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SECTION II
ORIGINAL ARTICLES

Treatment of Traumatic Radial Clubhand Deformity with Bone Loss Using the Ilizarov Apparatus

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Radial clubhand deformity secondary to atrophic nonunion of an open distal radius fracture with bone loss is a challenging reconstructive problem. Two patients with this deformity had staged reconstruction using the Ilizarov apparatus. After gradual realignment of the distal radius metaphyseal fragment, a proximal to distal bone transport of the radial shaft was done. At completion of the bone transport, the docking site was augmented with autologous iliac crest bone graft. Both patients achieved radiographic union at the proximal and distal ends of the bone transport site and were satisfied with the outcome. At 3 years followup, full finger and elbow mobility were maintained. The wrist had improved appearance with limited painless mobility. Posttraumatic radial club hand deformities with associated bone loss can be treated successfully with staged reconstruction using the Ilizarov apparatus and methodology.

Acquired radial clubhand deformity secondary to postinfectious bone loss after an open distal forearm fracture is an uncommon, yet challenging orthopaedic problem. In addition to malunion of the distal radius fracture, issues of bone loss, persistent infection, lack of functional hand and wrist mobility, limb length inequality, and appearance need to be addressed. Various treatment options exist, including debridement with cancellous [5,15] or structural nonvascularized bone grafting, open reduction internal fixation of the radius with ulnar shortening,[13,14] creation of a one-bone forearm,[3,7,9,12] use of vascularized fibula,[6,8] and bone transport using an external fixator.

Atrophic nonunion with shortening and deformities can be corrected with a well-planned staged procedure using percutaneous techniques such as gradual distraction and simultaneous correction across the nonunion site, followed by bone transport.[2,6] By obtaining a good preoperative evaluation and meticulously planning each step of the corrective sequence, good technical results and improved functional capabilities can be attained using the Ilizarov methodology.[2]

Although bone transport using an external fixator is well described in the English language literature for bone defects after open tibial[4,6] and ulnar fractures,[8] no similar report exists for distal radius fractures. Two patients with acquired posttraumatic radial clubhand deformity with segmental bone loss were treated using a staged technique of bony reconstruction using a circular external fixator. The details of the technique of this staged protocol involving gradual correction of deformity, bone transport of the radius, and subsequent autologous bone transport are described. The clinical and radiographic evaluations preoperatively and at the latest followup of more than 3 years are reviewed.

Treatment Strategy and Surgical Technique

The absence of underlying osteomyelitis is confirmed using standard diagnostic clinical, imaging, and laboratory investigations. In the presence of an active infection, debridement of the involved bony and soft tissue elements

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and the administration of appropriate antibiotics is necessary to achieve a healthy soft tissue bed. Clinical findings such as lack of fever, local drainage, swelling, and erythema in the forearm should be documented. This information is supplemented with plain radiographs and if indicated, advanced imaging studies such as a CT scan or an MRI scan confirming the lack of a sequestrum and soft tissue abscess. Blood work confirming a normalized leukocyte count, sedimentation rate, and C-reactive protein should be done before proceeding with the skeletal reconstruction.

Hand, wrist, and elbow mobility are maximized preoperatively with occupational therapy and ROM exercises. A scanogram and comparison radiographs of the contralateral wrist and forearm are done to assess the limb length inequality and malalignment.

The surgery is done with the patient supine, and the upper extremity resting on the radiolucent hand table. General anesthesia without the use of muscle relaxants is used to recognize the proximity of the motor nerves to the transfixation wires, such as the posterior interosseous nerve at the level of the proximal radioulnar joint. Any twitching of the wrist and finger extensors while inserting the radial neck wire is highly suggestive of the unacceptable proximity of the wire to the posterior interosseous nerve. This technical tip does not replace the need for careful positioning of the limb and detailed knowledge of the local anatomy while inserting transfixation wires. A sterile upper arm tourniquet is applied, but not inflated and intraoperative fluoroscopy is used.

A three-stage approach is described. The first stage involves gradual distraction across the atrophic radial nonunion site. A reference wire is placed in the distal radial fragment from a volar radial to a dorsal ulnar direction, staying just radial to the radial artery pulse. Using the contralateral distal radius as a template, an appropriate-sized Ilizarov ring is centered over the reference wire at the required radial and volar inclination. Distal fixation is supplemented with a dorsal to volar 3-mm half pin off the reference ring and a half ring across the four metacarpals (excluding the thumb) using a radial to ulnarly directed olive wire.

Proximal fixation consists of a two-ring frame centered over the proximal forearm, at right angles to the long axis of the ulnar shaft. Typical fixation consists of a radial to ulnar reference wire at the level of the proximal radioulnar joint, mounted off the most proximal ring. Proximity of the posterior interosseous nerve should be kept in mind. This motor branch of the radial nerve courses posterolaterally between the two heads of the supinator muscle and may come in direct contact with the neck of the radius. After emerging from the supinator, the nerve passes distally over the origin of the abductor pollicis longus to reach the interosseous membrane. Supination of the forearm displaces the nerve further posterolaterally while placing a proximal radioulnar reference wire.

Two additional half pins are placed – one dorsally into the proximal ulna off the proximal ring and the other in the midshaft of the radius off the middle (transport) ring. Two translational hinges,[16] one volar and the other dorsal (Fig 1) are placed between the proximal and middle rings, on the ulnar side, at the level of the atrophic radial nonunion. A distraction rod is placed on the radial side between the proximal and distal ring constructs. Dynamic slings to individual digits are suspended through elastic bands off a plate connected to the metacarpal half-ring through two threaded rods. The patient can be discharged home later the same day, if comfortable. No acute distraction is done. Regular occupational therapy is started for the fingers and elbow by the second postoperative day.

Starting approximately on the third postoperative day, gradual distraction across the malunion is begun, initially at 1 mm a day. The rate is modulated based on patient comfort, paresthesia, swelling, finger mobility, and radiographs. Appropriate distraction on the three threaded rods can be done to achieve the desired radial length and inclination. The patient typically is seen every 7 to 10 days and periodic radiographs of the wrist and forearm are taken. He or she is provided with a prescription for a 10-day course of an oral first-generation cephalosporin, and instructed to start taking it at the first sign of pin tract infection.

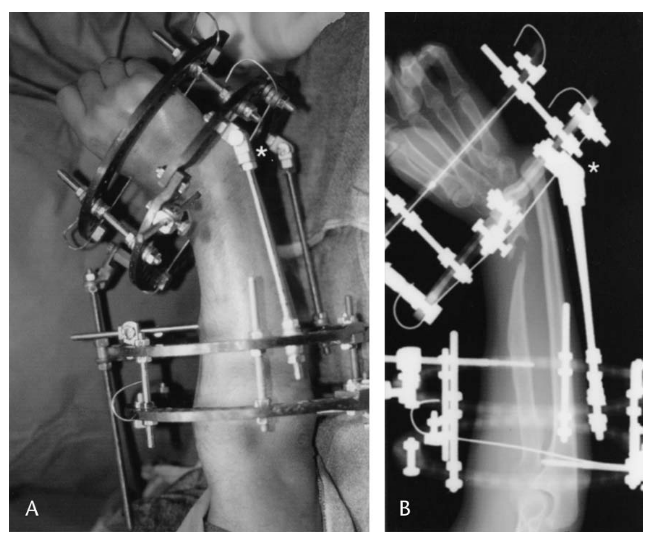

Fig 1A–B. A 23-year-old man (Case 1) presented with an acquired radial club hand deformity 3 years after an open distal radius fracture that resulted in severe bone loss and deformity. (A) The intraoperative clinical photograph and (B) radiograph show the application of an Ilizarov external fixator with hinges (*) between the proximal and distal ring constructs.

Once the desired radial position and length are achieved, the second staged procedure is scheduled. This involves a proximal to distal bone transport of the radius.

With the patient under general anesthesia, a second half pin is added in the middle third of the radius, mounted off the middle (transport) ring and another ulnar half pin is added to the proximal ring. A percutaneous low-energy multiple drill hole osteotomy is done in the proximal shaft of the radius. This is done under fluoroscopic guidance, using a 2.8-mm drill bit and tissue protector, followed by a thin ¼-inch osteotome to complete the osteotomy. As outlined earlier, one needs to give special attention to the proximity of the posterior interosseous nerve to the proximal radius, and take all precautions necessary to safeguard the integrity of this nerve. Although not done on the two patients reported here, a formal open approach to the radial neck may allow for a safer method of doing the proximal radial osteotomy.

Four equally-spaced threaded rods are passed through the three full rings, and the previously placed threaded rods and hinges are removed. Conical washers or plates or both can be used for minor angular and translational adjustments between the rings, if needed.

The patient usually goes home the same day, and continues with occupational therapy. The bone transport is started 5–10 days later. Compared with the lower extremity, the forearm bones are smaller in diameter. Often a distraction rate of 1 mm/day is not well tolerated and may lead to hypotrophic distraction callus. Therefore bone transport typically is started at 0.75 mm/day in three installments and the rate is adjusted based on radiographic appearance of the bony regenerate.

After appropriate docking of the transport segment to the distal radius is achieved, the patient is returned to the operating room for the final stage involving autologous bone grafting of the docking site. To avoid the risk of surgical site infection adjacent to the dorsal half pin at the distal radius metaphysis, a limited volar approach to the distal radius is used. The bone edges are freshened and autologous cancellous bone is harvested from the iliac crest is packed into and around the docking site (Fig 2).

No additional manipulation is done, and periodic clinical and radiographic followups are done until the transport and docking sites are healed. The external fixator is then removed, and a long arm cast is applied for 3 weeks, followed by a removable volar forearm splint for protection. The patient gradually returns to full activities, avoiding contact sports for approximately 4 months after external fixator removal.

Case Reports

The review of these two patients' medical records and radiographs was done with IRB approval.

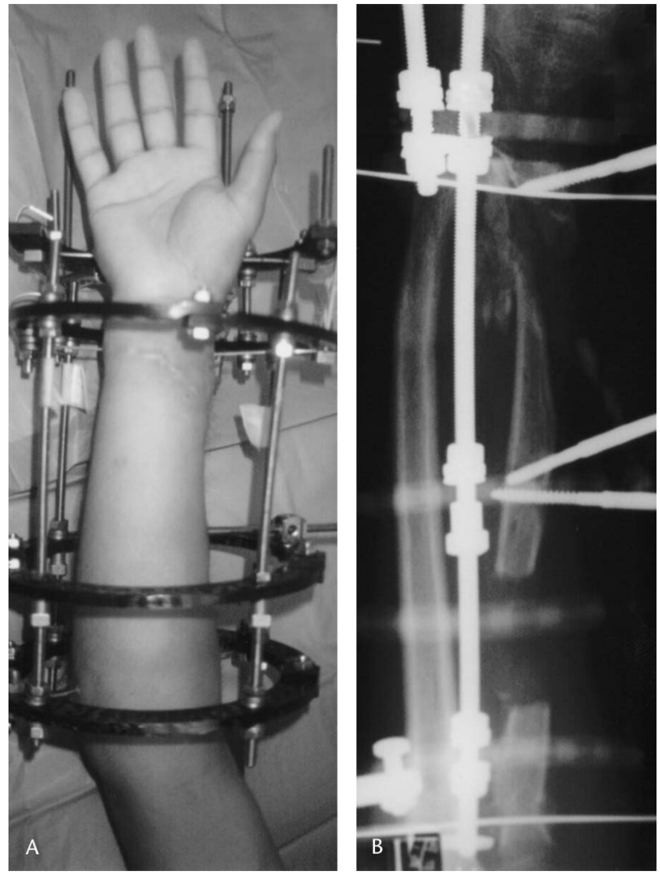

Fig 2A–B. (A) A photograph and (B) radiograph show that after gradual correction of the deformity through the atrophic nonunion, a 4.1-cm proximal to distal bone transport of the radius and subsequent autogenous bone graft of the distal docking site was done (Case 1).

Patient 1

A 23-year-old right-hand dominant man who was a construction worker presented with a progressive right forearm deformity. Approximately 3 years previously, he had an open distal radius fracture and was treated with open reduction internal fixation of the right radius. He had a postoperative infection develop and had hardware removal and debridement a few weeks after the initial surgery. He then wore a cast for 6 months, and had progressive radial deviation of the wrist.

Clinical examination confirmed a radial clubhand type deformity with a prominent distal ulna and multiple healed dorsal and volar forearm incisions. Radial deviation was 60° and ulnar deviation was –20°. Wrist dorsiflexion was 15° and volar flexion was 5°, some of which likely was occurring at the nonunion site rather than the radiocarpal joint. Forearm rotation was less than 5° in either direction. Neurovascular examination was intact and he essentially had full mobility of the hand and elbow.

Radiographs (Fig 1B) confirmed an atrophic malunion of the distal radius with distal radioulnar joint incongruity.

He had application of a multiplanar external fixator with gradual correction of the deformity through the atrophic nonunion site (Fig 2). Eight weeks later, after realignment of the distal forearm, he had a percutaneous proximal radius osteotomy with a 4.1-cm proximal to distal transport of the radius at the rate of 0.75 mm/day. After docking of the proximal radial shaft fragment into the distal radius metaphysis, an autologous iliac crest bone graft of the docking site was done through a limited volar forearm approach.

Radiographic healing of the docking site was confirmed on subsequent radiographs and the external fixator was removed with the patient under general anesthesia. He wore a long arm cast for 3 weeks followed by a forearm fracture brace for daytime use. The external fixator was worn by the patient for 9 months.

At the latest followup, 3 years 2 months after the initial surgery, he was gainfully employed as a construction worker and still was right hand dominant. He denied any wrist or forearm discomfort and was not using any analgesics or orthoses. Full finger and elbow mobility were present. He had limited painless forearm rotation of 40° pronation and 30° supination. Wrist mobility was painless and measured 20° extension and 5° flexion. He was pleased with his overall cosmetic and functional results (Fig 3).

Radiographs confirmed a healed distal radius malunion with complete consolidation of the transport gap. Residual incongruity of the distal radioulnar joint was seen.

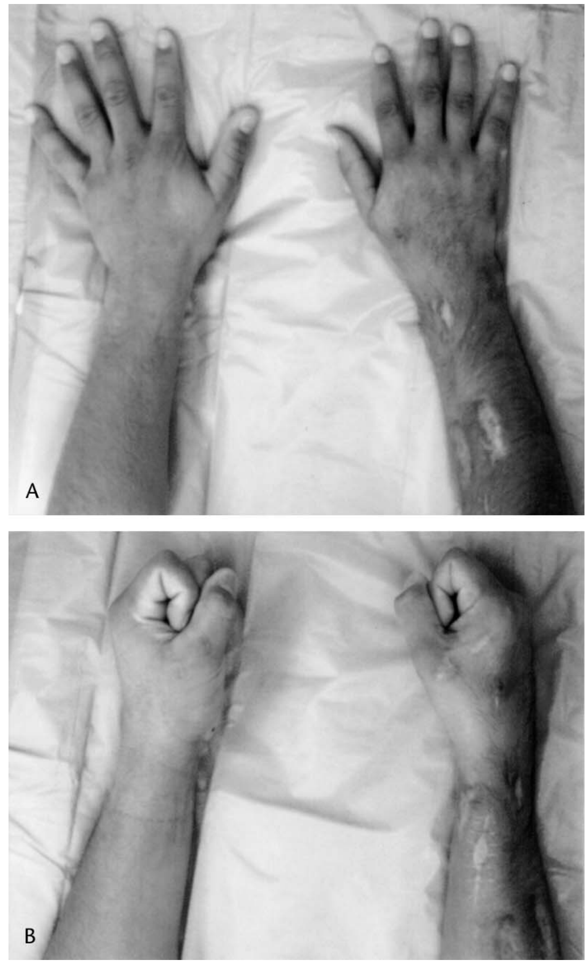

Fig 3A–B. The 3-year clinical followup of Patient 1 shows (A) improved appearance of the right wrist and (B) maintenance of finger mobility. The patient was gainfully employed as a construction worker and remained right hand dominant.

Patient 2

A 12-year-old right-hand dominant boy presented with a progressive radial clubhand deformity and stiffness of the left hand. He had an open fracture of the distal radius approximately 2 years previously and was treated with irrigation and debridement followed by application of a long arm cast. He subsequently had an infected malunion of the distal radius develop requiring multiple debridements, segmental resection of the distal radius diaphysis, and intravenous antibiotics for Staphylococcus aureus osteomyelitis. He presented with a dry wound and limited mobility of his left hand, and initially had occupational therapy to regain hand mobility. Additional clinical followup and laboratory parameters including leukocyte count, sedimentation rate, and C-reactive protein indicated absence of any active infection. Radiographs (Fig 4) revealed a distal radius malunion with distal radioulnar joint incongruity. His distal radius growth plate was visible but narrow.

After attainment of functional hand and elbow mobility, an Ilizarov mulitiplanar external fixator was applied to the left hand and forearm. Volar and dorsal hinges were centered over the ulnar aspect of the distal forearm at the level of the distal radius nonunion. Gradual correction of the radial clubhand deformity with creation of a 5.1-cm gap between the radial fragments was achieved. Seven weeks later, a percutaneous osteotomy of the proximal radius was done instead of a proximal to distal bone transport. The radius was transported at a rate of 0.75 mm/day after a 5-day wait. On radiographs taken at followup, premature consolidation of the radius was diagnosed and a repeat percutaneous osteotomy just distal to the original osteotomy of the radius was done. The remaining transport occurred uneventfully. He subsequently had iliac crest bone grafting of the docking site. He wore the external fixator for 9 months.

On the latest followup, 3 years 1 month after the initial surgery, he denied any wrist discomfort. He was not using

Fig 4A–B. Preoperative (A) AP and (B) lateral radiographs show both wrists of a 12-year-old boy (Patient 2) with left-sided acquired radial club hand deformity after an infected nonunion with bone loss of the distal radius. He was free of infection at the time of presentation 2 years after the initial injury. The incongruency of the left distal radioulnar joint can be seen.

Fig 5A–B. Final (A) AP and (B) lateral radiographs show consolidation of the 5-cm proximal bone transport and the distal docking sites of the radius (Patient 2). Mild loss of radial inclination and radioulnar joint incongruency persists. At 3-year followup, the patient is asymptomatic with full finger mobility and limited nonpainful wrist mobility.

any analgesics or orthoses. Full finger mobility was present. He lacked the terminal 5° elbow extension and had full flexion. He had limited painless forearm rotation of 35° pronation and 25° supination. Wrist mobility was painless and measured 20° extension and 5° flexion. He was pleased with his overall cosmetic and functional results.

Radiographs (Fig 5) confirmed a healed distal radius malunion with complete consolidation of the transport gap. Mild loss of radial inclination and incongruity of the distal radioulnar joint was seen.

DISCUSSION

Atrophic nonunion of the distal radius with forearm shortening and deformity is a challenging reconstructive problem. Percutaneous methods to treat similar deformities in the lower extremity are gaining popularity.[2,4,6,16,17] However, there is no report in the English language literature describing a bone transport of the radius as a part of staged reconstruction for a posttraumatic radial club hand deformity. The current technique was developed as an attempt to provide a comprehensive, safe, and effective means of treating this significant deformity.

Potential disadvantages with this technique include the possibility of neurovascular injury secondary to transfixion wires, pin tract infections, prolonged time wearing the external fixator, and a learning curve. One needs to exercise great caution and vigilance while placing wires and half pins in close proximity to neurovascular structures and tendons in the forearm.

Villa et al[17] reported on 13 patients having forearm lengthening without bone transport using the Ilizarov technique. The amount of lengthening ranged from 2 to 13 cm (10% to 143%). Eleven complications occurred, including three temporary deep radial nerve palsies, one sympathetic reflex dystrophy, one malunion, one delayed union, two refractures, and three cases of mild loss of motion. The total treatment time averaged 7 months with a range of 3 to 19 months.

Ono et al[14] used the circular external fixator for treatment of acquired radial clubhand deformity in one patient. Unlike the current report, they did not use a bone transport technique but instead attempted to distract through the nonunion site at the distal radius. Median nerve neurapraxia and a scanty regenerate requiring two attempts at bone grafting and an ulnar osteotomy with plate fixation complicated this procedure.

Compared with other reconstructive options cited in the literature[1,3,4,7,10,12–15,18] there are several potential benefits of the staged technique described in the current report. These advantages include the ability to safely distract the soft tissues through the atrophic nonunion site over several days and gradually restore length and alignment of the radius. This avoids acute lengthening and stretching of the neurovascular structures including the median nerve and problems with flexor tendon contractures and skin dehiscence. Donor site morbidity associated with harvesting the fibula[1,10,18] also is avoided.

The external fixator can be applied percutaneously and avoids the need for extensive open dissection of the soft tissues. The length of the forearm can be maintained and additional shortening with closing wedge-type osteotomies can be avoided. By using an external fixation device, one avoids permanent internal fixation and the need for an open procedure to remove the hardware. In the skeletally immature patient, the distal radius growth plate can be preserved.

Unlike creation of a one-bone forearm,[3,7,9,12] both bones of the forearm and thereby at least some forearm rotation can be preserved. If the patient has symptoms develop related to distal radioulnar joint incongruity, a salvage option such as a modified Sauve-Kapandji procedure[11] still can be used to restore painless forearm rotation.

Based on my early experience, the potential advantages outweigh the disadvantages in the use of the Ilizarov method for treatment of posttraumatic radial clubhand deformity. The described staged technique seems safe and effective in restoring length and maintaining appearance and function of the limb. The circular external fixator apparatus with its ability to simultaneously correct angular deformity and preserve limb length and transport bone fragments may be a useful adjunct in treating this difficult problem.

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