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Original Article

Combinations of fixation methods for adolescent forearm diaphysis fractures

Murat Gulcek

Bilkent City Hospital, Clinic of Orthopedic Surgery, Ankara, Turkey

Abstract

Aim: There is no consensus on treatment of forearm both bone diaphysis fractures in adolescents. In this study, we report the results of intramedullary fixation, plate-screw fixation, and combination of those methods in forearm fractures of adolescents.

Material and Methods: A total of 62 patients that were surgically treated, and completed their treatments in 11-year period (2003-2014) were included in the study. The forearm diaphysis double bone fracture was fixated with intramedullary nail in 23 adolescents. Both bones were fixated with plate-screw in 20 adolescents. In 19 patients, one bone was fixated with intramedullary nail, the other was fixated with plate-screw. Clinical results were graded in accordance with Price classification system.

Results: Three treatment groups were similar for clinical success. All three methods may be used with success rates of 65-75%.

Conclusions: The surgeon may choose intramedullary nail, plate-screw or their combination in accordance with the results of closed reduction maneuver in treatment of adolescent forearm double diaphysis fractures.

Keywords: Bone plate; bone wire; pediatric; radius fracture; ulna fracture

INTRODUCTION

Both bone fracture of forearm is one of the most frequent childhood fractures that they may cause severe complications (1,2). Surgical treatment is employed in case of unsuccessful conservative treatment, and in older children (3-8). Children younger than 10 years of age are usually treated with intramedullary fixation (5,9-15). The gold standard in adult forearm diaphysis fractures is plate-screw fixation (9,13,16). There is no consensus for treatment of adolescents (8,17-22).

In this study the patients are divided in to 3 group according to surgical technique used to fix the forearm fracture. Patients whom both forearm fracture fixed with elastic stable intramedullary nails (ESIN) is Group A, with plate and screw is Group B, and whom one of forearm bone was fixed with plate and the other one was fixed with ESIN is Group C.

Fixation of adolescent forearm diaphysis fractures have been performed with compression plates and elastic stable intramedullary nails (ESIN), however no series have been reported combination of them except for anecdotal cases.

The aim of this study was to compare radiological and clinical results of three different fixation techniques that provided union with different healing mechanism and report the results. We hypothesized that three techniques provided similar clinical success.

MATERIAL and METHODS

Adolescent patients who had surgery for instable forearm both bone diaphysis fractures between 2003 and 2014 were analyzed retrospectively. The study protocol was

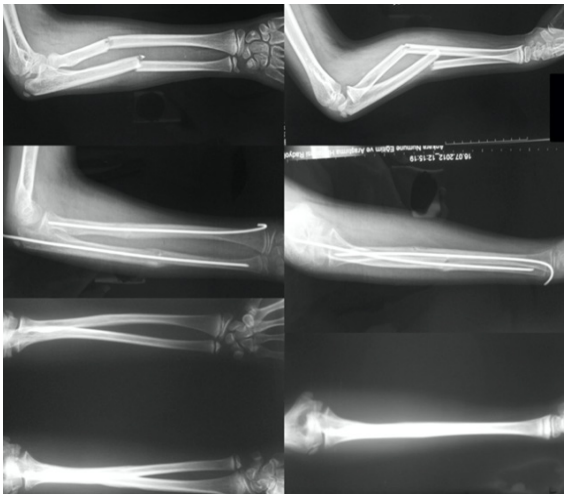

Figure 1. Group-A, Eleven-year-old male patient.

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Corresponding Author: Murat Gulcek, Bilkent City Hospital, Clinic of Orthopedic Surgery, Ankara, Turkey
E-mail: smgulcek1995@yahoo.com

approved by local Ethics Committee of our hospital. Adolescents between 10-16 years of age were included in the study. Indications for surgery were instable fractures that could not be reduced conservatively, or inability to maintain conservative reduction in those fractures. Open fractures, single bone fractures, and Monteggia and Galeazzi fractures were excluded. The fractures were classified in relation with AO/OTA classification (23).

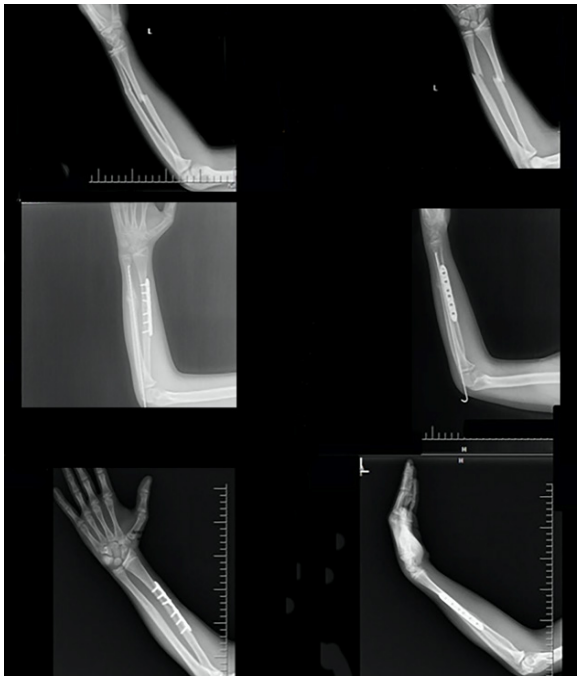

Figure 2. Group B-1, Twelve-year-old male patient

Figure 3. Group B-2, Thirteen-year-old female patient

Patients were divided into three groups in relation with the fixation method. Group A consisted of the ones with ESIN fixation of both radius and ulna (Figure 1). The patients who had ESIN fixation of one forearm bone, and plate fixation of other forearm bone were called as Group B (Figures 2,3). Group C consisted of the adolescents in whom both bones were fixed with plate fixation (Figure 4).

Figure 4. Group C, Fourteen-year-old male patient

Surgical Technique

Following closed reduction maneuver (not more than twice), the fractures were fixed with intramedullary nail (smooth Kirschner wire or titanium elastic nail) in whom both fractures could be reduced with closed reduction (Group A). If one fracture could be reduced and the other fracture could not be reduced after closed reduction, plate fixation was applied to unreduced bone, and ESIN was applied to reduced bone (Group B). If either fracture could not be reduced after closed reduction, both fractures were fixed with plate fixation (Group C). 3.5-mm plates and screws were used for fixation in adolescents that had open reduction (Figure 5).

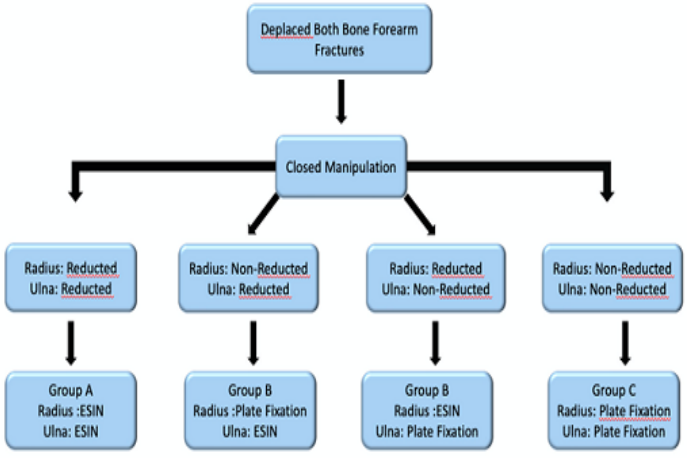

Figure 5. Flowchart shows the treatment plan

If both fractures were to be fixed with ESIN, radius was fixed first. Radial side of the distal radial metaphysis was chosen for entry point. Pre-bent elastic nail (2-2.5 mm) was advanced in retrograde manner under fluoroscopy to obtain fixation. The entry point was chosen as the very distal tip of the olecranon in ESIN application to ulna. Intramedullary nail was advanced in anterograde fashion to provide fixation. Plate fixation was performed with Thompson approach on the radial side, and with dorsal

longitudinal incision of ulna on the ulnar side. 3.5 mm-dynamic compression plate and screws were used. The plate was bent before fixation if the fracture was in the region of radial bow.

Clinical Assessment

Emergency room records, injury mechanisms, additional injuries, total operation time, control X-rays, range of motion of elbow and wrist neurological findings, and complications were examined from hospital records. After union of the fracture, adolescents were graded in relation with Price classification, adapted by Baldwin et al. (Table 1) (24).

Radiological imaging

Standard two-view preoperative, per-operative, and the postoperative control X-rays obtained in the last follow up visit were examined. Bone union criterion was regarded as union of at least three cortexes on two-view X-ray. If union is not accomplished in 3 month was regarded as delayed union, and loss of union on 6th month was regarded as non-union (25) .

Table 1. Forearm Fracture Fixation Outcome Classification*

Clinical Outcome Score	Clinical	ROM
Excellent	No complaints with activity	Loss of <10 degrees of ROM
Good	Minor complaints with strenuous activity	Loss of 11–30 degrees of ROM
Fair	Minor complaints during normal daily activities	Loss of 31–90 degrees of ROM
Poor	Major complaints	Loss of 90 degrees of ROM

* Price classification, adapted by Baldwin et al. ROM: Range of Motion

Rehabilitation Protocol

The same rehabilitation program was applied to all three groups. ROM exercises were started in early period when the pain disappeared after the operation.

Statistical Methods

All analyses were performed using SPSS (version 20.0) software. A two-sided p=0.05 was considered significant. The distribution of data set was analyzed with Kolmogorov-Smirnov test. Homogeneity of variance between groups was assessed with Levene test. Results were demonstrated as mean and standard deviation (median, min - max) for continuous variables, frequency (%) for categorical variables. When variance homogeneity and normality assumptions were not satisfied, Kruskal-Wallis test was used to compare more than two groups. Mann Whitney U test was applied to compare two groups when the normality assumption was violated.

RESULTS

Patient Characteristics

A total of 85 adolescents had surgical treatment for forearm both bone fractures. Six patients were lost from follow up, 9 patients had open fractures, 8 patients had additional fractures including wrist and elbow, and a total of 23 patients were excluded. Sixty-two patients were included in the study. The mean age of the patients was 12.9±1.9 (13, 10-16) years. There were no differences among groups for age. The mean follow up period was 11 (3-42) months. Baseline characteristics of the patients of the patients are presented in Table 2. According to AO/OTA classification, 42 (67.7%) patients were in 22-D/4.1, 3 (4.8%) were in 22-D/4.2, 14 (22.5%) were in 22-D/5.1, and 3 (%5) were in 22-D/5.2 subgroups.

Table 2. Baseline characteristics of the patients

	Group A (n=23)	Group B (n= 19)	Group C (n= 20)	Total (n = 62)
Age	12.9±2.1 (13,10-16)	12.8±1.7 (13,10-16)	13.2±1.9 (13,10-16)	13±1.9 (13.0,10-16)
Gender				
Male	19 (30.6%)	14 (22.6%)	16 (25.8%)	49 (79%)
Female	4 (6.4%)	5 (8.1%)	4 (6.4%)	13 (21%)
Side				
Right	15 (24.2%)	16 (25.8%)	12 (19.4%)	43 (69.3%)
Left	8 (12.9%)	3 (4.8%)	8 (12.9%)	19 (30.6%)

Results are demonstrated as mean ± standart deviation (median, min-max) for continuous variables, and frequency (%) for categorical variables

There were 23 patients in Group A, 19 patients in Group B, and 20 patients in Group C. Radius fractures of 13 patients in Group B were fixed with plate, and ulna fractures were fixed with ESIN (Group B1). Radius fractures of 6 patients were fixed with ESIN, and ulna fractures were fixed with plate (Group B2).

Functional Outcomes

The functional outcomes of the patients according to Price scoring system are presented in Table 3. There was ≥30 degrees movement limitation in 5 patients in Group 1, 2 patients in Group B, and 2 patients in Group C. One patient in group A had limitation of both supination and pronation, 2 patients had limitation of pronation, and 2 patients had limitation of supination. There was only supination limitation in Groups B and C. Despite those movement limitations, there was no difference among three study groups for clinical success, as determined by Price Scoring System.

The mean duration of surgery was for the Group C, 72.6 minutes (range, 62- 160 minutes), than that for the Group A, 103.4 minutes (range, 47 -185 minutes) and Group B, 132.6 minutes (range, 95-175 minutes).

Table 3. Forearm Functional Outcomes*

	Group A	Group B	Group C	Total
Excellent	15 (65.2%)	13 (68.4%)	15 (75%)	43 (69.4%)
Good	3 (13%)	4 (21.1%)	3 (15%)	10 (16.1%)
Fair	5 (21.7%)	2 (10.5%)	2 (10%)	9 (14.6%)
Poor	-	-	-	-
Total	23 (100.0%)	19 (100.0%)	20 (100.0%)	62 (100.0%)

*Modified from Price Classification by Baldwin [6, 33]

Mean time to union was 9.6±3.5 (8, 6-21) weeks (Table 4). The difference among the groups in terms of fracture healing was not statistically significant (p=0.575).

Complications

Asymptomatic delayed union was seen in 6/62 (9.6%) patients. Those patients were followed up and sportive activities were restricted. All but two patients had union within 6 months. There was non-union in 2 patients, and those were treated with plate-screw and union achieved. There was transient nerve injury in one patient in Group A, and in one patient in Group B-2. Both recovered during follow up. One patient in Group A fell down in postoperative week 2, and ESIN bent. The ESIN was removed, and the fracture was fixed with plate-screw. Re-fracture occurred in 2 patients in Group A, 2 patients in Group B, and 2 patients in Group C (between postoperative months 1 and 18). Those patients were treated using plate fixation. Non-union was not seen in any of those 6 patients. Four patients had superficial pin tract infection. Intramedullary Kirshner wire migrated backwards in one of them, and removed in postoperative month 1. The fracture healed with split and antibiotics treatment. There was no compartment syndrome, synostosis, or major nerve injury.

Table 4. Results of radiological union

	Group A (n=23)	Group B (n= 19)	Group C (n= 20)	p value
Time to union (weeks)	9.9±3.9 (9,6-21)	9.4±3.3 (8,6-18)	9.4±3.5 (8,7-21)	p=0.575

Results are demonstrated as mean±standart deviation (median, min-max) for continuous variables

DISCUSSION

We aimed to compare efficiencies of three different fixation techniques in forearm both bone diaphysis fractures of adolescents. Our results indicated that those three methods provided similar clinical success rates. However, rotational movement limitation of the forearm was the most frequent in the group that had ESIN fixation. To our knowledge, the results of hybrid fixation method were not previously reported.

Intramedullary fixation is usually preferred below the age of 10 years (9-14). Plate-screw is the preferred method in adult forearm diaphysis fractures. There is no consensus on the surgical fixation material to be used in adolescents, who are reaching skeletal maturity (8,18,19). İntramedullary or plate-screw fixation can be used for fixation of adolescent forearm fractures (24).

One of the forearm bones was fixed with compression plate, and the other one was fixed with ESIN in the hybrid

method. Although some series used this method in small number of patients, no studies up to date has focused on this hybrid technique (8). Combined use of fixation materials provided a similar success rate with use of ESIN alone, and use of plate-screw alone. Shorter surgical time have been described as advantages of hybrid fixation over other groups in children.

Union was established with absolute stability and primary bone healing in plate-screw group. In case of ESIN, union occurred with relative stability and secondary bone healing. Those two bone union mechanisms provided union together in the hybrid system.

Presence of more options for fixation materials enables completion of surgery with less manipulation and less iatrogenic trauma. We kept the number of closed reduction maneuvers and ESIN insertion trials at minimum. In this way, edema that might appear due to closed reduction maneuvers, recurrent trials for insertion of ESIN, and resulting risks for compartment syndrome and perioperative neurological deficit were minimized. Our success rates were similar in three groups. Therefore, the surgeon may choose among the techniques as he/she desires, or match to appropriate fixation method during the course of surgery.

Only a few studies focused adolescents while analyzing forearm diaphysis fractures in childhood as identified in the meta-analysis of Baldwin (18,19,21,24). Some studies reported the results of different age groups, open fractures, one-bone fractures, and forearm both bone closed fractures altogether (8,18,19,26). In our study, we analyzed the results of adolescents alone. In this way, factors that could affect success such as young age, open fractures, and one-bone fractures were excluded to report the results of a more homogenous study population.

Similar to preference for treatment, there is no consensus on the rate of complications in those fractures (6,26-28). Some studies reported that plate fixation was together with more complications, but some others claimed that ESIN (Elastic stable intramedullary nail fixation) and plate fixation had similar complication rates (19,28,30). It was reported that complications were more frequent in adolescent forearm diaphysis fractures fixed with ESIN when compared to younger children (8,29,31). In our series, we did not encounter compartment syndrome, major nerve or vessel injuries, and synostosis. The reason for this may be exclusion of the patients with open fractures, not choosing dorsal side of radius as insertion place of distal radial ESIN, not performing surgery within first 24 hours, and avoiding recurrent closed reduction and ESIN implantation maneuvers. This may be related to non-coercive closed reduction and surgical method we employed.

LIMITATIONS

There is no conservative treatment group. Retrospective design is a limitation.

CONCLUSION

Use of plate-screw and ESIN as fixating materials alone or in combination is effective treatments in adolescent forearm diaphysis fractures. Further, prospective studies on larger patient cohorts are needed to compare different fixation materials at every age group of adolescents.

Competing interests: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: The study protocol was approved by local Ethics Committee of our hospital.

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