Persistent non-union of the humeral shaft treated by plating and autologous bone grafting

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Abstract

Introduction Surgical treatment of persistent non-union of the humeral shaft is a complex situation because of the risk of failure and surgery-related complications. The primary objective of this study was to evaluate clinical and radiological results of a continuous series of persistent non-union treated with plating and bone grafting. The secondary objective was to expose factors contributing to the failure of prior bone union attempts.

Material and Methods Sixteen patients (average age of 52 years) were treated for persistent non-union of the humeral shaft in our department; six of these patients had predisposing comorbidities or addictions. The persistent non-union was treated by plating with autologous bone graft from the iliac crest in a single-stage procedure in 12 cases and a two-stage procedure in three cases; one case was treated with plating and vascularized fibula graft.

Results At a minimum follow-up of 12 months (average 78 months), four (25 %) failed to heal. The 12 other patients had bone union after an average of eight months. The average QuickDASH score was 48 points (18–72). A retrospective analysis of the prior attempts to treat the non-union revealed three cases of unstable fixation, four cases with no osteogenic supply and seven cases of positive microbiological cultures at the non-union site.

Conclusion Plating and autologous bone grafting resulted in union in only 75 % of persistent non-union of the humeral shaft. The persistent nature of the humeral shaft non-union could be attributed to deviating from validated rules for surgical treatment and/or the presence of a surgical site infection.

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Keywords Humeral shaft · Fracture · Non-union · Plating · Bone graft

Introduction

The combination of rigid plate fixation and iliac crest autograft results in a high success rate for aseptic non-union of the humeral shaft when no large defects are present [3, 4, 9, 12, 15, 17, 18, 20, 21, 32, 34–36]. The inherent biomechanics of the humeral shaft can explain why intramedullary (IM) nailing is not as successful as in the lower limb [1, 2, 7, 13, 19, 28, 34]. Persistent non-union can be defined as known failure of at least one surgical attempt at bone union in a confirmed case of non-union. As previously reported, different options can be proposed to reach union in this challenging situation [5, 6, 24, 25, 29].

We hypothesized that the combination of plating and autologous bone grafting would lead to union of a persistent non-union of the humeral shaft. The primary objective was to evaluate the clinical and radiological results of a series of persistent non-union cases. The secondary objective was to expose potential factors contributing to the failure of prior attempts at bone union during each step of the treatment process.

Material and methods

Study design

This was a retrospective, single-centre, continuous study. The following inclusion criteria were used: (1) failure of at least one surgical treatment of a confirmed non-union, (2) minimum of 12 months of radiological and clinical follow-up after treatment performed in our surgery unit. Non-union following periprosthetic fracture around an elbow or shoulder implant,

and pathological fractures due to primary or secondary lesions were excluded. Between January 1998 and March 2014, 79 patients with non-union of the humeral shaft were treated surgically. Sixteen of these patients were enrolled for the study based on the above criteria; eight had initially been treated for the non-union in our level 1 trauma unit and eight were referred to us by another centre.

Patient characteristics

There were ten women and six men with an average age of 52 years (29–85) (Table 1). Six patients were smokers, one patient was an intravenous drug addict, and one was an alcoholic. The initial fracture was caused by low-energy trauma in eight cases (fall at home) and by high-energy trauma in the eight other cases. Three fractures were open and three had neurological deficits. The first attempt at treating the non-union was made an average of 14.9 months (4–84) after the fracture was treated initially. During this first attempt at treating the non-union, microbiological samples were taken and three were positive: one for *Staphylococcus epidermidis*, another for *Propionibacterium acnes*, and the last for *Staphylococcus aureus*. These three patients were given appropriate antibiotics. Three patients (No. 6, 7, 9) had undergone at least two attempts at treating the non-union by another surgical team before being referred to our unit.

Surgical treatment

The 16 cases of persistent non-union were treated an average of 17 months (6–48) after the first failed attempt (Table II). The surgical treatment performed consisted of standard lateral plate fixation combined with iliac crest cortico-cancellous bone autograft in 15 cases and vascularized fibula in one case. Deep microbiological samples were taken intra-operatively in all patients; seven of them were positive (47 %). A two-stage procedure was used in three patients: removal of previous fixation hardware, cement spacer according to Masquelet technique [22], and then humerus stabilization with external fixation in two patients and a brace in one patient (Patients No. 4, 7, 10). After appropriate antibiotics therapy, the final fixation was added at three, five, and 18 months, respectively. In one patient (Patient No. 4), the microbiological samples collected during the second procedure were still positive.

Clinical and radiological evaluation

All patients were reviewed for this study: the overall clinical outcomes were evaluated based on the QuickDASH, including an assessment of arm pain and function [23]. Bone union was confirmed when the medial cortex was continuous on the A/P view and at least one bone bridge was present in front of or behind the plate on the lateral view.

Table 1 Epidemiological characteristics of the 16 patients with persistent nonunion of the humeral shaft from the initial fracture treatment to the first attempt to resolve the nonunion

Patient	Gender	Age (Years)	AO type	Circumstances	Associated lesions	Initial fracture treatment	Number of non union treatment	Non union treatment	Microbiology
1	M	31	A3	Car accident	radial nerve palsy	K wires	1	Nail	
2	F	32	A3	Fall from window	open fracture	K wires	1	Plate	Sterile
3	M	29	B3	Motorcycle accident	plexus palsy	K wires	1	Nail	
4	M	30	A3	Car accident		Nail	1	Plate + BG	
5	F	55	B2	Fall		K wires	1	Plate + BG	P. acnes
6	M	33	A2	Fall		Plate	2	(1) K wires; (2) Plate	
7	F	60	C2	Fall		Plate	3	(1) Plate; 2) Plate;(3) Dual Plates	Sterile
8	F	79	B1	Fall		K wires	1	Plate + BG	S. epidermidis
9	M	32	B2	Car accident		K wires	2	Plate + BG	Sterile
10	M	35	A3	Car accident	open fracture	K wires	1	K wires	
11	M	33	A3	Crushed by train	open fracture	Plate	1	Plate + BG	Sterile
12	F	78	A1	Fall		K wires	1	Plate	
13	F	70	A1	Fall		K wires	1	Plate	
14	F	67	A3	Fall		K wires	1	Plate + BG	S. aureus
15	F	83	A1	Fall		K wires	1	Nail	
16	F	85	B3	Car accident	radial and median nerve palsy	K wires	1	Plate + BG	

BG autologous bone graft

Statistical analysis

Statistical analysis was performed with the SAS software (SAS Institute, Cary, North Carolina). Quantitative variables were described by their average, maximum, and minimum values. The distribution of the data was analyzed with the Agostino-Pearson test. Means were compared in the different groups of patients; unpaired results were compared with the Mann–Whitney test. Relations between two qualitative variables were tested with the Fisher's exact test. The significance level was set at 0.05.

Results

Short-term results were available for all patients: there were no complications, including neurological ones, after surgical treatment. With an average follow-up of 78 months (12–160), 12 of the patients achieved bone union in an average of eight months (5–13) (Fig. 1). Two patients (No. 12, 15) died at six and five years after the surgical treatment for reasons unrelated to the procedure; bone union had been achieved at six and 12 months, respectively. The average QuickDASH score was 48 points (18–72) (Table 2).

Among the four patients (25 %) with failure of union, patient No. 5 was re-operated at another hospital and underwent bone resection and massive reconstruction with shoulder hemiarthroplasty. Patient No. 9 was not re-operated because a mental handicap made it difficult for him to follow postoperative instructions. Patients No. 6 and 10 were lost to follow-up during their failed treatment: one was homeless and the other was incarcerated. Only five of the seven patients with positive microbiological test results were treated with antibiotics; in two of these patients, one intraoperative sample was found to be positive, but it was considered cross-contaminated (Table 3).

A comparison of patients who failed the non-union treatment and those who achieved union revealed only the following statistically significant factors: first non-union treatment performed at non level 1 trauma unit hospital ($p = 0.04$; *Fisher's exact test*), length of time between the initial fracture and first attempt to treat the non-union (33 months for failed cases versus 8 months; $p = 0.003$; *Mann–Whitney test*).

Discussion

Our hypothesis was only partially confirmed, since only 12 of the 16 patients with persistent non-union achieved union. Among the four patients for whom the treatment failed, two had comorbidities that interfered with bone union (smoking, drug addiction) and one had an intellectual disability that made him non-compliant; a surgical site infection was present in three of these four cases. During the persistent non-union treatment, microbiological samples from the surgical site were positive in seven of 15 cases. This is the second learning point from this study: infection often results in very slow healing.

Of the 79 patients treated for non-union of the humeral shaft in the past 20 years at our hospital, 16 (20 %) had persistent non-union. This rate is higher than in published studies, partly

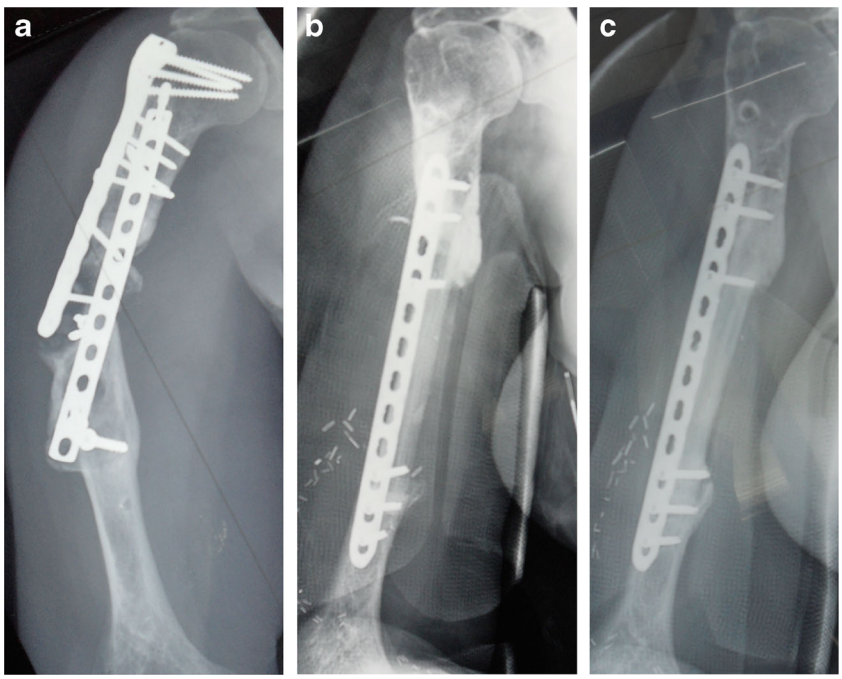

Fig. 1 Two successive failures of bone union by plating without bone addition (**a**). Removal of both plates; addition of vascularized fibula graft (**b**). Union visible on the A/P view (**c**) and lateral view (**d**) at 5 years' follow up

Table 2 Anatomical and radiological characteristics of 16 patients with persistent nonunion of the humeral shaft

Patient	Bone defect (cm)	Microbiology	Follow up (years)	Radiological result	QuickDASH (points)
1	0	Sterile	13	Union	38
2	0	Sterile	6	Union	41
3	0	Sterile	10	Union	38
4[a]	3	*P. aeruginosa*	5	Union	63
5	0	*S. epidermidis*	2	Not healed	72
6	0	Sterile	1	Not healed	
7[a]	8	*S. plurianimalium*	5	Union	42
8	0	*S. epidermidis*	12	Union	50
9	0	*S. capitis*	2	Not healed	34
10[a]	1	*MSSA*	1	Not healed	
11	0	*S. capitis, P. acnes*	6	Union	18
12	0	Sterile	1	Union	
13	0	Sterile	1.5	Union	49
14	2	Sterile	13	Union	68
15	0		12	Union	
16	0	Sterile	14	Union	61

MSSA methicillin sensitive Staphylococcus aureus

[a] Patients who underwent two stage treatment

because more difficult cases are referred to our teaching hospital. A limited review of literature identified 375 cases of non-union, with seven classified as persistent, which yields a rate of 1.8 % (Table 4).

A retrospective analysis of each of our persistent non-union cases revealed technical errors, both in the initial fracture treatment and the first attempt at treating the non-union. The initial fracture fixation was analyzed in 12 of 16 patients who had post-operative X-rays available. Among the 11 cases treated by pinning, seven did not fill the canal and/or had an intrafocal gap; the single nailing case had the same shortcomings. In three of the four plating cases, the screws were inserted incorrectly (intrafocal screw, short construct, and/or poor reduction). A critical analysis of the first attempt at treating the non-union was performed in all our patients. We found three instances of technical errors (one bundle pinning with incomplete reduction and non-filled canal, one pinning with site distraction, one plating with intrafocal screw), four cases in which no bone was added, one case in which allograft was used, and positive bacterial cultures in two cases.

These repeated failures of non-union treatment are rarely mentioned in large published retrospective studies. Ring et al. [31] described 22 patients with atrophic non-union who were osteoporotic and 72 years of age on average; 15 of them had already undergone a prior attempt at union. A surgical site infection was identified in three of those patients. These cases of persistent non-union had a long progression, averaging 28 months. Application of a long plate spanning the non-union site with screws over three-quarters of the length of the shaft, combined with autograft was successful in 91 % of cases. However, two

Table 3 Summary of non union cases that had positive microbiological samples and their antibiotics treatment

Patient	Microbiology	Antibiotics therapy	Duration (weeks)
4[a]	*P. aeruginosa*	Colimycine + ceftazidime	6
5	*S. epidermidis*	Sulphametoxazole + Rifampicin	12
7[a]	*S. plurianimalium* then sterile	Amoxicillin	6
8	*S. epidermidis*	Rifampicin + Cloxacillin	6
9	*S. capitis*	None	
10[a]	*MSSA* then sterile	Oxacillin + Clindamycin	6
11	*S. capitis, P. acnes*	None	

[a] two stage treatment; Underlined patient number = Failed union; MSSA: methicillin sensitive *Staphylococcus aureus*

Table 4 Main published studies on the treatment of aseptic non union of the humeral shaft and their union rates, demonstrating the rarity of persistent nonunion

Reference	No. of patients	Success rate primary treatment (%)	Average time to union (weeks)	Persistent non union (n)
Healy et al. [9]	26	92	22	2
Barquet et al. [4]	24	95	24	1
Rosen et al. [32]	32	95	24	3
Marti et al. [21]	51	100	23	
Segonds et al. [33]	30	100	16	
Hsu et al. [12]	105	100	10 16	
Lin et al. [17]	86	100	14 16	
Bernard et al. [3]	21	95	18	1

of the 22 patients still had a persistent non-union, and two had fibrous union at the fracture site. Our study is generally consistent with those findings [31].

The consensus when faced with primary non-union of the humeral shaft is to apply a plate and add bone to the site [3, 4, 9, 12, 17, 18, 20, 21, 32, 33]. Recommendations have been made relative to applying fixation to the lateral cortex and the type of bone supply despite high risk of radial nerve injury [11, 14, 16, 27]. The use of locking plates does not alter the outcome; the key technical feature is the number of cortices that each screw crosses above and below the non-union site [30, 32]. Shortening the non-union by a few millimeters provides compression; bone graft must be added if the defect is more than 3–4 cm long [33] (Fig. 2). The type of bone supplied—both in terms of its osteogenic ability and its volume—is of the utmost importance, over and above the decortication step [3, 10, 33]. The importance of the bone supply is debatable in cases of hypertrophic non-union, where the pathogenesis is more the result of mechanical instability than insufficient osteogenesis; in these cases, the non-united callus serves as the bone supply [13, 17]. The same principles apply in cases of persistent non-union, but with the need to identify any surgical site infection, particularly with commensal bacteria.

The present attitude after implementing treatment for humeral shaft fracture is decidedly interventionist: when the existing fixation is not mechanically optimal, surgical revision must be considered and proposed to the patient, especially when he/she has comorbidities or addictions that impede bone healing [26]. When the fixation is stable, but union is delayed or even absent in the typical time frame, injection of osteogenic factors is a simple procedure that has met with some success [8].

The main limitations of our study are its small sample size, retrospective nature, involvement of multiple surgeons, and

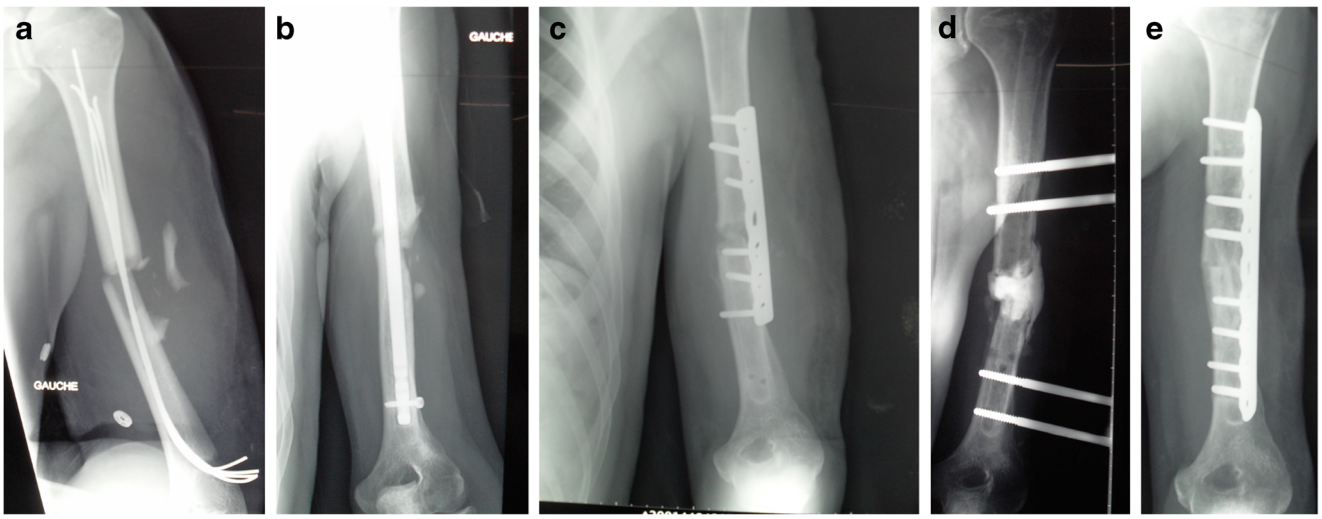

Fig. 2 Corner fracture of the humeral shaft treated with imperfect pinning (**a**) Revision with locked IM nail and site distraction (**b**). New revision with plate but no bone addition or reduction; fracture site was positive for *P. aeruginosa* (**c**). Masquelet technique consisted in removing the plate, stabilizing the site with an external fixator with cement spacer associated with appropriate general antibiotics (**d**), and 6 weeks later, plating and embedded iliac crest corticocancellous autograft (**e**)

long duration. However, it remains one of the few studies dedicated to this relatively rare complication.

Conclusion

This innovative case series of persistent non-union of the humeral shaft revealed a large number of technical and conceptual errors at each stage of treatment. The failure rate observed in this retrospective study was driven mainly by the patient's predisposition and surgical site infections. In every case, surgeons must be on guard for infections at the surgical site and microbiological samples should be collected systematically. However, plating and autologous bone grafting resulted in union in 75 % of these cases of persistent non-union of the humeral shaft.

Compliance with ethical standards

Conflict of interest None.

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