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Plating, nailing, external fixation, and fibular strut grafting for non-union of humeral shaft fractures

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ABSTRACT

Purpose. To compare various treatment modalities (plating, Ilizarov external fixation, and non-vascular fibular cortical strut grafting) for non-union of humeral shaft fractures.
Methods. Records of 9 women and 26 men aged 24 to 71 (mean, 42) years who presented with non-union of humeral shaft fractures were reviewed. The humeral shaft fractures were secondary to low-energy trauma (n=22) or vehicular accidents (n=13) and involved the proximal (n=9), middle (n=15), and distal (n=11) regions. 13 of the fractures were open. Infection was evident in 8 of the non-unions. For non-unions with infection (n=8), a 2-stage procedure entailing temporary Ilizarov fixation followed by plating was used. For non-unions without infection (n=23), one-stage plating and cancellous bone grafting was used. For non-unions of osteoporotic bone (n=4), one-stage non-vascularised fibular strut grafting was used. Outcome was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) scoring system.
Results. The 35 patients were followed up for a mean of 16 (range, 6–60) months. All achieved bone union except for one (who had persistent infection). Respectively for non-unions with infection, non-unions without infection, and non-unions of osteoporotic bone, the mean times to bone union were 6.5 (range, 4–10), 5 (range, 4–8), and 10 (range, 6–14) months, the mean improvement in DASH score was 30, 43, and 18, and malalignment was noted in 5, 2, and one patient. Three patients had a preoperative radial nerve palsy for which standard tendon transfer was performed 6 weeks after treatment for non-union.
Conclusion. Compression plating achieved the best results. An external fixator may be used temporarily for infected non-unions. Fibular strut grafting may be used when non-unions warrant additional stability.

Key words: *bone transplantation; external fixators; fibula; fractures, ununited; humeral fractures; Ilizarov technique*

INTRODUCTION

The incidence of non-union of humeral shaft fractures is 2 to 10% after conservative treatment and up to 15% after open reduction and internal fixation.[1–10] Delayed

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union and non-union are defined as the absence of bone union after 3 and 6 months, respectively.[1] The goals of treatment are mechanical stabilisation, biologic stimulation, and early joint mobilisation to optimise function.[8] The most successful treatment for non-union is open reduction and internal fixation with a compression plate in conjunction with autologous bone grafting.[2,11–14] Vascularised bone grafting and intramedullary allografting can also achieve some success but are technically challenging.[15–18] This study compared various treatment modalities (plating, Ilizarov external fixation, and non-vascular fibular cortical strut grafting) for non-union of humeral shaft fractures in terms of technical difficulties, union time, complications, and functional outcomes.

MATERIALS AND METHODS

Records of 9 women and 26 men aged 24 to 71 (mean, 42) years who presented with non-union of humeral shaft fractures (defined as no clinical and radiological signs of healing for at least 6 months) between 2005 and 2011 were reviewed. Patients with pathological fractures were excluded, as were those with co-morbidity that prevented surgery.

The humeral shaft fractures were secondary to low-energy trauma (n=22) or vehicular accidents (n=13) and involved the proximal (n=9), middle (n=15), and distal (n=11) regions. 24 of the patients injured the dominant hand. 13 of the fractures were open. Infection was evident in 8 of the non-unions.

Based on the presence of infection and/or osteoporotic bone, non-unions were treated using 3 different modalities. For non-unions with infection (n=8), a 2-stage procedure entailing temporary Ilizarov fixation followed by plating was used. The anterolateral approach was used for non-unions at the proximal and middle third of the shaft, and the posterior approach for non-unions at the distal third of the shaft. Treatment protocols included thorough debridement of the non-union site, removal of avascular bone, excision of sinus tracts, exploration of the radial nerve, removal of previous implants, and culture of tissue and pus and antibiotic sensitivity testing. In 4 of the patients, a temporary Ilizarov fixator was applied with pins in the safe zones (avoiding the nerves and vessels), and antibiotic-impregnated cement bead chains were inserted. In another 4 patients, a temporary humeral brace was used. Intravenous antibiotics were given for one week, followed by oral antibiotic for 5 weeks. Patients were monitored weekly until the total leukocyte count, C-reactive protein level, and erythrocyte sedimentation rate were within normal limits. The mean immobilisation period was 36 (range, 29–43) days. The second-stage procedure involved removal of the Ilizarov fixator and splinting until the pin tracks healed, followed by freshening of the non-union site, shingling of the bony ends, and internal fixation with a low-contact dynamic compression plate (n=4) for strong bones or a locking compression plate (n=4) for osteoporotic bones, along with autologous cancellous bone grafting (harvested from the anterior or posterior iliac crest). The drain was kept for 2 days; antibiotics were given intravenously for 2 days and then orally for 5 days.

For non-unions without infection (n=23), one-stage plating and cancellous bone grafting was used. This involved freshening of the non-union site,

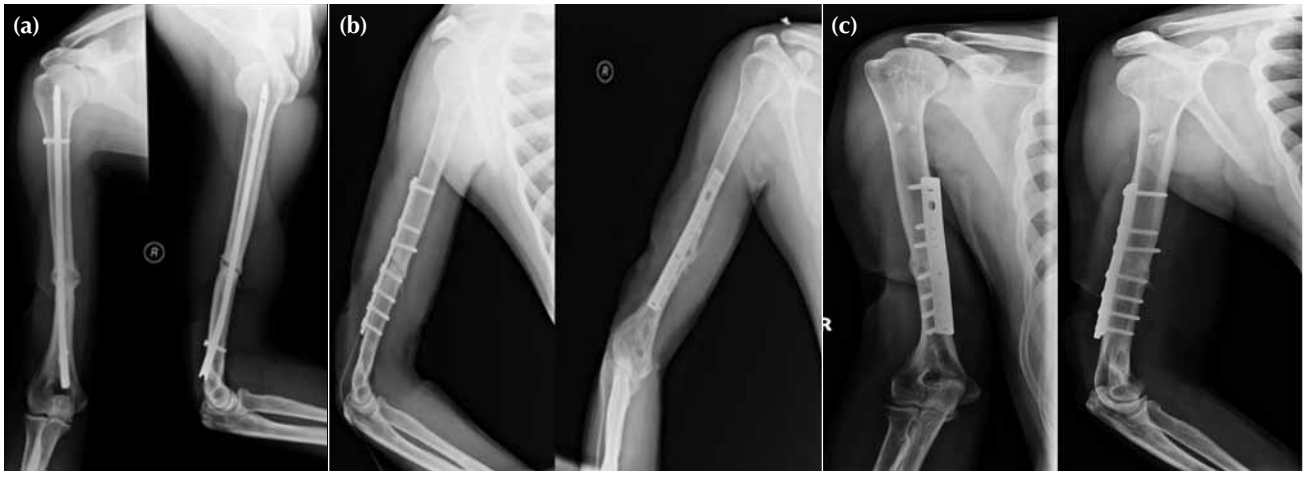

Figure 1 **(a)** Non-union with nail *in situ*, **(b)** treatment with compression plating and bone grafting, and **(c)** bone union within 5 months.

shingling of the bone end, and internal fixation with a low-contact dynamic compression plate (n=17) for strong bones or a locking compression plate (n=6) for osteoporotic bones, along with autologous cancellous bone grafting (Figs 1 and 2). The drain was kept for 2 days; antibiotics were given intravenously for 2 days and then orally for 5 days.

For non-unions of osteoporotic bone (n=4), one-stage non-vascularised fibular strut grafting was used. The graft was harvested from the contralateral fibula using a power drill and osteotome. It was inserted into the medullary canal and fixed with at least 4 screws through the plate (Fig. 3).

Bone union was defined as no pain and tenderness at the fracture site and union at 3 of the 4 cortices on radiographs. Outcome was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) scoring system.

RESULTS

The 35 patients were followed up for a mean of 16 (range, 6–60) months. All achieved bone union except for one (who had persistent infection). Respectively for non-unions with infection, non-unions without infection, and non-unions of osteoporotic bone, the mean times to bone union were 6.5 (range, 4–10), 5 (range, 4–8), and 10 (range, 6–14) months, the mean improvement in DASH score was 30, 43, and 18, and malalignment was noted in 5, 2, and one patient.

Three patients had a preoperative radial nerve palsy for which standard tendon transfer was performed 6 weeks after treatment for non-union. One of them had undergone surgical exploration and neurolysis at the time of primary fixation.

DISCUSSION

The quality of the soft-tissue envelope, the blood supply around the fracture, mechanical stability at the fracture site, and biologic revitalisation are important for deciding the treatment modality.[11] Poor bone quality or bone stock, scar tissue near neurovascular structures, and anatomic boundaries are challenges for treating non-unions.

Plate fixation is the gold standard for treating

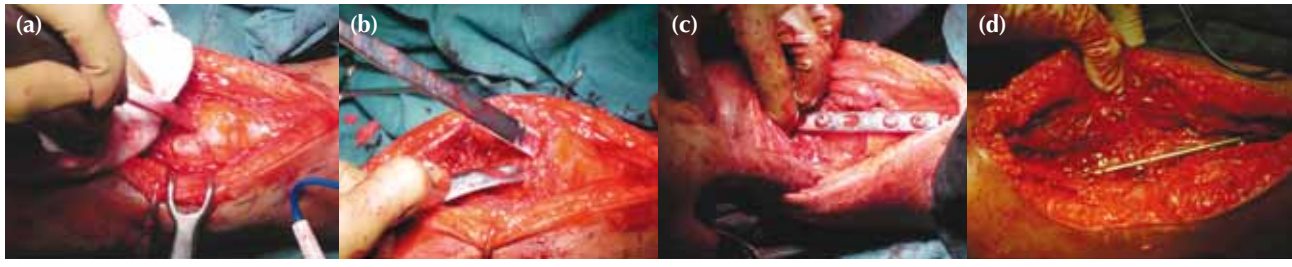

Figure 2 **(a)** Exploration of the non-union, **(b)** shingling and freshening of the non-union ends, **(c)** dynamic compression plating, and **(d)** morcellised bone grafting around the non-union site.

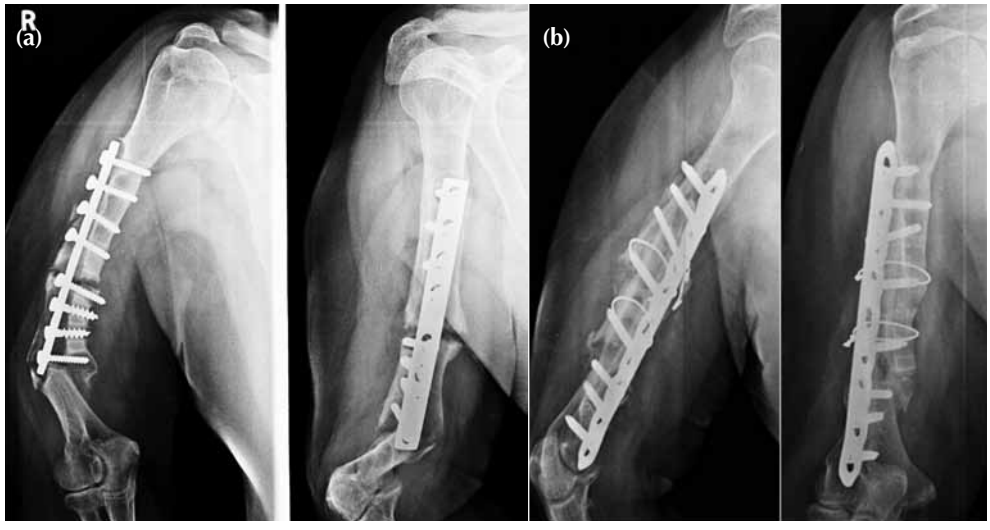

Figure 3 **(a)** Non-union with avascular sclerotic middle fragment of the humerus with implant failure, and **(b)** bone union after plating and fibular strut grafting.

non-unions. It enables compression,[14,19] correction of axis malalignment, and stimulation of osteogenesis (shingling, grafting) in a single procedure. Its union rate is reported to be 83 to 100%, with high subjective satisfaction.[13,20] Among various plating techniques, compression plating with autogenous grafting has yielded 92 to 100% healing rates.[11,21,22] Nonetheless, compression plating involves extensive soft-tissue dissection and leads to devitalisation of the bony fragments. Plate fixation is also associated with the risk of radial nerve injury (3 to 29%),[21] as at least 6 cortical screws are fixed on either side of the non-union.[20] Such a large dissection is sometimes morbid. In some distal shaft non-unions, there is insufficient space to engage 6 cortices. This technique is not advised for non-unions with infection, osteoporotic bones, long spiral and large segmented fracture lines, and especially distal metaphyseal non-unions, as more than 6 cortices and/or augmentation with strut grafts are required.[21] To increase stability, reconstruction with 2 plates at right angles has been advocated, but clinical outcome was not significantly different between single- and double-plate constructions.[11]

External fixation conserves the soft-tissue envelope and the vitality of remaining bone. This technique can be applied to osteoporotic and/or infected bones.[23] The fixator enables gradual compression of the non-union site, mimicking the weight-bearing status of the lower extremity.[24,25] Circular fixators have been successful in treating all types of non-unions including those of the humerus.[26] This technique gradually corrects displaced, angulated, shortened, and malunited fragments during the treatment. With controlled periods of compression and distraction, healing is stimulated and the quality of regenerated bone is improved. Gradual realignment and compression of the non-union site are possible during the treatment,[27,28] whereas reduction and static compression are achieved in the second-stage plate fixation. External fixation is superior to internal fixation when the non-union is complicated by deformity, infection, bone loss, and length discrepancy. However, the bulkiness of the frame and numerous wires are discomforting to patients.[24] Unilateral fixators are widely used in traumatic open fractures, but rarely in non-unions. External fixation enables temporary fixation until infection heals, and is followed by definitive treatment.

Non-vascular fibular strut grafting in conjunction with compression plating achieves bone union without the need of cancellous iliac crest grafts in osteoporotic, atrophic humeral non-unions.[29] This technique is easy, economical, and associated with less donor-site morbidity. The fibula acts as an internal splint and adds stability for osteosynthesis, and increases screw cortical purchase and thus resistance to screw pull-out. It also shares the load and helps bone growth and integration.[29] Fixation using a compression plate and a non-vascularised fibular graft achieves good outcome for infected non-union of the humerus despite prior multiple failed surgeries.[30] We recommend this technique for atrophic non-unions and in osteoporotic bones.

Intramedullary locking nails are controversial when it comes to treating humeral non-unions.[23] Successful results with retrograde nailing for lower limb non-unions have been reported.[24,30] Nonetheless, lack of weight bearing and inadequate compression diminish the success rate in humeral shaft non-unions.[31] Complaints related to the entry site can also be a problem.

Shingling to stimulate osteogenesis is an effective means of exposing the non-union without considerable devascularisation.[32] In diaphyseal non-unions, the periosteum is closely attached to the adjacent muscles and the subperiosteal bone, which receives its blood supply from the extra osseous tissue. Circumferential shearing of the external diaphyseal periphery preserves the blood supply for the fragments and bridges the non-union. This technique creates a well-irrigated bed to receive the bone grafts.

Autologous bone grafts are osteogenic (a source of living bone cells), osteoinductive (local recruitment of mesenchymal cells), and osteoconductive (scaffolding for growth of bone tissue). Biologically, it is superior to allografts or bone substitutes. Nonetheless, pain and haematomas ensue at harvest sites (commonly the anterior and posterior iliac crest). Allografts of demineralised bone matrix achieved similar results in treating humeral non-unions, while also avoiding donor-site morbidities.[6]

CONCLUSION

For non-infected non-unions, we recommend the use of a low-contact dynamic compression plate for strong bones and a locking compression plate for osteoporotic bones, along with morcellised bone grafting as a standard treatment. For infected non-unions, we recommend temporary use of an external fixator, followed by compression plating and non-vascularised fibular strut grafting for additional stability for gaps >3 cm and for extremely osteoporotic bones. The drawback of this study

was its retrospective nature and no comparison with intramedullary nailing and vascularised strut grafting.

DISCLOSURE

No conflicts of interest were declared by the authors.

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