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Treatment of humeral shaft non-unions by the Ilizarov method

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Abstract Thirty-five humeral shaft non-unions treated by the Ilizarov external fixator were studied after an average of 39 months. Bone union was achieved in all but one. The mean time to union was 5.5 months (range: 3–10 months). Major pin tract problems leading to removal of the Schanz screws occurred in three patients. A radial nerve palsy developed in three patients, two recovered spontaneously and one was treated with a triple tendon transfer.

Résumé Nous avons suivi 35 pseudarthroses de la diaphyse humérale traitées par fixateur d'Ilizarov avec un suivi moyen de 39.2 mois. La consolidation a été obtenue dans tout les cas sauf un. Le temps moyen de consolidation était de 5.5 mois (3–10 mois). Dans trois cas ont été observés des problèmes majeurs nécessitant l'ablation des vis de Schanz. Une paralysie du nerf radial a été noté dans trois cas, avec une récupération spontanée deux fois et traitement par un triple transfert tendineux dans l'autre cas.

Introduction

Fractures of the diaphysis of the humerus may not unite for 4 months after the instigation of either non-operative or conventional surgical treatment [3, 9]. Rosen [11] has defined a delay of 3 to 4 months in bony healing as a delayed union and a delay of 6 to 8 months as a non-union. We report the results of the treatment of 35 consecutive patients with non-union of the humeral shaft that were managed at our hospital using the Ilizarov external fixator.

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Materials and methods

We studied 35 patients with a clinically and radiologically confirmed non-union of a fracture of the humeral shaft. Twenty-five were male and ten were female, with a mean average age of 37.3 years (range: 13–69 years) on admission. These injuries had resulted from a traffic accident (18 patients), a fall (14 patients), or a gunshot wound (three patients). The initial treatment was non-operative in 16 and surgical in 19. The latter had undergone an average of 1.8 operations (range: 1–3); eight had required removal of an infected implant. However, no persistent clinical or laboratory signs of infection were noted in these eight patients on admission. The mean period between the initial treatment and the application of the Ilizarov external fixator was 11.7 months (range: 5–48 months). The non-unions were considered hypertrophic in nine patients and atrophic in 26. The fracture was in the proximal third of the diaphysis in six patients, the mid-diaphysis in 17 and the distal third in 12. Ten of the fractures were originally open (Table 1).

All the patients were treated with an Ilizarov external fixator using the circular-semicircular, pin-screw frame configuration described by Cattaneo et al. [1]. All previously inserted implants were removed. In patients with an atrophic non-union the bone ends were exposed and cleared of avascular tissue, the medullary canal was drilled, and autologous cortico-cancellous bone grafts harvested from the ilium were applied to the non-union. In patients with a non-union localised to the distal diaphysis the radial nerve was first exposed through a lateral longitudinal incision.

Active and passive elbow and shoulder movements were started on the first post-operative day. In all patients monofocal distraction for 7 days (1×0.25 mm/day) was followed by monofocal compression for 7 days (1×0.25 mm/day) until sufficient radiological bony union was observed. After operation X-rays were taken every 2 weeks and a daily 2-hour rehabilitation programme, which included active and passive range of motion and isometric exercises, was started. The presence of cortical continuum in a total of three anteroposterior and lateral X-ray views was regarded as evidence of adequate bony union. The connection rods were loosened, bony healing was confirmed clinically and the frame was removed. A protective plastic brace was then used for 1 month.

Table 1 Clinical data [*1* age (years), *2* sex, *3* time of non-union (months), *4* etiology, *5* previous treatment, *6* number of previous operations, *7* localisation, *8* type of non-union, *9* additional problems, *10* time of external fixation (months), *11* follow-up (months), *12* complications, *13* length of discrepancy (cm), *14* patient satisfaction]

1	2	3	4	5	6	7	8	9	10	11	12	13	14
24	M	12	Fall	Conservative	–	Middle 1/3	Atrophic	–	3	80	–	2.0	4
28	F	16	Fall	Conservative	–	Distal 1/3	Hypertrophic	Open fracture	5	78	Radial paralysis, complete recovery	2.0	1
17	F	9	Acc	Plate-screws	2	Proximal 1/3	Hypertrophic	Infected	4	68	–	5.0	3
77	M	5	Fall	Conservative	–	Proximal 1/3	Atrophic	–	5	68	–	3.0	2
15	M	13	GSW	Conservative	–	Distal 1/3	Atrophic	Open fracture, radial paralysis	5	66	–	3.0	3
26	F	18	Acc	Plate-screws	1	Proximal 1/3	Atrophic	–	10	59	–	3.0	4
24	M	5	Fall	Conservative	–	Middle 1/3	Atrophic	Infected	4	58	–	3.0	3
57	M	8	Fall	Conservative	–	Distal 1/3	Atrophic	Open fracture	9	48	–	3.0	3
36	M	6	Acc	Conservative	–	Distal 1/3	Atrophic	Open fracture, infected	10	48	Pin tract infection, pin removal	4.0	2
38	M	24	Fall	Plate-screws	2	Middle 1/3	Atrophic	Infected	6	47	–	2.0	2
59	M	15	Fall	Plate-screws	3	Middle 1/3	Hypertrophic	–	5	46	–	3.0	2
15	M	5	Fall	Conservative	–	Distal 1/3	Atrophic	–	5	46	–	3.0	1
26	M	28	Acc	Plate-screws	1	Middle 1/3	Atrophic	–	4	46	–	4.0	4
26	M	26	Fall	Conservative	–	Distal 1/3	Atrophic	Open fracture	8	44	–	2.0	4
41	M	20	Fall	Plate-screws	1	Proximal 1/3	Atrophic	–	7	43	Ulnar paralysis, complete recovery	3.0	1
13	F	12	Acc	Plate-screws	1	Middle 1/3	Atrophic	Infected	5	40	–	1.0	4
43	M	5	Acc	Plate-screws	2	Distal 1/3	Atrophic	–	6	39	Radial paralysis, complete recovery	2.0	2
63	F	5	Acc	Conservative	–	Middle 1/3	Atrophic	Open fracture, infected, radial paralysis	6	38	Pin tract infection, pin removal	1.0	2
43	M	8	Fall	IM nail	1	Distal 1/3	Hypertrophic	Open fracture	5	33	Radial paralysis, tendon transfer	2.0	1
59	M	7	Acc	Conservative	–	Proximal 1/3	Atrophic	–	9	30	Non-union, convert to IM nail	3.0	1
25	M	9	Fall	Conservative	–	Middle 1/3	Atrophic	Open fracture, infected	7	30	–	1.0	4
69	M	9	Acc	Plate-screws	2	Distal 1/3	Atrophic	Radial paralysis	4	28	–	1.0	4
37	M	13	Acc	Conservative	–	Middle 1/3	Hypertrophic	–	6	28	Pin tract infection, pin removal	3.0	3
49	M	15	Acc	Plate-screws	1	Middle 1/3	Atrophic	–	4	27	–	3.0	4
23	M	8	Fall	Conservative	–	Middle 1/3	Hypertrophic	–	4	27	–	4.0	4
48	M	7	Fall	Conservative	–	Middle 1/3	Atrophic	Open fracture	5	27	–	4.0	4
35	F	8	Fall	Plate-screws	3	Middle 1/3	Atrophic	–	6	25	–	3.0	4
50	F	48	Fall	IM nail	1	Middle 1/3	Hypertrophic	–	5	25	–	2.0	4
47	M	7	Acc	IM nail	1	Distal 1/3	Hypertrophic	Open fracture	5	24	–	1.0	4
18	M	9	Acc	Plate-screws	2	Middle 1/3	Atrophic	–	5	23	–	1.0	4
34	F	6	GSW	Conservative	–	Distal 1/3	Atrophic	–	5	24	–	2.0	4
60	M	17	Acc	IM nail	1	Proximal 1/3	Atrophic	Infected	5	25	–	1.0	4
36	F	6	Fall	Plate-screws	1	Middle 1/3	Hypertrophic	–	6	25	–	3.0	4
52	M	7	GSW	IM nail	1	Middle 1/3	Atrophic	Infected, radial paralysis	6	24	–	3.0	3
29	M	6	Acc	Plate-screws	3	Distal 1/3	Atrophic	–	6	24	–	2.0	3

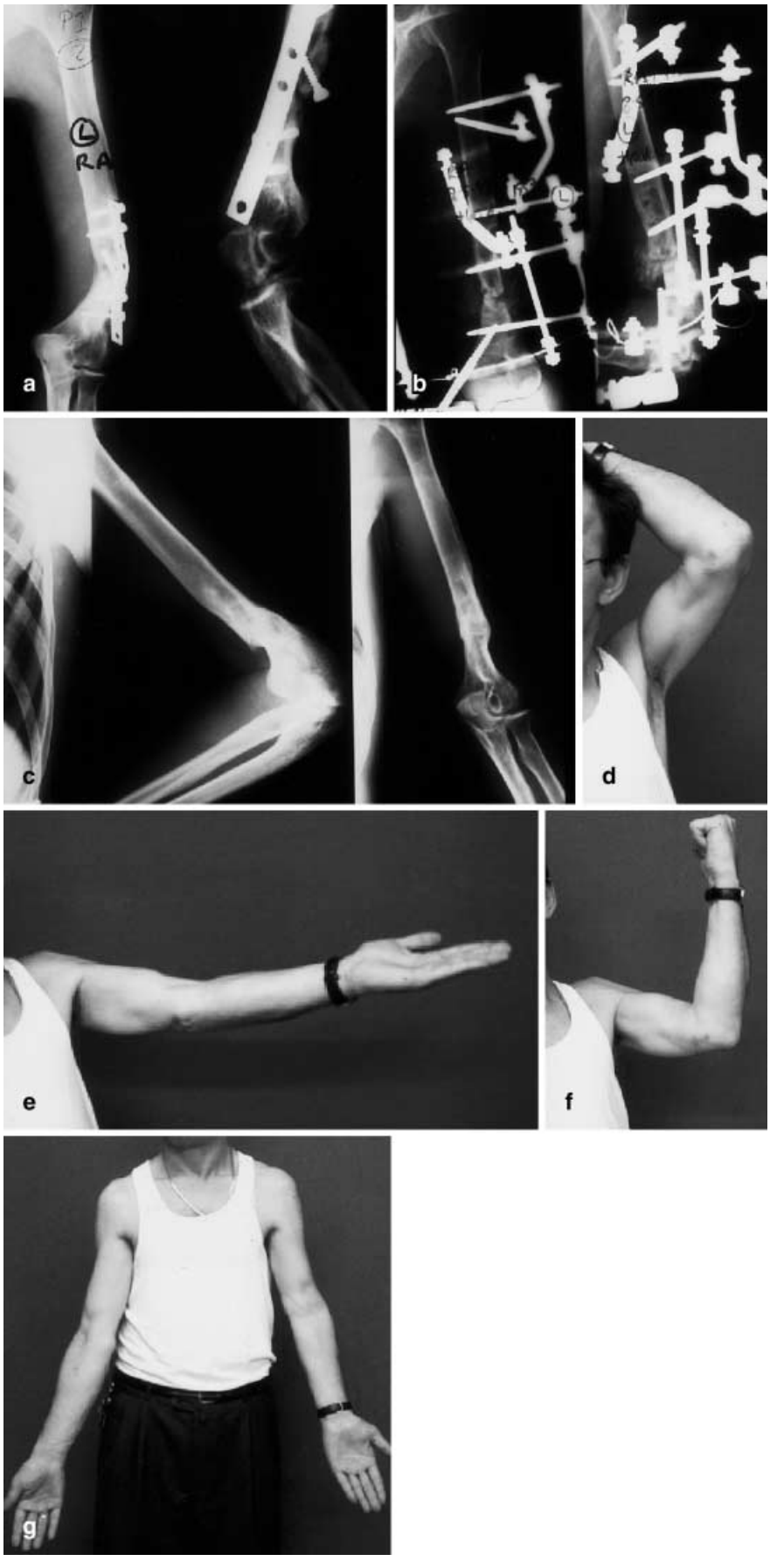

Fig. 1a–g Forty-one-year-old man, previously treated with plate and screw fixation for a short-oblique distal humeral shaft fracture (non-union period of 20 months). **a** Anteroposterior and lateral X-ray displaying non-union 19 months after the initial treatment. **b** Anteroposterior and lateral X-ray at the end of third post-operative month. **c** Anteroposterior and lateral X-ray at the end of 25th post-operative month. **d–g** Excellent shoulder and elbow function at the end of 25th post-operative month

Results

The patients were followed up for an average of 39.2 months (range: 24–80 months) after operation. The mean external fixation time was 5.5 months (range: 3–10 months). Autologous, cortico-cancellous bone grafts were used in 26 patients. All patients were treated by monofocal distraction and compression, but 26 also had additional bone grafting. Union was achieved in all but one fracture. After brace removal 32 patients had no restriction of shoulder or elbow movement during daily activities (Fig. 1) although three had had considerable restriction in performing daily activities before the Ilizarov fixation. When last examined the patients had a mean humeral shortening of 2.4 cm (range: 1–5 cm) which did not interfere with either cosmetic appearance or daily function (Table 1). Twenty-two patients had pin tract problems but only three did not respond to oral antibiotics and local pin site care. The infection soon subsided after pin removal.

Three patients had an early radial nerve palsy; two recovered completely after 3 months but one required a triple tendon transfer at the wrist after 6 months. Another patient had paraesthesia in the ulnar and radial dermatomes and this recovered at 6 months.

Patient satisfaction was recorded using the following score system: same functional status when compared to the uninjured side (4 points), better function when compared to the status following primary management (3 points), worse when compared with the status prior to external fixation (2 points), and not satisfied at all (1 point). The mean score of the whole group was 2.8 points (Table 1).

Discussion

One of the important factors in the management of non-unions is the preservation or restoration of the local blood supply. The nutrient artery enters the humerus between the middle and distal thirds of the diaphysis and wide surgical exposure may easily injure this vessel [11].

Modabber and Jupiter [9] claim that plate and screw fixation for the management of humeral shaft fractures and non-unions have many disadvantages such as injury to the periosteal blood supply, risk of iatrogenic nerve injury, blood loss and a long scar. Foster et al. [4] reported a rate of infection of up to 50% when plate and screw fixation was used for grade III open fractures and that many implants had to be removed. However, intramedullary nailing as described by Modabber and Jupiter [9] also has a considerable number of drawbacks such as problems in the shoulder or elbow depending on the point of insertion, risk of nerve injury, risk of producing a further fracture during nail insertion, disruption of the endosteal blood supply, risk of spreading a local infection to the whole bone, difficulties during implant removal and technical difficulties resulting from deformities or a very narrow medullary canal [2].

Most non-unions of the humeral shaft are displaced, angulated, over-riding, mal-united and complicated by bone loss or length discrepancy. These conditions cause problems during the performance of routine surgical operations. In addition, these standard techniques are contraindicated when the non-union is complicated by infection. When the initial treatment must consist of thorough debridement, excision of all dead tissue, irrigation and the use of local antibiotic carriers [2].

The Ilizarov system provides rigid fixation even in osteoporotic bone. Ilizarov believed that the callus between the bone fragments may be converted to bone by application of distraction forces to this area if the fracture site is properly fixed, well vascularised and the extremity is rehabilitated [5]. Controlled compression and distraction forces increase the quality and quantity of callus when applied to a fracture or a non-union [5, 8, 12]. Though Ilizarov does not recommend bone grafting for the treatment of non-unions, we added autogenous bone grafts in some of our patients aiming for more rapid healing of the bone which results in a shorter fixation time. We used autogenous cancellous bone graft in 14 of our patients who had had their previous implants removed. A shorter external fixation time will decrease the number of pin tract problems and the incidence of psychological problems.

Thus it appears that the Ilizarov system is superior to other methods of treatment especially where there is deformity, infection, bone loss, length discrepancy, and restriction of shoulder and elbow movement. Trans-osseous osteosynthesis also restores the function of the injured limb, increases local blood flow and stimulates osteogenesis. Mechanical stimulation increases local tissue nourishment thus encouraging the healing of hypertrophic and/or infected non-unions [9]. The Ilizarov device acts like ‘the surgeon’s hands on bone’, enabling complete correction of deformities with the help of hinges. If fractures are slow to unite, callus formation can be stimulated with episodes of compression-distraction [5, 8, 12]. Schatzker [13] comments that a modern treatment philosophy for non-unions should not focus solely on bone union but should also protect the surrounding soft tissues and allow for functional rehabilitation of the joints. Prolonged immobilisation causes atrophy of articular cartilage, intra-articular adhesions and contracture of the surrounding capsule and ligaments. The only solution is early functional rehabilitation and although plates and screws and intramedullary rods provide stable fixation, a period of immobilisation is usually necessary when they are used for the management of non-unions [4, 6, 11, 14]. The Ilizarov system is superior to other fixation systems as the patient is allowed early active and passive motion starting from the first postoperative day.

In the lower limbs the object of the treatment of non-unions is the promotion of fracture healing and the equalisation of leg length. In contrast, length discrepancies in humeral shaft non-unions of up to 4–5 cm do not cause any functional or cosmetic disability [7]. Ring et

al. [10] reported the results of a group of non-unions treated by a bridging compression plate and the filling of the defect with autogenous cortico-cancellous grafts. However, they did not comment on the benefit of this defect reconstruction. We did not find any functional or cosmetic disability in our patients, who only lost an average of 2.4 cm (range: 1–5 cm) of humeral length. Therefore, we believe that monofocal treatment is effective for humeral shaft non-unions with a length discrepancy of up to 5 cm and it necessitates a considerably shorter period of external fixation. In patients with a non-union and a length discrepancy of more than 5 cm, bifocal compression-distraction can produce fracture healing and restoration of humeral length.

Lammens et al. [8] reported the management with the Ilizarov external fixator of 30 patients with non-union of the humerus. Six of these were infected and they achieved union in 28 fractures after an average of 4.5 months. They commented that the Ilizarov external fixator encouraged solid healing, protection or improvement of the functional status of the patient and did not cause any major complications. However, in their series four patients suffered re-fracture following frame removal and this necessitated re-application of the Ilizarov apparatus.

We achieved similar results after an average period of 5 months and have not had any re-fractures following frame removal. We believe that the plastic brace worn after frame removal protects the regenerated bone. One of the disadvantages of the Ilizarov system is the weight of the frame although this can be overcome by using carbon fibre rings. We used these rings in all patients except the first eight. Their use makes the frame lighter and the rehabilitation easier. Their radiolucency increases the quality of the follow-up X-rays. Our rate of pin tract problems was minimal due to meticulous surgical technique and vigilant pin site care.

The Ilizarov method offers advantages over conventional surgical treatment in the management of humeral shaft non-unions. It allows the patient early functional rehabilitation, enables the surgeon to control the bone fragments throughout the period of external fixation and produces a high rate of healing accompanied by a very low rate of complications. It is therefore a valuable alternative to classic surgical methods of treatment. Furthermore, the Ilizarov system is unique as it also allows the treatment of deformed infected humeral shaft non-unions complicated by bone loss, and of problems of length discrepancy.

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