Percutaneous K-wires Fixation of Pediatric Both Bone Forearm Fractures: An updated Overview

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ABSTRACT

Forearm fractures are the most common fractures in children, representing 40 to 50 percent of all childhood fractures. In one large series, forearm shaft fractures of the radius ranked as the third most common fracture after distal radial fractures and supracondylar humeral fractures. In addition, midshaft forearm fractures are the most common sites for refracture in children and among the most common sites of pediatric open fractures.

The rate of forearm shaft fractures in school-age children (more than 5 years old) is more than double that in toddlers (1.5 to 5 years old). Age also may have an effect on injury severity. In boys there is a bimodality peak, the first at approximately age 9 years and the second at approximately 13 or 14 years of age. Girls show a single peak at approximately 5 or 6 years.

Because of numerous differences in both treatment and prognosis, shaft fractures are considered to be clinically distinct from fractures of the distal (metaphyseal fractures and physeal fractures) and proximal (radial neck fractures and physeal fractures) ends of the same bones. Many experienced clinicians have pointed out the increasing level of treatment difficulty as the level of forearm fracture moves proximally and more proximal fractures tend to occur in older patients. The goal of treatment of forearm and distal radius injuries is to facilitate union of the fracture in a position that restores functional range of motion to the elbow and forearm.

There is a subset of patients in whom surgical intervention is indicated. The most common indications for surgery are failure of closed reduction, open fractures, and fracture instability. When operative intervention is indicated different techniques can be employed such as intramedullary nailing, osteosynthesis with plate and screw fixation and external fixators. Intramedullary nailing has been shown to produce excellent clinical results and in contrast to plate fixation is considered as a minimal invasive procedure.

Keywords: Percutaneous; K-wires; Fractures

Pediatric both bone Forearm Fractures

Diaphyseal forearm fractures, commonly referred to as both bone forearm fractures (BBFF), are among the most commonly treated injuries in children and adolescents, representing 5% of all pediatric fractures. Despite a decrease in overall injury rate during childhood, incidence of
BBFF in children has steadily increased over the past decade. The mainstay of treatment in this population remains conservative management through closed means and casting. [1]

As long as angulation, rotation, and length fall within acceptable parameters, long arm casting is a successful and low-risk treatment option, and children generally do not develop significant elbow stiffness after prolonged cast immobilization. Over the past decade, however, there has been an increasing trend in operative management of these fractures. This trend is particularly true in the adolescent population (ie, patients who are 10-16 years of age) due to less remodeling potential. [2]

Successful treatment of BBFF results in restoration of anatomic alignment and functional range of pronosupination. The determination of treatment method and acceptable alignment are dependent upon several factors, including patient age, mechanism of injury, fracture pattern, and comorbidities, but is perhaps most largely influenced by the remodeling potential of the individual patient. In general, remodeling potential decreases with age as well as increasing distance of the fracture from the more biologically active physes of the distal radius and ulna. Current surgical treatment options include both flexible intramedullary nails (FIN) and open reduction internal fixation (ORIF) with rigid plate fixation. Both methods have advantages and disadvantages, but the literature has failed to demonstrate superiority of 1 method over another. The purpose of this article is to review the current evidence for treatment of pediatric BBFF and provide clinical recommendations for care of these common injuries. [3]

A study using the 2010 NEISS report, estimated in children aged 0 to 19 years, 5,333,733 emergency room (ER) visits, of which 788,925 (14.7%) were fracture related. Forearm fractures account for 17.8% of all fractures in pediatric age. [4]

Other study found forearm fractures to be significantly more frequent in school age children (65%) and adolescents (63%) compared to infants (42%) and preschool children (50%). Both forearm bones were fractured in 50.1% of cases of forearm injuries and there were significantly more males than females (63.6% vs. 36.4%). [5]

Understanding pediatric forearm anatomy offers important guidelines for treatment in the nonoperative and operative settings. Anatomically, the ulna is relatively straight and static, it plays a more important role in maintaining forearm stability, especially when subjected to buckling and torsional stress. Radius and ulna are attached by the proximal annular ligament, by the interosseous membrane along the diaphysis, and distally by the ligaments of the distal radioulnar joint and triangular fibrocartilage complex. The radial bow, an apex lateral bend in the radius, increases the range of pronation. The interosseous membrane is higher strain proximally in neutral and pronation and is higher strain distally when in supination. The distal radial and ulnar growth plates are responsible for 75% and 81% of the longitudinal growth of each bone, respectively. This polarization of growth shows why distal fractures demonstrate a higher remodeling potential than do fractures closer to the elbow. Additional remodeling can also be attributed to elevation of the thick osteogenic periosteum after fracture. Pediatric forearm fractures typically follow indirect trauma, such as a fall on an outstretched hand coupled with a rotational component. Single bone forearm fractures are far less common and are typically the result of direct trauma. However, single bone forearm fractures of the ulna or radius should always raise suspicion for a Monteggia or Galeazzi fracture dislocation.
respectively. Understanding the deforming forces is essential to the reduction in both-bone forearm fractures (Fig. 1). [6]

The bicep attaches proximally at the bicipital tuberosity on the anterior medial radius. The supinator and bicep flex and supinate the proximal fragment, when there is a proximal fracture. Fractures that happened in the middle third are altered by the pronator quadratus more distally, which pronates the distal fragment, meantime the impact of bicep on the more proximal fragment is negated by the pronator teres, causing the fragment to remain in neutral position. The brachioradialis dorsiflexes and deviates radially the distal fragment during a distal third fractures. [7]

The acceptable degree of angulation at initial reduction at different segments of the forearm bones is still an issue. The remodelling capability is known to be better for younger children. As the child grows, this advantage may diminish, and the remodelling potential may not be sufficient to correct the deformity fully before skeletal maturity. The question now is how much time before skeletal maturity is considered enough for the angulation to be satisfactorily corrected by remodelling with a favourable functional outcome. [7]

There is also some controversy regarding the functional outcome of forearm fractures in children. The unsatisfactory functional outcome documented before the skeletal maturity might not be accurate since the bone has not stopped remodelling. The angulation may not need to be fully corrected to obtain good or excellent functional outcome. Children with some residual angulation may still be able to have a good outcome at skeletal maturity. [8]
Aetiology and Classification

In most cases, forearm fractures in children are sustained as the result of a fall on an outstretched arm. Other mechanisms of injury can include a direct blow such as during sporting activities. Non-accidental injury should always be considered and if there is any doubt as to the mechanism of injury, early involvement of the paediatric service is mandatory. [10]

Olecranon Fractures

Isolated olecranon fractures in children are uncommon. Separation of the olecranon apophysis has been reported but it is rare. Fractures involving the metaphyseal part of the olecranon in the paediatric population tend not to occur as the result of triceps muscle avulsion but are more commonly the result of a fall onto an outstretched arm with the elbow locked in extension. In this position, the olecranon is trapped in the olecranon fossa and if the elbow collapses into valgus or varus, the olecranon is sheared off. Associated injuries such as lateral condyle or radial neck fractures are common and need to be excluded by careful examination of the radiographs (Fig. 2). [11]
Fig. 2: Olecranon fracture with associated radial neck fracture dislocation. [12]

Olecranon fractures have been classified (Table 1) to take account of both acute fractures and chronic repetitive injuries to the apophysis as the result of sporting activity, in particular tennis, gymnastics or baseball pitching. (7)

Table 1: Classification of olecranon fractures [13]

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>I</td>
<td>Apophysitis</td>
</tr>
<tr>
<td>II</td>
<td>Stress fracture</td>
</tr>
<tr>
<td>IIIa</td>
<td>Apophyseal avulsion</td>
</tr>
<tr>
<td>IIIb</td>
<td>Apophyseal – metaphyseal fracture</td>
</tr>
</tbody>
</table>

Radial Head and Neck Fractures

Radial head and neck fractures account for approximately 5% of all paediatric elbow fractures. In children, fractures at the proximal end of the radius tend to occur through the neck and, in contrast to adults, less commonly involve the radial head. Fractures can occur in isolation or may be associated with an elbow dislocation or olecranon fracture. Radial neck fractures can involve the physis (Fig. 3) and when the physis is involved, the most common pattern is the Salter & Harris type II fracture. [14].
Treatment and Indications for Surgery

The treatment of the individual fractures described above will vary in many cases. Paediatric forearm fractures can be managed conservatively with surgery only indicated for the displaced fractures. [15]

**Olecranon**

The majority (80%) of fractures are undisplaced and can be managed with a plaster cast alone. The elbow should be immobilised for a period of 3–6 weeks at 90°, depending on the age of the child. [16]

**Indication for Surgery**

Displacement at the fracture site with loss of active elbow extension.

**Post-Operative Care**

The arm is protected in an above-elbow cylinder with the wrist free. Early mobilisation of the fingers and wrist is encouraged. The cast is maintained for a 4–6 week period. The longitudinal K-wires should be removed early to avoid prolonged compression across the apophysis and are usually removed 8–10 weeks after surgery. [16]

**Radial Neck**

Many radial neck fractures are undisplaced and can be managed conservatively and up to 30° of angulation at the radial neck is acceptable. Early mobilisation with a collar-and-cuff sling for comfort should be encouraged. The sling can generally be discontinued after a period of 2–3 weeks, as comfort allows. A return to normal function can be anticipated although full elbow extension may take a month or two to recover. [17]

**Indication for Surgery**

More than 30° of angulation at the radial neck requires surgical intervention. [17]

**Post-Operative Care**

A radial neck fracture that has been stabilised with a direct wire through the soft tissues at the elbow will need to be protected in an above-elbow plaster cast to avoid loosening the wire though forearm rotation. The cast is maintained for a 4 week period and at that stage the K-wire can be removed in the clinic. Radial neck fractures stabilised with a retrograde intramedullary wire do not require a cast and early mobilisation of the elbow and arm is encouraged. The buried wire will need to be removed once the fracture has united as a day-case procedure under general anaesthetic. Typically this will be 2–3 months after the initial surgery.
Fig. 3: Radial neck fracture – Salter & Harris Type IV [14]

Radial neck fractures are classified according to the angular deformity and displacement. A number of classifications have been described and most are based on the degree of angulation of the head in relation to the long axis of the radius (Table 2). [18]

Table 2: Classification of radial neck fractures [18]

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>0° with translation</td>
</tr>
<tr>
<td>Grade 2</td>
<td>&lt;30°</td>
</tr>
<tr>
<td>Grade 3</td>
<td>30–60°</td>
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<tr>
<td>Grade 4a</td>
<td>60–80°</td>
</tr>
<tr>
<td>Grade 4b</td>
<td>&gt;80°</td>
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Percutaneous K-wires Fixation of Pediatric Both Bone Forearm Fractures

Introduction

Pediatric forearm fractures, one of the most common fractures, are treated with closed reduction and plaster cast. Although anatomic reduction is not always necessary because of remodeling capacity in children, open reduction and internal fixation is performed if closed reduction is not successful. Diaphyseal angulation of >10 and malrotation of >45 are widely accepted criteria for operative intervention.2,3 In children who have an open physis with bone still growing, depending on the initial physeal injury or the surgical procedure, some abnormalities in the wrist can be expected. [19]

Several techniques have been used for the treatment of diaphyseal forearm fractures other than conservative treatment. Recently, an increasing number of reports on intramedullary fixation
of forearm fractures have documented better results with fewer complications. Flexible intramedullary nails work with three-point fixation. Although the pre-bent titanium rods are suitable, standard Kirschner wires, which are available in most operating rooms, usually are used for fixation. However, few reports exist in the literature on the distal radioulnar joint after pediatric forearm fractures treated with intramedullary K-wires. [20]

A study reported that fractures placed proximally and healed with shortening of >3 mm at the distal radioulnar joint often had unsatisfactory results [21]. Other study reported that positive ulnar variance could cause disturbances in the wrist due to ulnar impingement. Many authors reported good results with K-wire fixation; only few considered the distal radioulnar joint but neither used standard wrist radiographs. Radiographs taken with the beam centered over the midshaft inevitably distorts distal joint relation and is not informative [22]

Several studies have concentrated on the amount of residual angulation which is allowable and the potential for remodeling. Hughston recommended that fractures in patients over 14 years of age should be treated as for adults but, that in children under 10 years of age with distal third fractures, 30° to 40° of angulation was acceptable. [23] Daruwalla suggested that no more than 10° of angulation should be allowed in children over the age of ten. [24] Fuller and McCullough reported that up to 20° of angulation in distal third fractures would be accepted in patients under 14 years. Generally speaking, the younger the child, the more distal the fracture and the smaller the angulation, the better the result. [23]

Translation of the fracture is the most important risk factor for poor outcome. Proctor et al identified two factors which increase the chance of redisplacement of forearm fractures in children: the presence of complete displacement and failure to achieve a perfect reduction. [25] Mani et al have shown a predicted failure rate of 60% if the radial fracture is displaced by more than half the diameter of the radius and 68% after complete displacement. These authors advised the addition of percutaneous Kirschner wires for cases with high risk of redisplacement. [26]

Operative Technique

The procedure was performed under general anaesthesia and image intensifier control. An arm tourniquet was applied but inflated only when antegrade intramedullary K-wire fixation was planned. Satisfactory reduction was defined as at least 75% of bony apposition across the fracture site and angulation of less than 15° in patients under ten years of age or 10° over this age. Rotational mal-alignment was corrected and assessed before fixation by checking the width and shape of bone fragments and after fixation by detecting any limitation in the range of forearm rotation. Grossly displaced distal ulnar fractures (G III & G IV) were also reduced and percutaneous K-wire fixation was done to add more stability of fixation. No fixation was attempted for distal ulnar epiphyseal injury or minimally displaced fractures. [27]

In cases managed by retrograde K-wire fixation, a (1.2-1.8 mm) K-wire was inserted from the radial stylloid through the metaphyseal part of the distal fragment in a more proximal fracture (between the 1/6 and 1/3 of the total length of the radius). If the fracture was more distal (1/6 or less of radius), it was possible to insert the K-wire through the distal radial epiphysis. After crossing the fracture, the tip of the K-wire was directed into the opposite cortex of the radius. For the more proximal fractures, the K-wire was passed up the medulla for at least 4 cm beyond
the fracture site. An extra-wire was inserted from the dorsoulnar aspect, if the surgeon judged that fixation was insecure with the first wire (fig 4). [27]

For ante-grade K-wire fixation, a small longitudinal stab incision (1.5-2 cm) was made at the mid-lateral border of the radius. The brachioradialis tendon together with the underlying superficial radial nerve were retracted volarly and tendons of the extensor carpi radialis longus and brevis dorsally to expose the insertion of pronator teres. After minimal retraction of the pronator tendon insertion, a hole was made, the size of which was less than half the diameter of bone. At first the drill bit was directed perpendicular to the bone then obliquely to provide a smooth passage for insertion of K-wires without endangering the bone. A drill sleeve was used to protect the soft tissue and to control the drill bit over the bone. [28]

In cases in which two K-wires were used for antegrade intramedullary (IM) fixation, the sum of their width should be less than the size of the medulla to facilitate their gliding and prevent jamming. For young patients with a narrow medulla, one K-wire was used ante-grade and augmented with another retro-grade K-wire. The K-wires were pre-bent and inserted over a Thandle with their tips directed radially. Once the tips of the wires reached the fracture, the distal fragment was manipulated to obtain an acceptable reduction. Then one K-wire was rotated 180° and pushed toward the ulnar side of the distal fragment. The other K-wire was directed to the radial styloid guided with the C-arm through anteroposterior (AP) and lateral images (fig 5). In cases in which the fracture was unstable and had the tendency for radial drift, the lateral K-wire was used to help and maintain the reduction by pushing it into the radial styloid then rotating it to keep the distal fragment in the reduced position. Fixation of an ulnar fracture was done by the antegrade technique in most cases using one K-wire inserted percutaneously. In each technique of fixation K-wires were buried under the skin. [28]

An above-elbow plaster cast with the forearm and wrist in neutral position was applied for an average duration of 5.4 weeks (range 4-10) during which the child was encouraged to move fingers fully. After removal of the cast, patients were asked to strengthen the wrist grip and to move the forearm, and elbow. K-wires were removed under anaesthesia after an average time interval of 9.9 weeks (range 8-21). [28]
Fig. 4. — a. A 15-year-old boy presented with a Grade IV displaced distal radial fracture with an angulated distal ulnar fracture; b. he was treated with closed reduction and percutaneous retrograde K-wire fixation for the radius, two K-wires were used from radial styloid as the first one was not holding well, so another one was inserted and kept there; c. satisfactory end results. [29]
In a study of Nobuaki Tsukamoto et al., [30] found that; the advantages of intramedullary nailing for PDBFF over internal fixation with plates and conservative treatment are assumed to be maintenance of accurate reduction, reduction of complications such as neurovascular injury non-union and cross-union, negligible cosmetic defect, and the fact that wires are removable under local anesthesia. [30]

Although fixation with intramedullary nailing does not seem to be rigid enough, by using a larger intramedullary nail, stability against angular stress can be increased and the strong periosteum of children is resistant to torsional stress. According to a cadaver study, the degree
of rotational instability of the forearm both-bone fractures could be markedly reduced with the use of intramedullary nailing with 3.2-mm Rush pins. [31]

In the present study, the primary stability produced by intramedullary nailing was not as rigid as that used in the aforementioned experimental study because smaller K-wires (1.2–2.4 mm) were used due to the small diameter of pediatric forearm bones. The size of nails practically selected in previous studies ranged from 1.5 to 3 mm, and the use of a nail size equating to 60% of the medullary diameter was recommended when performing an elastic stable intramedullary nailing technique in order to prevent malunion. [32]

The use of thin K-wires (e.g., 1.2 mm in a patient in the present study) might yield suboptimal primary stability, and the maintenance of reduction would more heavily depend on how stable external immobilization was applied. However, because the size of the K-wires was not significantly associated with the tendency of refracture, the major etiology of refracture could be attributed to factors other than the primary stability produced by the intramedullary K-wires. Careful postoperative observation should therefore be continued until the achievement of satisfactory fracture healing with maintained reduction, even after appropriate intramedullary nailing for PBDF. [33]

The incidence of refracture of the forearm treated with intramedullary nailing is reported to be 4.4–16.7%, and refracture was reported to occur at 2–9 months after primary fracture. This incidence is comparable to the incidence of refracture in conservatively treated forearm fractures, which ranges from 1.4 to 14.7%. In this study, they found a similar incidence of refracture to past studies of both surgical and conservative treatment. Several studies have reported the occurrence of forearm refracture with the intramedullary nails retained in place, as was also observed in one of the patients in the present study (Case 5). [15]

These past studies reported that refracture with retention of the intramedullary nails occurred at 3–15 months after the primary fracture or surgery. The late timing of refractures suggests that the time required for complete healing was longer than expected, even in cases in which the PBDF seemed stable following reduction with the use of intramedullary nailing. Makki et al. recommended that the removal of the intramedullary nail not be performed within 6 months of insertion, because of a higher risk of refracture, especially in children of 9 years of age or older. [34] Flynn et al. demonstrated that delayed union of PBDF (>90 days) was more common in patients of ≥10 years of age who were treated with intramedullary nail fixation. [35] According to the results from Makki et al. and Flynn et al., a period of at least 3–6 months is required for adequate consolidation of PBDF after intramedullary nailing, especially in older children. In the present study, there were some patients with short retention of K-wire. Such a short duration may mainly be due to the placement of the K-wires exposed at the skin, as was performed in 25 patients (median 44 days). With the K-wires exposed, it would be difficult to maintain the wires for several months because of the high possibility of infection, as was seen in six patients who became complicated with infection at the wire insertion site. In contrast, a longer intramedullary retention of K-wire was generally observed when the ends of the K-wires were buried under the skin (median 123 days). Shoemaker et al. recommended burying K-wires in intramedullary fixation of pediatric forearm fractures in order to retain K-wires for 3–5 months and thereby minimize the loss of reduction, risk of infection, and length.
of postoperative immobilization. This strategy of long retention was also recommended by other studies. [36]

However, Kelly et al. suggested that the strategy of exposing intramedullary nails and their early removal (median 1.2 months) in pediatric forearm fractures would not cause significant differences in complications, including refracture, compared to a strategy of buried intramedullary nails and late removal (median 3.5 months). Despite such controversy concerning these two removal strategies, it seems safer to bury K-wires at the primary surgery in order to retain intramedullary nails for several months until adequate fracture healing has been achieved, specifically with respect to preventing refracture. [37]

Refractures were located in the middle or proximal third of the forearm. This tendency was in line with that reported by Baitner et al., who found that children with proximal and middle one-third forearm fractures had a greater risk of refracture in comparison with forearm fractures located in the distal one-third. Residual angular displacement might have contributed to refracture in Case 3, in whom angular displacement of the radius progressed after primary surgery possibly due to the short insertion of K-wire over the fracture site. Persistent angulation of the forearm is considered a risk factor for refracture, and the larger the residual angulation is, the earlier refracture is likely to occur. [38]

In 5 of 6 patients with refracture, they observed radiographic findings of immature healing at the primary fracture site (e.g. a residual fracture line and notch in the cortex). The incidence of refracture associated with radiographic immature fracture healing was higher than that reported by Baitner et al., who demonstrated that, at the latest follow up visit before occurrence of refracture, fracture lines were still visible on 42% of the radiuses and 50% of the ulnas among 63 patients with refracture of pediatric forearm fractures treated either conservatively or surgically. [38]

The proportion of patients who had immature fracture healing at the time of release from both K-wire and external immobilization was higher in the patients who eventually sustained refracture than in those without refractures. In the clinical setting, because some physicians may believe that satisfactory fracture healing has been obtained based on physical improvement (e.g. recovery of motion without pain) and the period from the primary fractures, the degree of radiographic fracture consolidation may be underestimated, which may lead to the decision to remove K-wires and external immobilization earlier than is optimal. [38]

The patients with refracture (at the time of primary fracture) included young girls of 3–4 years of age and adolescent boys of 11–12 years of age. According to a large epidemiological study conducted in the UK, the incidence of pediatric forearm diaphyseal fracture by age showed a bimodal distribution in boys with an early peak at preschool age and a later peak in adolescence, and a unimodal distribution in girls with the highest incidence in preschool age after which the incidence declined. In the present study, boys were more likely to sustain both primary fractures and refractures during sports activity. The active behavior of adolescent boys might increase the likelihood of refracture in this age group. In the cases of refracture in younger 3 girls, refracture might be attributed to the younger peak of incidence of fracture itself and the mechanical weakness of the bones. The tendency for refracture of bones with mechanical weakness is supported by the study of Rousset et al. who found that refracture of
forearm diaphyseal fractures after intramedullary nailing with elastic nails was likely to occur in patients of < 7 years of age with low body weight (< 24 kg) and thin a medullary diameter. [39]

In a study of Mostafa et al., [40] found that; Conservative treatment for displaced distal forearm fractures in children is possible, but reduction must be perfect and the cast must be well moulded. The most important risk factors for re-displacement and poor outcome of distal radial fracture were children older than 10 years with fracture translation more than half the diameter of the bone at the fracture site or angulation more than 20°, failure to achieve a perfect reduction, repeated reduction maneuvers, and the presence of additional fracture of the ulna. [40]

Percutaneous Kirschner wires are widely used for treating children’s fractures such as supracondylar fracture of the humerus and shaft fractures of the forearm bones; however, their use in high-risk distal radial fractures in children has not been popularized. Several previous studies recommended the use of percutaneous K-wire directly for stabilization of high-risk fracture and reserved open reduction and K-wire fixation if closed reduction failed and for open fractures. [40]

Noonan and Price reported that successful outcomes are based on restoration of adequate pronation and supination and to a lesser degree, acceptable cosmesis. All cases in this study were operated and immobilized with the forearm in neutral or slight supination position. This will help to keep the interosseous membrane stretched and space most wide, regaining maximum range of motion after cast removal. A study noted that limitation of forearm rotation has usually been associated with immobilization of the forearm in full pronation, however, the cause of the interosseous membrane scarring is still unknown. This study indicates that residual dorsal angulation and radial deviation of the distal fragment were significantly associated with a decrease in the range of forearm rotation and unsatisfactory end results. Roberts found that residual radial deviation of the distal fragment was more closely related to the loss of forearm rotation than was dorsal angulation. He explained this by the narrowing of the interosseous space which did not occur with dorsal angulation. [41]

Other study found that; The use of intramedullary K-wire for fixation of forearm fractures in children has been shown to be successful with fewer complications. This method provides reasonable stability on the frontal and sagittal plane; however, few reports exist on the effect on the wrist. [3]

One of the foremost concerns in the management of forearm fractures in children is loss of forearm rotation. A study reported that greater loss of motion of the forearm occurred in mid-third deformities. The other reason for the loss of rotation is soft tissue injury. [42] Other study reported 30 of loss of rotation at a 13% rate. In this series, they found that radial angulation has a greater effect on forearm rotation (P < 0.05). These findings support that the restoration of the radial bow at the time of open reduction is important for the unrestricted rotation of the forearm. It is more important in older children related to diminished remodeling capacity. [6]

A study reported that to prevent refracture, pin removal should not be performed before 3 months postoperatively. [43] Delayed pin removal for up to 10 months. This case raises concerns about leaving the end of the K-wire outside the skin. Other study reported 2 infections
in cases where the K-wires were left outside the skin; 1 K-wire was deep and required surgical debridement. If the bent tip of the wire is buried in the soft tissue beneath the skin, delaying pin removal does not cause defect and prevents infection. The rate of refracture is reported as 2% to 12% and occurred in the cases where hardware was removed early. No episodes of refracture were reported in this series, which could be related to delaying pin removal because it is difficult to restrict full-unprotected activity in this active age group. [44]

However, Kwires should not be left in bone for a long period, especially if they are not buried beneath the skin, because they increase the

References:


