Fractures of the Radial and Ulnar Shafts In the Pediatric Patient

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A. Anatomic factors
There are specific muscle forces that act on the radial shaft both proximally and distally. The effects of these forces is greatest when the ulna remains intact. These need to be considered when managing fractures of the shaft on the radius (Fig. 1).

B. Classification.
The best classification that impacts on determining the method of treatment is that based upon the degree of biomechanical failure. There are three degrees of biomechanical failure (Fig. 2).

a. Plastic Deformation
In this case the ulna has been subjected to a bending force greater than the elastic limit of the shaft but less than the “fracture point”. This results in a permanent deformity because there has been structural realignment of the microscopic units.

b. Greenstick failure
The bending force applied to this radial shaft was sufficient to cause failure of the cortex on the tension side. Because much of the initial force was dissipated in exceeding the elastic and plastic limits, there is not enough to complete the fracture of the cortex on the tension side. This cortex remains plastically deformed. There is usually enough residual stability so that the fracture fragments are subjected to only angulatory and rotational deformities.

c. Complete fracture
If sufficient force is applied both cortices will fail resulting in a complete separation of the fragments. As a result, there is no intrinsic stability to the deforming forces of the forearm muscles. There is most prominently a shortening of the fracture fragments.
C. Treatment.

1. Plastic deformity. These fractures require a prolonged force applied over a fulcrum placed at the apex of the deformity. This is necessary to realign the internal osteon bone units (Fig. 3).

The end-point for the correction is when the clinically apparent aspect of the deformity has been corrected and the range of forearm rotation has been re-established. There will not be a total reestablishment of the anatomical alignment on the radiographs.

2. Greenstick fractures.
   a. Two deformities. The deformity with greenstick fractures usually is a combination of both rotational and angular components.
   b. Rotational-angular relationships. These two components can be combined into two distinct combinations.
      1.) Apex-volar with supination of the distal fragment (Fig. 4a).
      2.) Apex-dorsal with pronation of the distal fragment (Fig. 4b).

Figure 3. Reduction of plastic deformity. The apex of the angulation is placed over an object to serve as a fulcrum. In the opposite direction constant pressure is applied for a few minutes to each end of the shaft. This gradually corrects the plastic deformity.

Figure 4. Greenstick angular-rational relationships. a. Supination-apex dorsal. With this combination there is rotation of the distal fragment into supination producing a concurrent dorsal angulation at the fracture site. This is the most common greenstick fracture pattern. b. Pronation-apex volar. In this combination the distal fragment is rotated into pronation producing an apex volar angulation at the fracture site.
c. Treatment. To reduce these fractures both the angular and rotational components need to be corrected. Usually when the rotational component is corrected, the angular component is corrected as well.

1.) The apex-volar/supination combination is usually corrected by pronating the distal fragment (Fig. 5).

2.) The apex-dorsal/pronation combination is corrected by supinating the distal fragment (Fig. 6).

d. Post-reduction immobilization. These fractures are placed for 4 weeks in long arm casts with the elbow flexed and the appropriate rotational correction. Following this, if the alignment has remained satisfactory, the forearm can be immobilized with a short arm cast for another 4 weeks. Following removal the cast, the forearm is then usually protected for another month with a removable splint.
3. Complete fractures.
   a. Characteristics. There are many factors that need to be considered when treating the complete fracture patterns. These include:
   1. Muscle forces more of a deforming factor
   2. Greater soft tissue injury,
   3. There is almost no intrinsic stability to prevent linear, rotational and/or length malalignment.

   b. Rotational alignment. Determination of rotational malalignment may require a very careful evaluation of the pre and post-reduction images. Sometime the only clue may be a difference in the opposing diameters of the fracture surfaces. It needs to be remembered that the bicipital tuberosity and the radial styloid must be 180° to each other.

   For this reason the alignment of the injury images may give a clue as to the correct post-reduction position (Fig. 7).

   ![Figure 7. Rotational malignment](image)

   a, b. Injury AP and Lateral image of a 7 year old male who sustained complete mid-shaft fractures of both the radius and ulna. c, d. This fracture was manipulated and the forearm was placed in neutral rotation with the elbow flexed 90°. The linear alignment appears satisfactory. There is 90° rotation as evidenced by the differences in the diameters of the opposing fracture surfaces. This fracture required to have the distal fragments re-rotated into supination. Note on the initial images the proximal radius was rotated into supination.

d. Loss of reduction. It is not unusual for shaft fractures to develop late angulation. This is especially a problem in small children with short fat forearms. In these cases, placing the upper extremity in a long arm cast with the elbow extended may prevent the development of late angulation. This is especially indicated if this is the second manipulation. To be effective the cast has to be well molded in the supracondylar area. In addition since the cast will have a tendency to migrate distally, the thumb needs to be incorporated into the cast to prevent the edge of the cast form rubbing against the thenar eminence (Fig. 27).
d. Limits of acceptability. Price and his co-workers over the years have determined guidelines for acceptable limits of reduction. They are somewhat age dependent (Table I).

![Figure 27. Long arm elbow extension cast.](image)

**Figure 27. Long arm elbow extension cast.** a. X-rays taken two weeks post-reduction demonstrating pronation of the distal fragment (grey arrow) and 20° of apex posterior angulation. The elbow has slipped up into the cast (white arrow and dotted line). b. Clinical appearance with an unsightly posterior prominence. c,b. The fracture alignment was corrected by re-manipulating and placing the forearm in a long arm cast with the elbow in extension. d. Clinical view of the long arm cast.

<table>
<thead>
<tr>
<th>Table I Limits of Acceptability</th>
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<tr>
<td><strong>Angulation</strong></td>
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<tr>
<td>Less than 9 years</td>
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<td>9 years and greater</td>
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<tr>
<td><strong>Rotation</strong></td>
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<tr>
<td>Less than 9 years</td>
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<tr>
<td>9 years and greater</td>
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<tr>
<td><strong>Shortening</strong></td>
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<tr>
<td>Usually not a problem</td>
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<tr>
<td><strong>Interosseous impingement</strong></td>
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<td>An unpredictable indicator</td>
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e. Operative Indications. The operative indications are pretty much the same as with fractures in the other areas of the radius. They include: 1. Open Fractures, 2. Associated Soft Tissue Injuries, 3. Inability to Maintain a Closed Reduction, 4. Ipsilateral fractures, 5. Re-fractures (relative). One almost absolute indication is where the ulnar shaft remains intact. In this instance, it is very difficult to control the position of the radius non-operatively.

f. Surgical procedures. In the pediatric age group, Elastic Intramedullary Nail Stabilization has proved to be an effective method of surgical management. This has been true especially for the Grade I open fractures (Fig. 28).
Intramedullary stabilization. a,b. Injury images of a 6 year old female with a Grade I open fracture of the ulna shaft. It had minimal contamination. c. Following debridement, both fractures were stabilized with K-wires placed intramedullary. This allowed the wound to be easily inspected in addition to facilitating early motion.

Radial Shaft FX IM fixation

Intramedullary fixation of children's diaphyseal forearm fractures is becoming the surgical technique of choice, in those cases that warrant surgical intervention. This method offers both technical advantages and patient benefits over alternative techniques and implants that have been used in the past. We present a two-centre study assessing the outcome of either Kirschner wires or elastic stable intramedullary nails (ESIN) as the method of fracture stabilisation in such diaphyseal forearm fractures. A total of 36 children underwent K-wire fixation and 24 children underwent ESIN fixation. All fractures united with no resultant subjective disability. The complication rate following K-wires was 16% and that following nail fixation 9%. Loss of forearm rotation was documented in four children in the K-wire group and three children stabilised with nails. These results confirm an excellent outcome following intramedullary fixation. We have demonstrated no difference in outcome between K-wires and ESIN, although the nails do offer some theoretical advantages.

This retrospective study evaluated the results of plating versus intramedullary fixation in the management of unstable, diaphyseal fractures of both bones of the forearm in children. Of the 64 children included, 45 were treated with intramedullary fixation, 19 with plating. Only A3 forearm fractures of the middle third or the transition zones were included; Galeazzi, Monteggia, and Greenstick fractures were excluded. Full radiological follow-up to union was obtained in all cases and 60 patients returned for clinical evaluation 32.3 months (plating) and 20.6 months (intramedullary fixation) after injury. The functional outcome did not differ significantly. In the intramedullary fixation group, we found two major complications (refracture and non-union) and nine minor complications (two delayed unions, three thumb neuropathies, two rod migrations, two skin infections). In the plate group, there were two major complications (refractures) and one minor complication (thumb neuropathy). Plating resulted in significantly worse results for surgical approach, operating times, frequency and duration of hospitalisation, and cosmetic outcome. In conclusion, intramedullary fixation of an unstable forearm fracture in skeletally immature patients is a safe, child-friendly, minimally invasive technique that allows early functional treatment with an excellent functional and cosmetic outcome.


Between January 1980 and December 1989, 133 consecutive patients were treated for a fracture of the shaft of one or both forearm bones (134 forearms in total). All fractures were stabilized with AO/ASIF 3.5 mm stainless-steel dynamic compression plates. The 1 year follow-up rate was 99 per cent; the long-term follow-up rate was 92 per cent (the mean long-term follow-up was 10.2 years (range, 2.7-15.2)) so there were 96 men and 35 women, with an average age of 37.5 years (range, 16-63). Twenty-two per cent of the forearms had open fractures, 26 per cent of patients had sustained multiple injuries and 19 per cent had a head injury. One hundred and twenty-seven of 132 forearms (96.2 per cent) underwent problem-free consolidation before 6 months. Two delayed unions and two non-unions required reoperation. There was one superficial infection in a patient with a closed fracture. Plates were removed from 70 patients (53 per cent) at a mean of 33.1 months (range, 8-122) after the first operation. In this group, there were three refractures (4.3 per cent) occurring at a mean of 8.7 months (range, 0-14) after plate removal. This study confirms the safety and efficacy of plate osteosynthesis in forearm shaft fractures: a high union rate and low complication rate can be anticipated. The data presented form the most reliable information on this subject currently available with the longest and highest rate of follow up of a sufficient number of patients using a single implant system in a single institution.

INTRODUCTION: This study analyses the results of 50 displaced diaphyseal forearm fractures in children treated with flexible intramedullary nailing.

METHODS: Between 1999 and 2002 we treated 50 children aged between 5 and 15 years, with diaphyseal fractures of the forearm using Flexible intramedullary nailing (FIN). Both bones were fractures in 45 patients, radius only in 4 and ulna only in 1. The indications for fixation were instability (26), re-displacement (20), and open fractures (4). RESULTS: 24 patients were reduced closed, followed by nailing, while 26 fractures required open reduction of either one bone(16 cases) or both bones(10 cases) prior to nailing. Bony union of all fractures was achieved by an average of 7 weeks (range 6 weeks to 4 months) with one delayed union. Pronation was restricted by an average of 20 degrees in 9 patients. Two patients developed post operative compartment syndrome requiring fasciotomy. Three patients were lost to follow-up. INTERPRETATION: FIN led to early bony union with acceptable bony alignment in all 47 patients available at final follow-up. We therefore recommend FIN for the treatment of unstable diaphyseal forearm fractures in children.


OBJECTIVES: This retrospective review evaluates the efficiency of standard intramedullary Kirschner wires for the treatment of unstable diaphyseal forearm fractures in children. DESIGN: Retrospective review. SETTING: Large teaching and research hospital in Turkey. PATIENTS: Thirty-one patients with diaphyseal forearm fractures were treated by surgical method between 1988 and 1998. The mean age was 12.3 years (range 7 to 17 years). The mean follow-up period was 4.2 years (1 to 6.2 years). INTERVENTION: The method of treatment of each forearm fracture was open reduction and intramedullary Kirschner wire fixation using a mini-incision. MAIN OUTCOME MEASUREMENTS: Fracture union, growth disturbance of the forearm, and complications were evaluated. RESULTS: Union was obtained in all cases except two (6.4 percent). No forearm inequality was observed. CONCLUSIONS: Intramedullary fixation is a useful technique for unstable shaft fractures of the forearm in children that can not be treated by closed manipulation.


Results of 29 forearm bones shaft fracture treatment with 3.5mm self compressive plate in 26 patients aged 18-64 (mean 33) are presented. Open reduction with 3.5mm self compressive plate fixation has been performed in all cases. Anderson et al criteria were used to assess functional and radiological outcome. Excellent and good functional results were achieved in 25 cases, one was rated fair, no poor results were observed.
We retrospectively reviewed 16 children younger than 13 years with 17 fractures of the shafts of the radius or ulna or both who had undergone an open reduction-internal fixation (ORIF). ORIF was performed when a closed reduction was deemed unacceptable in 14 radius fractures and for three unstable open fractures of the radius. The average age was 9.4 +/- 2.3 years (range, 5.0-12.5). Of the 14 fractures with an unacceptable closed reduction, soft-tissue interposition was encountered in seven. Fixation was secured by plates and screws, percutaneous Steinmann pins, or intramedullary Steinmann pins. There were no delayed unions or nonunions, no infections, and no neurovascular injuries. The average follow-up was 12.3 months; all 17 fractures had excellent results (forearm rotation loss of < 10 degrees). Our study indicates that excellent results can be expected with no increased risk of complications if the treating physician elects to proceed with an ORIF in a pediatric forearm fracture with proper indications.

Twenty-six skeletally immature patients with 27 displaced, diaphyseal forearm fractures treated by open reduction and internal fixation were reviewed. The mean age of the patients at the time of injury was 11.5 years (range, 4-15). Indications for surgery included open fractures (10), unacceptable closed reduction (14), and loss of reduction (three). Anatomic or near anatomic fixation was achieved with either compression plates or intramedullary wires. The average time to union was 3.5 months. The average length of follow-up was 39 months (range, 9-98). All but three patients
regained full range of motion equal to that of the uninjured extremity. Three complications occurred, including one deep infection resulting in delayed union, one nonunion with failure of hardware, and one proximal radioulnar cross-union. We conclude that open reduction and internal fixation is indicated and can be safely performed in children with open or unstable or both-bone forearm fractures when closed treatment methods have failed. Fixation is reliably achieved with compression plating or intramedullary nailing.

Remember !!
Most Forearm Fractures Can Be Treated NON-OPERATIVELY*