 3: Nonunion on plate treated with longer plate + GCS

All patients achieved bone union within a mean period of 5 months (range, 3–7 months). Union was defined by the absence of pain at the nonunion site and radiographic evidence of bone healing. Among the 50 patients, union was achieved within the first 3 months in 13 cases, between 3 and 6 months in 22 cases, between 6 and 9 months in 14 cases, and after 9 months in one case.

Analysis according to nonunion location demonstrated a longer time to union for lesions involving the middle third of the humeral shaft (Table 2). Furthermore, union appeared to be achieved more readily in patients treated earlier and in cases of hypertrophic nonunion (Table 2).

No patient required further surgical intervention after definitive union had been achieved. Intraoperative bacteriological cultures were negative in all cases. Therefore, only prophylactic antibiotic therapy was administered for 24 to 48 hours postoperatively.

Functional outcomes may be evaluated using several scoring systems, including the Stewart and Hundley classification, the criteria proposed by Chaix and Ray, and the Western Orthopaedic Society (SOO) score. In the present study, functional outcomes were assessed primarily according to the Stewart and Hundley classification.

Among the 50 patients included in the study, the 48 patients who achieved union after a single surgical procedure had predominantly very good functional outcomes. The two patients who required revision surgery before achieving union were classified as having fair functional results.

Overall, functional outcomes were rated as excellent in 18 patients (Figs. 1 and 2), good in 29 patients, and fair in 3 patients.

Table 2: Average time to consolidation according to the treatment site and type of nonunion

Consolidation factors	Number of cases	Average consolidation time
Seat		
1/3 upper	11	4 months
1/3 medium	31	5 months
1/3 lower	8	5 months
Anatomopathological type		
Hypertrophic non-union	9	3 months
Eutrophic non-union Atrophic non-union.	12 29	4 months 5 months

Discussion

The incidence of aseptic humeral shaft nonunion reported in the literature ranges from 1% to 10%, depending on the initial treatment modality [7–11]. Humeral shaft nonunion differs from nonunion affecting the lower limbs because the predominant mechanical forces acting on the humerus are rotational and distractive rather than compressive [2,12,13]. Consequently, successful treatment relies primarily on achieving adequate rotational stability, as failure to control these forces may compromise fracture healing and lead to nonunion.

Several factors have been identified as contributing to the development of humeral shaft nonunion. Patient-related risk factors, including obesity, smoking, alcoholism, and osteoporosis, are well recognized and have been consistently reported in the literature [10,14–16]. The influence of fracture location remains controversial. While several authors have identified the middle third of the humerus as the most frequent site of nonunion [12,13,17], others have reported a predominance at the proximal–middle third junction [16,18], the distal third [19], or the proximal third [14]. In the present study, nonunion occurred most frequently in the middle third of the humeral shaft. This finding may be explained by the vascular anatomy of the humerus, as the principal nutrient artery enters the bone at the level of the middle third along its medial aspect [20]. Injury at this location may compromise vascular supply and adversely affect bone healing.

Fracture morphology also appears to influence the risk of nonunion. Transverse and short oblique fractures are generally considered particularly susceptible because of their limited bone contact surface and reduced biological healing potential. Comminuted fractures represent another recognized risk factor due to devascularization of intermediate fragments and disruption of the local biological environment [21]. Although open fractures have also been implicated, their frequent association with severe comminution makes it difficult to determine their independent role in the development of nonunion.

Technical errors during initial fracture management constitute another major cause of nonunion. Persistent distraction at the fracture site, inadequate implant selection, insufficient fixation, or suboptimal surgical technique may all compromise bone healing [2,10,12,16]. In our series, technical shortcomings were identified in ten patients, supporting the findings of previous studies that emphasized their contribution to treatment failure.

Several surgical options have been proposed for the management of humeral shaft nonunion. Locked intramedullary nailing has been advocated by some authors because it allows treatment without extensive exposure of the nonunion site, thereby preserving periosteal vascularity and reducing the risk of infection and radial nerve injury [22,23]. However, other studies have reported less favorable outcomes, with failure rates ranging from 40% to 60%, mainly attributed to inadequate rotational stability and disruption of the endosteal blood supply [13,23–25]. Additional complications include locking failure and postoperative rotator cuff symptoms, reported in up to 40% of cases [13]. Consequently, several authors recommend intramedullary nailing only in selected cases of hypertrophic nonunion involving the proximal third of the humeral shaft [13,25–27].

External fixation, particularly using the Ilizarov technique, has traditionally been reserved for septic nonunion but has also been advocated by some authors for aseptic cases [16,28–31]. Its main advantages include preservation of the biological environment, avoidance of extensive surgical exposure, and the ability to provide progressive compression and stable fixation [11,16,29–32]. Nevertheless, this technique is associated with several drawbacks, including pin-tract infection, nerve injury, elbow stiffness, secondary fractures after frame removal, and prolonged treatment duration [16,30,32]. Although union rates are generally comparable to those reported with plate fixation, patients often require external fixation for prolonged periods, averaging approximately six months (Table 4).

Table 3: Results of locked intramedullary nailing series

Authors	Number of cases	Consolidation (%) After the first recovery	Deadline (months)
Loomer and Kokan, [36]	6	100	4
Fattah *et al*., [25]	6	33	5
Pietu *et al*., [22]	5	100	3.5
McKee *et al*., [13]	10	40	4.5
Salanne and Aribit , [17]	11	54.5	6
Dujardin *et al*., [24]	13	60	5
Our series (PV)	50	100	5

Table 4: Results of external fixator series

Authors	Number of cases	Consolidation (%) After the first recovery	Deadline (months)
Lammens *et al*., [16]	24	96	4.5
Raschke *et al*., [11]	1	100	4
Patel *et al*., [32]	6	83	6
Micic *et al*., [29]	11	90.3	3.6
El- Rosasy , [28]	18	100	4.2
Our series (PV)	50	100	5

Plate fixation combined with autologous bone grafting remains the most widely used and extensively documented technique for the treatment of humeral shaft nonunion. This approach offers the advantage of providing both optimal mechanical stability and biological stimulation of bone healing within a single procedure. Compression plate osteosynthesis ensures rigid fixation and allows direct compression across the nonunion site [3,33]. Furthermore, surgical exposure facilitates thorough debridement of fibrous tissue, reopening of the medullary canal, and collection of bacteriological samples when required.

The role of bone grafting appears to be crucial in achieving successful union. Gérard *et al.,*and Healy *et al.,*reported failure rates of 36% and 45%, respectively, when plate fixation was performed without associated bone grafting [10,12]. These outcomes are comparable to those reported with intramedullary nailing and emphasize the importance of biological augmentation in the treatment of nonunion [27]. Several authors have also demonstrated that union can occasionally be achieved through bone grafting alone without modification of the existing fixation construct [10,12,34]. Consequently, most authors advocate the routine use of bone grafting when treating humeral shaft nonunion with plate osteosynthesis [10,13,21,25,34–39].

Nevertheless, some authors have suggested that osteomuscular decortication may provide sufficient biological stimulation and could therefore represent an alternative to bone grafting, particularly in view of the potential donor-site morbidity associated with graft harvesting [2,4]. Despite its effectiveness, the combination of plate fixation and bone grafting is not without complications, most notably infection and radial nerve injury.

In the present series, no cases of infection were observed. Similar findings have been reported by Loomer and Kokan [36], Rosen [21], and Müller and Thomas [3], whereas Fattah *et al.,*[25] reported a 4% infection rate and Zinghi *et al.,*[35] reported six cases of infection, corresponding to an incidence of approximately 4%. Concerning neurological complications, we observed five cases of transient radial nerve palsy (10%), all of which resolved spontaneously. These results are comparable to those reported in the literature, with rates of 6% reported by Loomer and Kokan [36], 4% by Fattah *et al.,*[25], and 4% by Barquet *et al.,*[40], whereas Healy *et al.,*[10] described one case of permanent radial nerve palsy (4%) (Table 5).

Meticulous surgical technique remains essential to minimize these complications. In particular, anterior plate placement may reduce the risk of direct contact with the radial nerve. Implant removal after union is rarely discussed in the literature. In our series, no patient required hardware removal because the implants remained asymptomatic through out follow-up.

Published union rates following plate fixation and bone grafting generally approach 95%, exceeding those reported for intramedullary nailing and remaining comparable to those achieved with external fixation [30]. Our findings are consistent with these observations, with an overall union rate of 100%, where as previously reported rates range from 91% to 100%. Based on both our results and the available literature, plate fixation combined with autologous bone grafting remains one of the most reliable and effective treatment options for aseptic humeral shaft non union.

Table 5: Results compared with screwed plate series

Authors	**Number of cases**	**Consolidation (%) After the first recovery**	**Deadline (months)**	**Sepsis**	**Radial paralysis**
Loomer and Kokan, [36]	20	90	3	1	2(resolutives)
Müller and Thomas, 1979 [3]	12	100	4	0	0
Fattah *et al.*, [25]	19	100	4	1	2(resolutives)
Healy *et al.*, [10]	26	92	5.5	0	1 definitive
Rosen, [21]	32	97	6	0	0
McKee *et al.*, [13]	9	100	4	1	0
Our series	50	100	5	0	5(resolutives)

Conclusion

Aseptic humeral shaft nonunion remains a challenging complication of fracture management. Its occurrence is multifactorial and may be influenced by patient-related factors, fracture characteristics, and technical aspects of the initial treatment. In our series, the middle third of the humeral shaft was the most frequently affected location, and technical errors were identified as an important contributing factor in several cases.

Although various surgical options have been described, our results support the use of compression plate fixation combined with autologous bone grafting as a reliable and effective treatment strategy. This technique provides both mechanical stability and biological enhancement of bone healing, resulting in a high union rate and satisfactory functional outcomes.

Nevertheless, prevention remains the best treatment. Careful initial fracture management, appropriate implant selection, and meticulous surgical technique are essential to minimize the risk of nonunion and optimize clinical outcomes.

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