Treatment of post-infection nonunion of the supracondylar humerus with Ilizarov external fixator

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\textbf{Background:} Nonunion of the supracondylar area of the humerus is a very difficult area to treat. The Ilizarov method has been shown to be effective in the treatment of nonunion of the humeral diaphysis. However, there is little in the literature regarding the treatment of nonunion of the supracondylar area especially in post-infection cases.

\textbf{Methods:} Eight patients with a mean age of 45.73 ± 11.42 years were treated for post-infection nonunion of the supracondylar area of the humerus with the Ilizarov method and followed up for 3 years. All had undergone at least 2 previous failed operations. The patients were evaluated radiologically and clinically with an outcome survey using the Disabilities of the Arm, Shoulder and Hand (DASH) score.

\textbf{Results:} Solid union was achieved in all patients in a mean time of 6.87 ± 0.99 months. All patients had improvement in shoulder and elbow motion after treatment. The mean DASH score before surgery was 90.66 ± 5.66, whereas that after surgery was 24.62 ± 3.85. There was a significant improvement in the DASH score after surgery; the mean difference was 66.04 ± 1.81, with a $t$ value of 35.88 ($P < .001$). All patients were satisfied with the treatment and returned to a more normal lifestyle with no pain, as well as complete soft-tissue recovery. None had recurrence of infection.

\textbf{Conclusion:} Ilizarov treatment for post-infection nonunion of the supracondylar humerus was shown to be effective, reliable, and tolerated by the patients.

\textbf{Level of evidence:} Level IV, Therapeutic Study.

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\textbf{Keywords:} Treatment; nonunion; humerus; ring fixator

Distal humeral fractures account for approximately 4% of all fractures.\textsuperscript{3} Approximately 2% to 5% of these fractures progress to nonunion.\textsuperscript{8,11}

Nonunion of the supracondylar area of the humerus is very difficult to treat because there is always little bone stalk and a great degree of instability, being close to a stiff elbow joint. Causes of nonunion may be failed conservative treatment or failed internal fixation with or without infection. In such a condition, the bone is osteopenic with bone resorption or bone loss in the medial and lateral columns due to previous fixation. The soft-tissue bed is not healthy, and capsular adhesions of the elbow with limited range are always present. In such cases, the use of plate fixation and bone grafting is not suitable, especially in those with post-infection nonunion.\textsuperscript{5,12,18,19,23,24}

The advantages of using the Ilizarov circular external fixator for such conditions include the ability to obtain rigid fixation, adjust axial alignment of the bone, compress the
nonunion site, and allow early movement of the elbow after surgery, without the risk of loss of correction or reactivation of infection.

The Ilizarov method has been shown to be effective in the treatment of nonunion of the humeral diaphysis. It has also been used in the treatment of supracondylar fractures.6,10,22 We studied the results of using the Ilizarov circular external fixator in the treatment of post-infection nonunion of the supracondylar area of the humerus.

Methods

In this prospective study, we describe the results of 8 consecutive patients treated with the Ilizarov method for post-infection nonunion of the supracondylar area of the humerus since 2004 at Kasr EL Aini Hospital, a referral hospital at Cairo University. The mean follow-up period was 3.22 ± 0.65 years (range, 2.40-4.20 years) after completion of treatment. Table 1 gives details on patient data. The inclusion criteria were post-infection cases of nonunion of a low supracondylar humerus with bone resorption and sclerotic ends. Patients without a history of infection or with high supracondylar nonunion and elderly patients with bone osteopenia were not included in this study and were treated with a plate and screws and elbow arthroplasty, respectively. There were 4 men and 4 women with a mean age of 45.37 ± 11.42 years (range, 19-56 years).

High-energy trauma was the cause of the original fracture in 7 patients; the fracture was closed in 5 patients and open in 2. Two of these patients had an intra-articular extension to the elbow that was reduced by the primary surgery. In 1 patient, the nonunion was on top of a corrective osteotomy for cubitus varus. Three had other ipsilateral fractures: forearm, olecranon, and wrist. All patients had undergone at least 2 previous operations (range, 2-4). These included internal fixation with plates and screws, uni-frame external fixation, K-wire fixation, or a combination thereof that resulted in nonunion with infection. No patient presented to our hospital with active infection; rather, patients were referred from other centers after control of infection and debridement. The type of organism was Staphylococcus aureus in all cases. The type of antibiotic used was determined according to sensitivity testing. Cefazolin was used in 6 patients for at least 2 weeks, whereas vancomycin in combination with sefazine was used in 2. The mean time from injury to presentation was 20 ± 6.50 months (range, 12-30 months). Six patients presented with nerve palsy of the partial or complete median, ulnar, and radial nerve; one had a tourniquet paralysis. One of these had a vascular injury that was treated successfully primarily.

Preoperative radiographs were obtained, and vascular and neurologic assessments were performed. After consenting to participate, patients were evaluated by clinical examination and with an outcome survey using the Disabilities of the Arm, Shoulder and Hand (DASH) score. Preoperatively, all patients had limitation of activities of daily living with pain, abnormal mobility at the nonunion site, and limited range of motion of the elbow.

Surgical procedure

With the patient under general anesthesia, the humerus was exposed through a posterior approach and triceps splitting. The ulnar nerve was explored, released, and retracted. In cases of ulnar nerve palsy we performed either neurolysis and anterior transposition or microsurgical repair/grafting together with anterior transfer. Any previous fixation devices were removed. Surgical excision of all intervening fibrous tissue and dead bone was done to reach bleeding bone edges, together with complete elbow release performed via an anterior and posterior capsulotomy. In all cases, intraoperatively, we did not find any signs of active infection, with negative deep cultures. The bone ends were approximated and compressed with the fixator. The bone defects after debridement were less than 2 cm in all cases, so shortening and compression were accepted.15,20 We used a combination of threaded half pins and wires to fix the humerus. To allow movements around the elbow, we used semi-circular rings in the construct of the Ilizarov frame distally, but in 1 patient, we had to place a complete ring that was changed 1 month later. In the distal fragment, we placed 2 half pins in the medial and lateral columns of the humerus perpendicular to the bone from posterior to anterior and 2 crossing wires in a horizontal plane parallel to the joint line. However, in 1 case, it was only possible to place 1 half pin in 1 of the columns in addition to the 2 crossing wires, and it was a rigid construct. In the proximal fragment, we used at least 2 half pins in 2 different planes through 1 ring or several half pins above each other through different semicircular rings.

Iliac crest cancellous bone graft was used in 3 cases when there was irregularity of bone ends. Compression of bone ends was continued during the follow-up period. In 2 patients, there were no radiologic signs of healing at 6 weeks, so we applied progressive distraction with periods of compression (0.5 mm of distraction per day for 7 days followed by 1 mm of compression per day for 7 days over a 4-week period).

All patients underwent a postoperative program of rehabilitation with special concern regarding elbow range.

Union was evaluated by radiographic assessment and clinical examination monthly. The radiographic criterion for healing of nonunion was complete bone bridging on at least 2 projections. Clinically, union was assessed by loosening the connecting rods and applying stress to the nonunion. If there was complete radiologic and clinical union, the fixator was removed with the patient under anesthesia with gentle elbow manipulation to reach maximum range of flexion and extension and a cast brace applied for 2 months with active elbow range of motion.

Results

Solid union was achieved in all patients (Fig. 1). The mean time to achieve full union was 6.87 ± 0.99 months (range, 6-8 months).

The mean follow-up period after frame removal was 3.22 ± 0.65 years (range, 2.40-4.20 years).

Minor problems—pin-tract infections—were seen in almost all patients but were treated with oral antibiotics. No permanent pin-site problems were encountered.

There was shortening of the arm, with a mean of 3.12 ± 0.64 cm (range, 2-4 cm). This shortening was the result of previous surgeries and bone resorption, especially in patients who underwent debridement, or the technique of operative compression of the nonunion site.
<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Previous operations</th>
<th>Comorbidity</th>
<th>Time from injury to presentation (mo)</th>
<th>Index operation</th>
<th>Time to union (mo)</th>
<th>Postoperative elbow range: Extension/ flexion (°)</th>
<th>Humeral shortening (cm)</th>
<th>Follow-up period (y)</th>
<th>DASH score percent preoperatively/postoperatively</th>
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<td>1</td>
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<td>2</td>
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<td>M</td>
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<td>Freshening of nonunion site</td>
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<td>−40/110</td>
<td>3</td>
<td>3.6</td>
<td>95.8/25.8</td>
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ORIF, open reduction—internal fixation.
Figure 1  (A) Preoperative radiograph showing nonunion of supracondylar humerus after plate fixation. (B) Radiograph showing application of Ilizarov external fixator. (C) Postoperative radiograph, anteroposterior view, showing full union of humerus. (D) Postoperative radiograph, lateral view, showing full union of humerus. (E) Follow-up photo of patient showing range of elbow flexion. (F) Follow-up photo of patient showing range of elbow extension.
After healing, the shortening did not appear to compromise function, and no patient asked for further surgery to lengthen the humerus.

In 2 patients, there was a varus deformity of the elbow, with a mean of 12.5° (range, 10°–30°), that was obvious clinically in 1 of the patients (Fig. 2) who also had a posterior displacement of 30° and elbow range of 40° to 110°. This patient was satisfied with the result and did not ask for any further treatment. In these 2 patients, because of the very low fracture site and the configuration of the healthy bone edges of the proximal and distal fragments after debridement, we had to accept this deformity because of the good bone contact and stability we have achieved.10 No elbow instability was encountered in any patient.

Minor neurologic problems were observed from this procedure. Two patients (cases 1 and 6) had a paresthesia of the ulnar nerve that disappeared after removal of the adjacent K-wire, and the patients had an otherwise uneventful recovery.

For the group of patients referred with a pre-existing nerve deficit, the results were as follows: cases presenting with ulnar nerve palsy that required neurolysis (cases 3, 7, and 8) returned to full function (sensory and motor recovery). Those who required microsurgical repair or grafting (cases 2, 4, and 5) achieved good hand function with protective sensation improving with each follow-up visit.

Cases with radial nerve (case 5) or partial median nerve (cases 2 and 4) who were treated by tendon transfer to restore finger extension and thumb opposition reached a hand function with good grip, pinch, and grasp.

All of the patients were satisfied with the treatment and returned to a more normal lifestyle. No patient complained of pain at the nonunion site after treatment. None had recurrence of the infection, and complete soft-tissue recovery was achieved in all patients.

Comparing the results of elbow range was difficult because preoperative range was part from the fracture site. At the latest follow-up, the range of motion of the elbow was as follows: the mean angle of extension was 32.5° ± 11.64°, ranging between −40° and −10°, and the mean angle of flexion was 108.75° ± 16.42°, ranging between 100° and 140°. The mean Mayo Elbow Performance Score was 78.75 ± 5.17 (range, 70–85).

All patients had improvement in shoulder and elbow motion after treatment. The mean DASH score before surgery was 90.66 ± 5.66 (range, 80.8–96.6), whereas the mean score after surgery was 24.62 ± 3.85 (range, 17.50–29.16). This showed a significant improvement in the DASH score after surgery; the mean difference was 66.04 ± 1.81, with a t value of 35.88 (P < .001).

Discussion

Treatment of fractures of the distal humerus especially in low types near the supracondylar area is difficult, and nonunion may result. Treatment of such distal humeral nonunions in the supracondylar area, particularly those on top of infection with severe deformity after several failed operations for internal fixation, is complex and difficult.9,12 Repeated surgeries in the supracondylar area above the elbow usually end up with elbow contractures, articular cartilage deterioration, and in most cases, ulnar nerve problems.4,24

Because of the complexity of the problem, decision making in the management of supracondylar humeral nonunion is difficult and not clear in the literature especially in post-infection cases.19,22

Many treatment options have been described, including open reduction—internal fixation with plates and screws,8,21 intramedullary nailing with interfragmentary wiring,14 elbow arthroplasty,17 and free vascularized bone grafting.2

In this series, we have used the Ilizarov method in treating patients with post-infection nonunion of the supracondylar area of the humerus. The advantages of this technique are its safety on top of previous infections and that it can achieve good alignment of the bone with stable reduction and rigid fixation of the fracture, allows early mobilization, and can apply gradual compression or intermittent compression if there are any signs of delayed healing.

The clinical results and outcome of this work are comparable to the results of other authors.4,10 We believe that the high success rate regarding clinical outcome may be because of the standardization of technique, with the surgical technique performed at least 4 months after healing of infection with negative blood test findings; use of a posterior approach; exposure of the ulnar nerve, which is then dealt with accordingly; undoing the nonunion site with complete debridement of fibrous tissue to reach bleeding bone; complete release of the distal bone fragment anteriorly and posteriorly to achieve reduction and release the elbow; reaching opposing bone ends with a coated surface area; applying bone graft if there is irregularity of surface or gap comprising more than one-third of the circumference; proper frame construction; application of direct compression; application of intermittent compression during follow-up; early physiotherapy; removal of frame only after full union according to the criteria of Heckman et al; and application of a cast brace for a further 2 months.

Although one of the disadvantages of the Ilizarov fixator is that it is bulky and can cause discomfort in some patients, the stability of the nonunion site offered by the external fixator allowed more shoulder mobility to the patient and the whole arm became more functional. This allowed the patients to accept the condition and compensated for the discomfort of the external fixator.

Comparing the preoperative and postoperative range of motion of the elbow was difficult in our series because the movements were from the pseudarthrosis site preoperatively. The need for elbow release at a later stage to
improve the range was not required in our patients as in other series.\textsuperscript{1,16} The mean range of motion of the elbow in this series was 76.25\textdegree, with a Mayo Elbow Performance Score of 78.75 points.

A number of patients, as a result of previous operations, presented with shortening; however, acute shortening intraoperatively during application of the external fixator was never more than 2 cm and was tolerated. The final shortening of the humerus during the last follow-up was 3.12 \pm 0.46 cm on average. This did not appear to affect the clinical or functional outcomes.

Dealing with the pre-existing nerve deficit during the same operation in which the external fixator was applied either by microsurgery or by tendon transfer was not a problem, and the patient was able to participate in the postoperative physiotherapy program with the applied external fixator.

Varus deformity was encountered in 2 patients. This was due to the already severe preoperative deformity and the very low irregular fracture just above the olecranon fossa that required us to keep as much of bone contact together, so we had to accept such deformity.\textsuperscript{10} This deformity was clinically visible in 1 of the patients, who was satisfied with the overall result and did not ask for further surgery.

**Conclusion**

Ilizarov treatment for post-infection nonunion of the supracondylar humerus was shown to be effective, reliable, and tolerated by the patients.

**Disclaimer**

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References