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Forearm lengthening

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Abstract Eleven cases of forearm shortening underwent lengthening using Ilizarov principles. The aetiology was hereditary multiple exostosis in 6 cases, radial club hand in 2 cases, and trauma in 3 cases. Average age at operation was 15.5 years (range, 9–40 years). At an average follow-up of 3.5 years (range, 2–6 years), there were 8 good, 2 fair and one poor results. Achieved lengthening ranged from 2 cm (10% of the original bone length) to 11 cm (110%). The average healing index was 40 days/cm. There were no neurovascular problems. Complications included pin tract infections in all cases, fracture of the regenerated bone in one case, breakage of a half pin in one case and increased carpal subluxation in another case. Combination of Ilizarov method and hybrid fixation provides a relatively safe method of forearm lengthening with possibility of deformity correction and gradual reduction of chronic dislocations.

Key words Forearm bones • Ilizarov method • Lengthening

Introduction

Moderate discrepancy in length of the upper limbs does not produce a significant functional deficit requiring bone lengthening. However, shortening of a single bone in the forearm usually leads to deformity and limitation of motion. Radial shortening may present with diminished grip strength, prominence of the ulnar head, limitation of pronation and supination, and radial club hand deformity in marked cases. Ulnar shortening can lead to radial head dislocation and loss of rotation [1]. Therefore, the primary indication for forearm lengthening is discrepancy in length between the ipsilateral radius and ulna. The aetiology may be congenital, trauma or hereditary multiple exostosis.

Another indication is marked shortening in cases of longitudinal congenital deficiency, which causes functional and cosmetic problems. The disability is marked during adolescence due to growth of the humerus, which may keep the hand away from the face. The shortening in these cases may be 50% of normal. Marked discrepancy (more than 5 cm) between both forearms is a relative indication as it may interfere with daily activities.

There are a few reports of forearm lengthening using different techniques [1–3], with variable rates of postoperative complications and a relatively short follow-up. Ilizarov method [4], based on the law of tension stress, has improved the results. However, the use of transfixing wires to the forearm has been fraught with a risk of neurovascular injury. This paper represents my experience with the first 11 cases of forearm lengthening using hybrid fixation and Ilizarov principles.

Materials and methods

From 1993 to 2001, 11 cases of forearm shortening (Table 1) were treated by lengthening at Benha Faculty of Medicine. There were 6 males and 5 females. The aetiology was hereditary mul-

Table 1 Clinical characteristics and outcomes of treatment for forearm shortening

Case	Age, years	Gender	Side	Diagnosis	Previous operations, n	Lengthening, cm		Healing index days/cm		Complications	Results
						Radius	Ulna	Radius	Ulna		
1	9	M	L	HME	0	-	3	-	35	PTI	Good
2	13.5	M	L	HME	0	-	4	-	36	Readjustment under GA; PTI	Good
3	10	M	R	HME	1	-	2.5	-	36	PTI	Good
4	9	F	R	HME	0	-	3	-	37	PTI	Good
5	10	F	L	HME	0	-	2	-	35	PTI	Good
6	12	M	R	Radial aplasia	4	-	11	-	43	Ulnocarpal fusion Fracture of regenerated bone Readjustment under GA	Fair
7	27	M	R	Infective nonunion of forearm bones	3	4	4	44	44	PTI Broken half pin	Good
8	14.5	F	L	Radial aplasia	0	-	4	-	42	PTI	Fair
9	40	F	L	Aseptic nonunion of radius	2	3	-	48	-	PTI	Good
10	14.5	F	R	Aseptic nonunion of radius and malunion of ulna	2	3.5	3.5	40	40	PTI	Good
11	11	M	L	HME	10	8	6.5	42	38	PTI Increased carpal subluxation	Poor

L, left; *R*, right; *HME*, hereditary multiple exostosis; *PTI*, pin tract infection; *GA*, general anaesthesia

tiple exostosis in 6 cases, trauma in 3 cases and radial aplasia in 2 cases. Patients with hereditary multiple exostosis had ulnar shortening and dislocated radial head in all cases except one patient who had shortening of both forearm bones.

Corticotomy of the proximal ulna was done with transfixation of the distal parts of both bones, then gradual distraction was applied to reduce the radial head. An olive wire was used in two cases to complete the reduction (Fig 1).

Excision of lower radial exostosis was performed in two cases due to marked enlargement, which led to limitation of motion. Radial osteotomy was done in one case to correct the angulated articular surface.

The traumatic cases included a patient with infective hypertrophic nonunion of both forearm bones with 20° angulation and 4 cm shortening, which developed after 3 previous operations. The time between the trauma and the definitive procedure was 4 years. Ilizarov rings were applied perpendicular to the bones, distraction was applied from the concave side and hinges were placed on the convex side to induce correction of the deformity and bone lengthening concomitantly without osteotomy. The plan was to continue radial lengthening alone, afterwards to compensate for negative ulnar variance. However, the patient was not cooperative, he returned for follow-up after consolidation of the lengthening, and refused further intervention. The second patient had aseptic nonunion of the lower radius after 2 previous operations for an injury suffered 2 years earlier. Osteotomy was performed in the middle part with distraction, and compression was applied at the nonunion site. The third patient had stiff nonunion of the middle part of the radius and malunion of the ulna after trauma 8 years earlier. Ulnar osteotomy was done and distraction was applied from this site and the nonunion.

The average age at operation was 15.5 years with a range from 9 years to 40 years. The average number of previous operations was two (range, 0–10. Lengthening of both bones similarly was performed in two cases, differentially in another case and

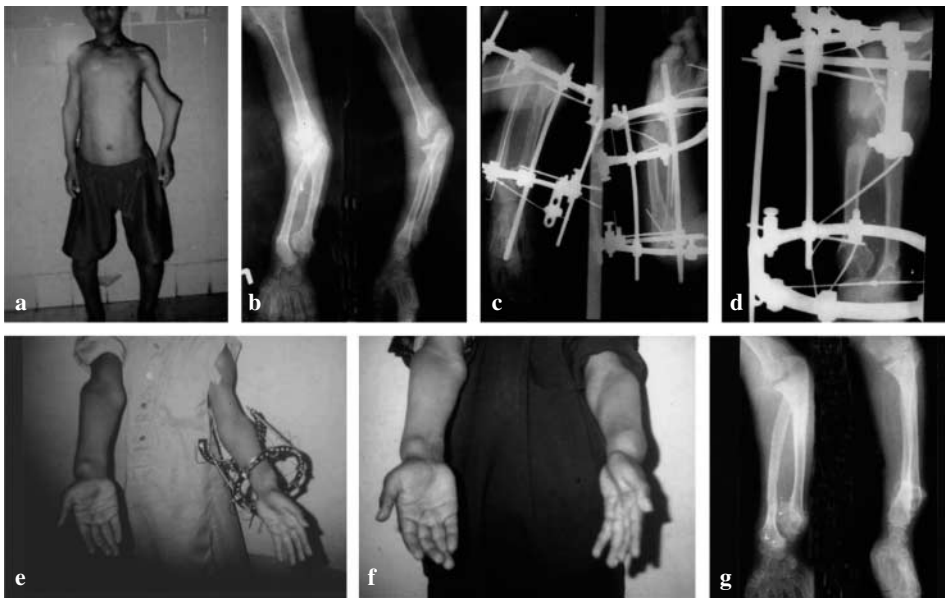

Fig. 1a-g *A 13.5-year-old boy (case 2) with hereditary multiple exostosis with dislocated radial head at the left elbow*. **a** Preoperative photograph. **b** Preoperative anteroposterior and lateral radiographs. **c** Immediate postoperative radiograph revealing osteotomy of the upper ulna and distal radius with K-wire fixation. **d** Radiograph at the end of distraction. **e** Photograph at the end of correction. **f** Photograph after removal of the apparatus. **g** Radiograph after removal

in a single bone in 8 cases including 7 ulnar lengthenings. The operative time ranged from 1.5 to 3.5 hours. The operative procedure included hybrid fixation according to Dahl [5] using 3-mm half pins and 1.5-mm K wires. Proximally, usually we apply 5/8 ring to allow for elbow flexion and another ring is added to augment the proximal fixation if there is enough space. Distally one or two full rings are applied perpendicular to bone. A half ring if needed was applied to the metacarpals to correct the deformity or to guard against its development during large lengthenings. Sub-periosteal osteotomy with minimal dissection was performed after the application of the external fixator except in two cases. After a waiting period of 3–10 days according to the age of the patient, distraction was applied at a rate of 0.33 mm every 8 hours. This rate was modified according to the progression of regenerate in the distraction gap.

There were two cases of radial aplasia. The first case aged 12 years had complete absence of the radius, while the second one aged 14.5 years lacked the distal part. Hand angulation and translation in the two cases were measured [6]. Angulation is represented by the angle between the longitudinal axis of the middle metacarpal and a line perpendicular to the distal articular surface of the distal ulna. Translation is the perpendicular distance between the base of the middle finger metacarpal and the distal continuation of the mid-axis of the ulna.

The results were assessed according to the method reported by Villa et al. [2] with some modifications. This evaluation is based on the achievement of the planned lengthening distance, range of motion of the elbow, wrist and fingers, functional activities and patient's satisfaction. A good result meant achievement of the projected area of lengthening, increased range of motion, improvement of the functional activities and patient satisfaction. If the area of lengthening obtained was ≤1 cm than expected or the range of motion did not change or decreased less than 10% of normal, better functional activities and a satisfied patient indicated a fair result. A poor result denoted more than 1 cm shortening post-operatively, deteriorated range of motion more than 10%, decreased functional activities or patient dissatisfaction.

Results

At an average follow-up period of 3.5 years (range, 2–6 years), there were 8 good, 2 fair and one poor results. Lengthening ranged from 2 cm (10%) to 11 cm (110%) of the original bone length (average, 4 cm). The average healing index was 40 days/cm (range, 35–48 days/cm).

For the two cases with radial club hand, angulation improved from 72° to 48° and from 32° to 2°. Translation decreased from 26 mm to 18 mm and from 33 mm to 28 mm postoperatively.

Complications

Pin tract infection occurred in all cases (100%). A half pin was exchanged under general anaesthesia due to persistent infection in one case. A K wire was removed without anaesthesia for the same reason in another case.

Fracture of the regenerated bone developed in one case after loosening the nuts as a preliminary step before fixator removed. Therefore, the nuts were tightened once more and we waited for 1.5 months until complete consolidation before fixator removal. Readjustment of the frame in the outpatient clinic was performed in two cases. One half pin broke due to trauma after complete bone consolidation in a single case.

Increased carpal subluxation in patient 11 developed after fixator removal. This complication was treated by reapplication of the fixator to the forearm and metacarpals after 6 months and reduction using properly positioned hinges. Then, splintage was applied for 3 months. Howe-

ver, the deformity gradually recurred. This case was graded as a poor result despite the fact that the parents were satisfied with the final outcome due to diminution of the range of motion. Ulnocarpal fusion occurred in one case of complete radial aplasia.

Discussion

Forearm deformities are common in hereditary multiple exostosis. These deformities comprise ulnar shortening, radial head dislocation, radial bowing, lower radial articular deformities and carpal slip [5]. These deformities develop gradually, are well tolerated and lead to little loss of function [7]. The surgical interference was planned after serious discussion with the patients and their families. Actually, their main concern was focused on cosmetic appearance especially the dislocated radial head and sometimes pain due to large osteochondorma. Conventional treatment consist of excision of the radial head, which may be followed by numerous complications [8]. Indirect reduction using gradual ulnar lengthening seemed to be a satisfactory solution [1]. Overcorrection by 0.5–1 cm was performed in the younger patients (cases 1, 3, 4, 5) as recurrence of the deformity was anticipated (Fig. 2) [9]. This technique had been used in 5 cases. An olive wire was used to complete the reduction in two cases. The range of motion improved in all of them with cosmetic improvement. However, in Dahl's series [5], there was permanent loss of motion in 3 of 7 patients treated by gradual radial head reduction, possibly because they did not attempt to complete reduction of the radial head but just improved its position. Besides, loss of forearm rotation was particularly severe in a single case when a bulbous distal ulnar osteochondroma impinged against the distal radius during ulnar lengthening.

Shortening of the forearm and reduced digital function are the major factors that compromise function in an extremity with radial club hand [10]. In the patients treated with wrist centralisation, the total active digital motion was significantly greater compared with that of untreated patients. Besides, when the hand is aligned with the ulna, the length of the extremity from the axilla to the finger tips naturally is augmented [10]. During adolescence, the humeral length increases, which may move the hand away from the patient's face and comprise the function due to forearm shortening. The literature of radial club hand was focused on programs designed for babies diagnosed at birth. Many authors recommended centralisation before the age of one year. Others considered the age of three years as the limit, as the distal ulnar epiphysis broadens considerably, making the operative procedure more difficult [11]. Older children, especially those over 12 years, have already developed functional patterns of use of the radially deviated hand [12]. Therefore, two cases reported here of patients aged 12 and 14.5 years were beyond the age for conventional treatment. In addition, late interference in these cases was fraught with interference of function. We have been able to partially correct the wrist deformity using distraction. Besides, it was possible to correct the ulnar deformity and lengthen the forearm up to 110% of the original length. At last follow-up, there was mild limitation of the range of motion. However, there was functional improvement and they were graded as fair results.

Villa et al. [2] in 1990 reported posterior bowing at the level of the proximal ulnar corticotomy site during lengthening of the ulna in two cases with radial club hand deformity. They recommended positioning the proximal ring in 10° of extension to guard against angulation. The application of a half pin perpendicular to the proximal ulna in our cases increased frame stability in this plane and may have prevented the development of this deformity (Fig. 3).

Marked carpal subluxation and limitation of wrist movements developed in one case, which was graded as a poor result despite the parents' satisfaction. In this case, differential lengthening of the radius and ulna was performed and fixation of the metacarpals was applied. After fixator removal, displacement of the carpus occurred

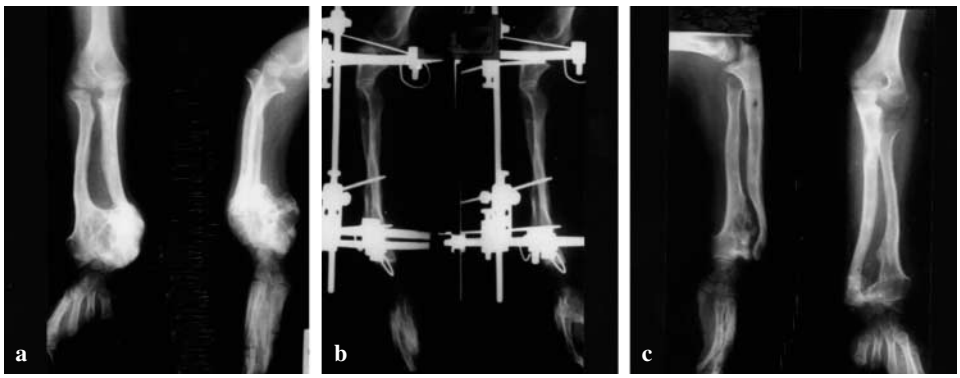

Fig. 2a-c *A 10-years-old boy (Case 3) with hereditary multiple exostosis, dislocated radial head at the right elbow and very large exostosis of the lower radius*. **a** Postoperative anteroposterior and lateral radiographs. **b** Postoperative view at the end of distraction and exostosis removal. **c** Radiographs at the 2-year follow-up showing overlengthening of the ulna

Fig. 3a-g *A 12-year-old boy (case 6) with bilateral radial aplasia*. **a** Preoperative photograph. **b** Preoperative radiographs. **c** Postoperative radiographs. **d** Radiograph before fixator removal. **e** Radiographs at last follow-up (after 6 years) of the operated and nonoperated sides. **f** Photograph at last follow-up. **g** Photograph showing functional activities

gradually. The marked carpal subluxation may have been prevented if wrist arthrodesis was done first. Therefore, stability of the wrist joint is a prerequisite before forearm lengthening in such cases.

The healing index was 55 days/cm for the radius and 50 days/cm for the ulna in a series of ten patients age 3–13 years who underwent forearm lengthening by callotasis using unilateral fixator [3]. The healing index in the present report was only 40 days/cm despite the older age of the patients (9–40 years). The low healing index may be due to the use of low energy osteotomy using an osteotome with minimal soft tissue dissection, while most of the cases reported by Abe et al. [3] underwent osteotomy using an oscillating saw and acute correction of deformity. They also had high rates of callus fracture (50%), delayed consolidation (10%) and absence of callus formation (10%), which required bone grafting. Gradual correction of deformities, applying low energy osteotomy and the application of a ring fixator with more stability may explain the present low rate of regenerative complications.

Successful treatment of post-traumatic tibial pseudarthrosis in children and adults using distraction osteogenesis has been reported [13, 14]. In this study, patient 7 had a history of 3 unsuccessful operations for an open fracture of both forearm bones. Preoperatively, examination revealed stiff, hypertrophic nonunion of the middle part of both radius and ulna, 20° angulation and 4 cm shortening. According to Ilizarov [4], gradual distraction alone can stimulate regenerative formation in stiff non-union. Therefore, we achieved consolidation without any real surgical incision.

In conclusion, forearm lengthening can be a safe procedure with the application of Ilizarov principles and hybrid fixation.

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