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Management of pediatric forearm fracture, a prospective study comparing the outcome of open reduction internal fixation with plate and screws method and closed reduction flexible intramedullary nailing method

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Abstract

Background and Objectives: to compare the outcome of open reduction-internal fixation with plate and screws method and closed reduction-flexible intramedullary nailing method in the management of pediatric patients with unstable forearm fractures as regard to functional and cosmetic outcome.

Patients and Methods: The final assessments of 42 pediatric patients between the ages of 5 to 15 years old, who were operated from April 2010 to February 2011 for both-bone forearm fractures in Erbil Teaching Hospital and Private Hospital with adequate follow up, were done and their medical records were prospectively evaluated.

Results:42 children with unstable forearm fractures 21 were treated with open reduction and internal fixation of both radius and ulna using plate and screws (Group1)(mean age ,13years) and 21 were treated with close reduction and flexible intramedullary fixation (Group2)(mean age ,11years). Patient characteristics in the 2 groups were compared. In Four patients of Group 2, closed reduction was not possible because of soft tissue interposition that required open reduction with minimum incision at the fracture site. All patients achieved bone union; the mean union times were similar (P value=0.81), only one patient in each group had delayed union. Operating times were shorter in flexible nailing group (100 minutes in Group1 vs. 69 minutes in Group2, p<0.001).

Conclusions: There was no significant difference in union rate between the methods. The functional outcome between the two groups was compared; there was no significant difference between them. Like other investigators, we also found 90.5% of excellent functional outcomes after the treatment of unstable forearm fractures by means of plating. As indicated in the literature, we found 95% of excellent functional results after flexible intramedullary nailing.

Keywords: Forearm fractures, flexible nail, internal fixation, prospective study

Introduction

Forearm fractures are common in children, especially those aged ≥10 years.1Most can be treated conservatively with closed reduction and cast immobilization, because of rapid healing and remodeling of angulations in children.2Surgical intervention is required when satisfactory reduction cannot be achieved or maintained.[3–5] Although there are many positive aspects of fracture healing in children (among them spontaneous axial correction, faster healing, and high tolerance of longer immobilization of adjacent joints), they do not relieve the need for complex treatment of forearm fractures. The complications described in the literature indicate that a simple conservative therapy is no longer appropriate. A treatment concept for these fractures that is suitable for children has to consider the geometry of the fracture, as well as its localization and the child's age.[6, 7] many investigators have pointed out that axial malalignment of more than 10° should be corrected instead of being left to an incalculable spontaneous correction. Were there to be fracture healing with a false axial position in the mid shaft of between 5° and

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30°, it would lead to impeded supination movement of up to 27% and to impeded pronation movement of up to 80%, [5], 7-11 why many experts demand a primary fixation for displaced forearm fractures, in these situations, if left untreated, malunion is more likely to occur, which will disturb the function of the upper extremities.[5, 7] A number of import- ant principles should be followed to achieve the ideal goal of fracture union without deformity or dysfunction. As long as the physis are open, remodeling can occur. The remodeling capacity depends on the age, the site of fracture, the direction of angulations and its magnitude. Rotational deformity does not remodel.[12]Open reduction and internal fixation can provide accurate and stable fixation, but soft tissue exposure may lead to complications such as infection, neurovascular injuries, scarring and delayed union or non-union12. Removal of the plates may also be associated with significant complications.[47, 51, 52] Over the past 30 years, intramedullary fixation has become more popular than plates and screws for treatment of unstable forearm fractures in the pediatric population due to several advantages such as maintenance of reduction, minimally Invasive and relatively easy application, protection of bone alignment, and rapid bone healing.[13-15, 17,18] but there are certain complications like compartment syndrome, delay union, and refractor after removal of the nails. [12]For unstable fractures, intramedullary fixation can be performed using a variety of implants such as K-wires, Rush pins, Steinman pins or flexible nails. [12] forearm fractures is controversial.11, 19 90% of pediatric forearm fractures are successfully treated conservatively by closed reduction and casting.[13-16] the remaining 10% are irreducible or unstable fractures that requires surgical operation.[16]Pediatric both-bone forearm fractures differ from those in adults. In children these injuries usually are managed closed, while operative intervention often is required in adults. Indications for operative intervention in pediatric both-bone forearm fractures include failure of closed reduction, open fractures, irreducible fractures, unstable fractures, pathological fractures, fractures involving neurovascular compromise, malunions, and refractures. [5, 9, 21, 22] Acceptable methods of operative fixation include flexible intramedullary nailing [15,17,23,24] and compression wire or Steinman pin fixation also is used in some younger children.[19]Plate fixation becomes more common near skeletal maturity, while intramedullary nailing is used more often in younger children. The form of fixation often is a matter of surgeon preference as some studies mention excellent results with plate or intramedullary fixation.[19, 26, 27] Fractures in the mid and proximal aspects of the radius and ulna have less predict- able remodeling than fractures of the distal third. They tend to have a higher incident of re displacement and residual angulation after closed reductions and cannot remodel as well as distal fractures.[5, 7, 15, 28, 29] Controversy exists as to what constitutes acceptable angulation, displacement, and rotation. Patients aged <8 or <10 years can tolerate increased amounts of angulation and displacement than can older children.[5,7,8,21,30,42] Operative intervention has been recommended in prior studies for angulation >10°, malrotation, and displacement >50%.[27,42] Forearm fractures are approximately 3.4% of all pediatric fractures and about 30% of all upper extremity fractures.3218% of pediatric both bone fore- arm fractures are observed in the middle third, 7% in the proximal third, and 75% in the distal third.[33] The aim of this study is to compare the outcome of open reduction-internal fixation with plate and screws method and closed reduction flexible intramedullary nailing method in the management of pediatric patients with unstable forearm fractures as regard to functional and cosmetic outcome.

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Patients and Methods

The final assessments of 42 pediatric patients between the ages of 5 to 15 years old, who were operated from April 2010 to February 2011 for both bone forearm fractures in Erbil Teaching Hospital and Private Hospital with adequate follow up were done and their medical records were prospectively evaluated. Patients with distal metaphysical fractures, Monteggia and Galeazzi fracture dislocations, open fractures, radial head fractures and additional fractures in the ipsilateral arm were excluded. Group1; (21 patients), 15 boys (71.4%) and 6 girl (28.6%) (Mean age, 13 years) underwent open reduction-internal fixation with plates. Whereas Group2; (21 patients), 17 boys (81%) and 4 girls (19%) (Mean age, 11 years) underwent closed reduction-intramedullary fixation. Patients were followed up for 3 months. All patients had been initially treated with closed reduction and casting. Indications for operative intervention in pediatric age group in this study include failure of closed reduction, irreducible fracture s and unstable fractures. Range of movements of the elbow, wrist, and forearm, as well as clinical and cosmetic results were compared. Fractures were categorized as proximal, middle, or distal according to the anatomic location. Operation methods Flexible intramedullary fixation: In the forearm the two bones are nailed in a counter-rotating manner using just one nail for each bone, since the radius and ulna form a single unit together with the interosseous membrane . Determine nail diameter: Flexible Nails are available in five diameters: 2.0 mm, 2.5 mm, 3.0 mm, 3.5 mm and 4.0 mm; and are 440 mm in length. The nails are color-coded for easy identification. The nail diameter should be about two thirds of the medullary isthmus. Fixation of the radius done with the ascending technique. The patient is placed in a supine position. Generally, fixation of the radius is practicable if it is possible to guide the distal fragment with the intramedullary nail. A 1—2 cm incision is made at the radial side of the distal radius (approximately 2cm proximal to distal epiphyseal plate), the soft tissue is spread, protecting the superficial branch of the radial nerve. An awl is introduced into the bone proximal to the epiphyseal disc (under fluoroscopic control) first perpendicularly and then obliquely towards the elbow and a sufficiently strong elastic nail (thickness 1.5—4 mm) is inserted. The nail is then guided across the fracture under fluoroscopic control in two planes and the fracture is reduced by external manipulation and the nail is pushed proximally and fixed into the proximal metaphysis. The distal end of the nail is then bent and cut 5-10 mm from the bone, the skin is closed with one stitch. Fixation of the ulna done with the descending technique. A proximal dorsoulnar incision (2cm distal to the apophyseal plate) and exposure of the bone are carried out. The nail tip is rotated in the distal ulna towards the radius in order to place tension on the nails. Ideally, the bone that is most difficult to reduce (usually the radius) should be fixed first since this allows better fracture reduction. Final positioning and anchoring of nails: Align the nails so that the tips point toward each other, thereby providing oval bracing of the interosseous membrane. The bones take up their normal curved position.To avoid skin irritation, the nail ends should not project from the bone by more than 5–10 mm.In the postoperative period, the patients are placed in a long arm cast brace for three weeks followed by a short arm cast for an additional two weeks to enable elbow and for earm rotational movements Figure (1).

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(A) (B)

Figure (1): (A) Anteroposterior and lateral radiographs of a 12-year-old boy with unstable right forearm fractures. **(B)** Flexible intramedullary nailing of both bones, 7 weeks after operation.

Plate Fixation

Ulna:A longitudinal incision is made above the ulna. The fracture is exposed between the layers of the extensor carpi ulnaris and the flexor carpi ulnaris muscles. After irrigation and removal of the fracture haematoma the fracture is reduced. The length of the plate is chosen such that at each side of the fracture, six cortices are held; the plate is fixed on the dorsal or dorsoulnar side. Where rotation is unclear the radial fracture must be stabilized first, which allows free pronation and supination. Depending on the age of the child, 3.5 or 2.7 mm DC plates are used. Aninter fragmentary lag screw is not needed. Radius: Redial access as described by Thompson is the rule: a dorsolateral skin incision with a 4-5 cm skin bridge to the ulnar incision; splitting of the fascia be- tween the extensor digitorum communis muscle and the extensor carpiradialis brevis muscle; distally the tend on of the extensor pollicis longus muscle as well as the superficial radial nerve must be saved. The fracture is treated as described above, concluding with another fluoroscopic control and examination of the free range of motion of the forearm Figure (2). In the postoperative period, the patients are placed in a long arm cast brace for two weeks and early mobilization was started after soft-tissue healing. All patients were followed up until bone union, based on radiology (formation of callus and consolidation) and clinical findings (no tenderness and pain). At the final follow-up, Range of movements of the elbow, wrist, and forearm were measured. Clinical outcome was graded according to Price ET al.[29] Table (1). Cosmesis were classified according to patient satisfaction Table (2).40 Analysis of data was carried out us- in software (Microsoft excel 2003 computer program) and the (statistical package for social sciences) SPSS for Window version 15.0 (SPSS Inc, Chicago, IL) used to find out association between variables by calculating chi-square test and Fisher exact test. P value < 0.05 regarded as significance. RESULTS As shown in Table III, of the 42 children with unstable forearm fractures 21 were treated with open reduction and internal fixation of both radius and ulna using plate and screws (Group1)(mean age ,13years) and 21 were treated with close reduction and flexible intramedullary fixation (Group2)(mean age,11years). Patient characteristics in the 2 groups were compared. In 4 patients of Group 2, closed reduction was not possible because of soft tissue interposition that required open reduction with minimum incision at the fracture site. All patients achieved bone union; the mean union times were similar (P value=0.81), only one patient

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in each group had delayed union. Operating times were shorter in flexible nailing group (100 minutes in Group1 vs. 69 minutes in Group2, p<0.001)

Figure (2): (A) Anteroposterior and lateral radiograph of a 15-year-old boy with unstable forearm fractures**. (B**) 2 weeks after open reduction-internal fixation with plate and screws.

Table (1): Clinical outcomes grading

Outcomes	Symptoms	Loss of forearm rotation
Excellent	No complaint with strenuous activities	$<11^{O}$
Good	Mild complaint with strenuous activities	$11\text{-}30^{O}$
Fair	Mild complaint with daily activities	$31\text{-}90^{O}$
Poor	All other results	

Table (2): cosmesis according to patient satisfaction

Outcomes	Patient Satisfaction
Excellent	No complaint
Acceptable	Conspicuous but patient feels comfortable
poor	Remarkable and annoying scar formation

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Functional outcomes

At the follow-up examinations, we evaluated the functional outcomes with respect to had excellent clinical outcomes, except two in the plating group and one in intramedullary group, with good result but a supination loss of 15º. The children in both groups showed free mobility (no restriction) of the elbow and wrist Patient functional and cosmetic outcomes in the 2 groups were compared Table (4). In Group1: 19 patients (90.5%) had excellent mobility of the elbow and wrist as well as the range of motion of the forearm. All patients functional outcomes and two patients (9.5%) had good functional outcome both with loss of supination of about 15 Figure (3).In Group2:20 patients (95%) had excellent functional out comes and one patient (5%) had good functional outcome with loss of supination of about 15° Figure (4)

Table (3): patient characteristics

Parameters	**Plating (n=21)**	**Intramedullary nailing (n=21)**	
Mean age (years)	13	11	
Sex (male/female)	15/6	17/4	
Side (right/left)	12/9	13/8	
Fracture level: Distal Middle Proximal	 4 (19%) 13 (62%) 4 (19%)	 3 (14.3%) 15(71.4%) 3 (14.3%)	
Aetiology: Bicycle accident Fall Sports	 2 (9.5%) 15 (62%) 4 (19%)	 4 (19%) 8 (38.1%) 9 (42.9%)	
Mean (range) Operating time (minutes)	100 (70 – 120)	69 (45 – 90)	P value <0.001
Mean (range) time to union (weeks)	9 (8-14)	8.8 (8-16)	P value 0.81

Table (4): patient functional and outcomes

	Plating (n=21)	Intramedullary nailing (n=21)	P value
Clinical outcome: Excellent Good	 19 (90.5%) 2 (9.5%)	 20 (95%) 1 (5%)	1
Cosmoses: Excellent Acceptable Poor	 6 (28.6%) 9 (42.8%) 6 (28.6%)	 14 (66.7%) 7 (33.3%) 0	0.008

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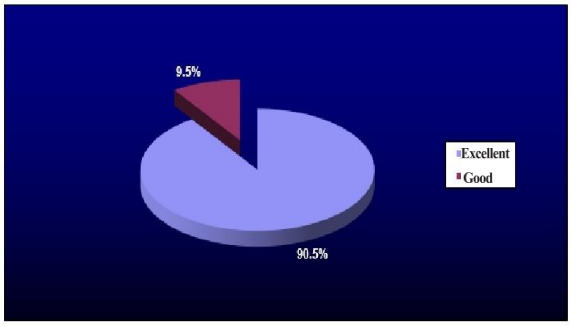

Figure (3): functional and outcomes of Group 1

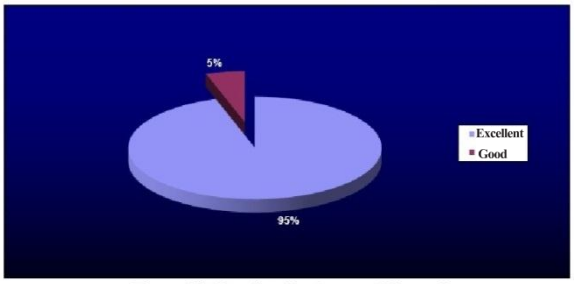

Figure IV: Functional outcomes of Group 2

Figure (4): functional and outcomes of Group2

Fair and Poor results were not observed in any of the groups. There were no significant differences in the range of motion of the forearm between the two groups. Functional out comes in the two groups were not significantly different (P value =1)

Cosmetic Outcomes

In Group I, the average length of the scar on the radial side was 10.2 (7—13) cm. In 11/21 children, the scars were clearly visible; 6 scars were discretely broader and 4 were narrow. The average length of the scar on the ulnar side was 10.1 (7—13) cm; 9/ 21 scars were narrow, 7 were discretely broader and 5 were clearly broader. In Group II, the average length of the scar on the radial side was 2.5 (1.5-3.5) cm; 7 scars were discretely broader and 14 were narrow. The average length of the scar on the ulnar side was 2.9 (2.0- 4.9) cm; 16/21 scars were still discernible as narrow scars, 5 were clearly broader. In the respective plating and intramedullary nailing groups, cosmoses was excellent in 6 patients (28.6%) and 14 patients (66.7%), acceptable in 9 patients (42.8%) and 7 patients (33.3%), and poor in 6 patients (28.6%) and 0 figure (4) and (5). Cosmoses were superior in IMN group (p=0.008).

Complications

In Group 1: Two complications were observed Loss of extension of the thumb was observed in one patient in the early postoperative period. This complication was thought to be related to the iatrogenic injury to posterior branch of the radial nerve and resolved spontaneously in 5 months. Delayed healing was observed in one patient who healed in 14 weeks. In Group 2: Two complications were observed Delayed healing was observed in one patient and bony union was seen at postoperative 16 weeks. Irritation of the hardware caused a painful ulnar bursitis in one patient which resolved totally after implant removal. No patient had a superficial and deep infection or osteomyelitis, vascular or anesthesia related complications were not observed in both groups. No limb length inequality and rotational deformities

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were observed clinically in this study. Discussion most fore- arm fractures in children can be successfully managed with closed reduction and casting. Surgical intervention is needed when reduction cannot be achieved or maintained.[19] Adequate initial reduction is particularly important in older children, because of high complication rates following revision surgery for malunion and a decrease in spontaneous correction rates for deformities.[39] Our study population was patients with unstable forearm fractures; a study has shown that these kinds of fractures are better to be treated by operation method.[33] various treatment algorithms in the management of pediatric forearm fractures are proposed. Many authors accept a fracture angulations of up to 10° for conservative treatment, [11, 35] while some accept up to 20° of angulation.[5,27] How- ever there is a consensus regarding that a rotational deformity cannot be accepted in any case.[35] Obvious limitation of forearm rotation 36 observed clinically in case of narrowing of the interosseous space. In our study angulations >10°, displacement >50% and mal- rotation are not accepted and required operation. On the other hand; there are several methods for operation including plate and screw fixation, flexible intramedullary nailing, K-wire fixation and rush pins fixation.[12]however there are possible complications of each type of operations. Therefore we compared plate and screw versus flexible intramedullary nailing to determine their efficacy in the management and complication rate. Evaluation was performed for both techniques during operation for duration of surgery. Operation time was shorter for the group 2.The possible explanations is that intramedullary nailing does not require extensive anatomical dissection if compared to plate and screw, furthermore the technique of intramedullary nailing is easier.[15] There was no significant difference in union rate between the two methods as P value was 0.81. Kose ET al.[53] observed similar finding in a study the functional outcome between the two groups was compared, there was no significant difference between them (P value =1). Like other investigators, 4, 39 we also found 90.5% of excellent functional outcomes after the treatment of unstable forearm fractures by means of plating. As indicated in the literature, 24, 48. Functional results after flexible intramedullary nailing. Additional assessment was performed for cosmetic outcome; patient with flexible intramedullary nailing group had superior result in this regard if compared to other group (P value 0.008) as intramedullary nailing did not require large skin incision and extensive soft tis- sue dissection because intramedullary nailing is designed for close reduction with minimal skin incision subsequently patient with this technique was get minimal scar formation. Similar finding was observed in other studies. [27, 40]. Both intramedullary fixation and plating are successful treatment modalities [44, 45] and have advantages and disadvantages. Rotational stability is difficult to maintain with intramedullary fixation, especially in older children (because of the larger intramedullary canal width).Plating provides a much more stable fixation.[46]despite shorter immobilization periods needed for plating, full range of elbow and wrist movements can be achieved in both modalities. Clinical outcomes are not associated with anatomic reduction, as a full range of movement may be attained despite residual malalignment. Other factors such as fibrosis of the interosseous membrane may play a rolein the clinical outcome.[41]Elective removal of plates carries a high risk of nerve injury because of difficulty in identifying the nerve in the presence of adhesions and fibrosis.[47] Refractures occurred in 19%51of patients after plate removal. In our study, 11 patients had plate removal, neither refracture nor nerve injury occurred, but the cosmesis were poor. We found the following disadvantages of plating: the need for two extended operations with significantly longer operation times than for nailing, requiring two inpatient stays with a significantly longer duration of hospitalization. Despite the high subjective satisfaction for the functional

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outcome achieved in both groups there was a clear difference in satisfaction with the cosmetic outcome. The scars on the forearms in the plating group were sufficiently influential that good function was not as important in the subjective evaluation as the aesthetic outcome. An advantage of plating is the significantly shorter duration of radiographic examinations. Flexible intramedullary fixation meets modern standards of biological fixation: minimally invasive insertion of fixation material with preservation of the fracture haematoma through the insertion of the intramedullary splints distant from the fracture. Functional follow-up treatment, fewer inpatients stays and outpatient removal of fixation material is possible. A percutaneous technique facilitates a very good cosmetic outcome. In our study, both surgical techniques achieved similar clinical out- comes. However, flexible intramedullary fixation was a better treatment for unstable forearm fractures in skeletally immature patients. Its advantages included better cosmesis (shorter incision scars), shorter operating times (because of simpler technique) and easier hard- ware removal. Flexible intramedullary nailing is superior for less exposure, earlier callus formation as fracture side is not opened and hematoma is not evacuated and no periosteal stripping. Similar findings was observed in other studies.[38, 40, 43] The complication rates for open reduction internal fixation with plates have been re- ported as 0-33%, [16] and for intramedullary fixation as 0-16%. [14, 24, 50] Lascombes et al reported 4 major (%5) and 10 minor (12%) complications in 85 patients managed with intramedullary fixation.[24] Some authors who have compared the two methods believe that both methods may give equally same results.[19, 27]. In this study, the com- plication rates in both group was similar (9.5%), delayed healing observed in both group, loss of extension of the thumb was observed in one patient in group 1 and painful ulnar bursitis in one patient in group 2. No patient had a superficial and deep infection or osteomyelitis, vascular or anesthesia related complications were not observed in both groups. No limb length inequality and rotational deformities were observed clinically in this study. The necessity and duration of immobilization in the postoperative period is unclear. Some authors have recommended early active range of motion without immobilization for better soft tissue and fracture healing.[24, 50] Lascombes et al reported secondary displacement of the fracture in%5 of the patients when postoperative immobilization was not used. Postoperative immobilization was used as an adjunct to the fixation in both groups and secondary displacement was not observed. No difficulty was observed in restoration of the elbow and forearm motions.

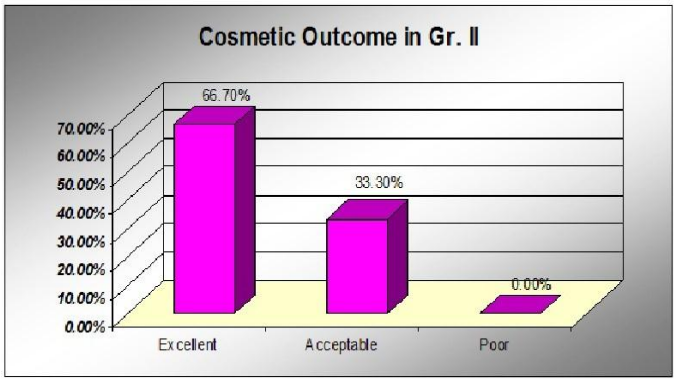

Figure (5): Cosmetic outcome in group 2

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