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Original Article

Flexible intramedullary nailing had better outcomes than kirschner wire fixation in children with distal humeral metaphyseal-diaphyseal junction fracture: a retrospective observational analysis

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Abstract: The effectiveness evaluation of flexible intramedullary nailing (FIN) and kirschner wire fixation (K-wire) used for MDJ fractures fixation have been described in multiple reports. But there have been few reports about comparison between FIN and K-wire in children with distal humeral MDJ fracture. In our retrospective study, Nineteen children received K-wire and twenty children received FIN, during the follow-up, six children in the K-wire group and one children in the FIN group was found to have postoperative cubitus varus; fixation method was an independent risk factor for postoperative cubitus varus ($P = 0.001$), fixation methods contributed significantly to operation time ($t = 6.519$, $P < 0.001$), surgical blood loss ($t = 5.349$, $P < 0.001$) and postoperative fracture healing time ($t = 4.940$, $P < 0.001$). We can conclude that FIN was related with lower incidence of postoperative cubitus varus, shorter operation time, less surgical blood loss and shorter fracture healing time compared to K-wire in children with MDJ fractures of the distal humerus.

Keywords: Flexible intramedullary nailing, metaphyseal-diaphyseal junction fracture, kirschner wire fixation

Introduction

Fractures of the distal humerus are the most common elbow fractures in pediatrics [1]. Most of these fractures are supracondylar humeral fractures which course through the olecranon fossa and account for almost 17% of all childhood fractures and more than 50% of all elbow fractures [2]. Distal humeral MDJ fractures occurring just proximal to the olecranon fossa are much less common and account for just 3% of displaced fractures of the distal humerus [2]. However, this subset of distal humeral fractures are difficult to treat and more prune to develop postoperative complications including reoperation, cubitus varus and delayed healing [3, 4]. The humeral distal diaphysis is more triangular and the periosteum is thinner compared to that in the supracondylar region. These characteristics make MDJ fractures less stable than supracondylar fractures [4]. To resolve this problem, proper fixation might be essential [5].

Both K-wire and FIN have been reported to be used for MDJ fractures fixation [3]. For K-wire, placing the pins into the diaphysis by closed reduction and percutaneous pinning is difficult due to the proximity of the fracture line to the joint. Thereafter open reduction is usually needed which might lead to more treatment-related injuries. In these circumstances, FIN might be an alternative [6, 7]. Martin et al. had tried the use of FIN in supracondylar humeral fractures and stated that FIN was safe and effective [7, 8]. We have treated cases of severely displaced distal humeral MDJ fractures in children with either retrograde or anterograde intramedullary nails since 2009 based on their guardians' wills. In current retrospective study, we evaluated the clinical outcomes of FIN against K-wire in treating children distal humeral MDJ fractures.

Patients and methods

Subjects

This retrospective study was approved by the Institutional Review Boards of The Shanghai Children's Medical Center (IRB No. 14692). Thirty-nine children who received either K-wire or FIN for a displaced distal humeral MDJ fracture were identified between June 2009 and June 2012 after excluding open injuries. Patients were diagnosed with displaced distal humeral MDJ fractures based on the following two criteria: 1) skeletal immaturity, as determined by the presence of open epiphyses, and 2) a displaced distal humeral fracture at the MDJ just proximal to the olecranon fossa. Records were retrospectively reviewed and all data were collected in regarding to age, sex, injury side, fracture causes, fixation type (K-wire or FIN), surgical blood loss, operation time, fracture healing time, postoperative cubitus varus and time of follow-up.

Surgical procedure

All patients were diagnosed and treated by senior pediatric orthopedic surgeons in our hospital. The attending pediatric orthopedic surgeons clearly stated the potential risks and benefits of K-wire and FIN to the parents who made the choice of fixation types. As regards surgical procedures, children were firstly taken to the operating room for attempted closed reduction and fixation with either K-wire or FIN. If proper fixation with closed reduction could not be achieved, open reduction was then performed via a medial elbow approach.

For K-wire, two to six wires were placed through the medial and lateral epicondyles to keep the pins as divergent as possible at the fracture site. Stability was further ensured by inserting the wires into the medial column or both columns of the humerus. For FIN, titanium flexible nails (Synthes, Paoli, PA, USA) were used. The nails were introduced bluntly down to the bone via a small incision in the distal medial and lateral epicondyles. For pins that were directed via the medial epicondyle, careful retraction of the posterior soft tissues were needed to avoid possible ulnar nerve injury. Further entry into the intramedullary canal superior to the olecranon fossa was facilitated by earlier drilling. The nails were then driven in a retrograde manner until they entered the proximal fracture fragment. Rotations of the nails were used to optimize the reduction if necessary. The implants were then trimmed and buried under the skin in all cases. Implant removal was conducted in all patients after adequate fracture healing were seen.

Study design and outcome measures

The purpose of this retrospective observational study was to evaluate the clinical outcomes of FIN versus K-wires fixation in treating children distal humeral MDJ fracture. We firstly extracted all the data regarding surgical treatments of these fractures in our hospital. Multivariate logistic and linear regression were performed to investigate the relationship between different fixation strategies and the selected outcome measures. To further verify the influences of fixation methods on cubitus varus occurrence, a matched case-control study was performed. Seven cases diagnosed with postoperative cubitus varus were matched at an 1:1 ratio with controlled patients by age (age gap ≤ 2 year), sex, injury side (left or right), fracture causes (fall or traffic accident) and associated injuries (no or yes).

Statistical analysis

Demographic parameters, intraoperative and postoperative outcomes were extracted and synthesized as mean ± S.D. for continuous variables, or frequency and percentages for categorical variables. Statistical analysis was performed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). Briefly, binary multivariate logistic regression (0 for FIN and 1 for K-wire) with forward: LR (likelihood ratio)-selection procedure was conducted to seek out the potential risk factors for cubitus varus. The following parameters were included in the logistic regression model: age, sex, injury side, fracture causes, associated injuries, fracture heal time and fixation methods. Of these variables, age (1 for "less than or equal to 3 years of age", 2 for "more than 3 and not more than 6 years of age", 3 for "more than 6 and not more than 9 years of age"; 4 for "more than 9 years of age") and fracture healing time (1 for "less than or equal to 1.5 months"; 2 for "more than 1.5 and not more than 3 months"; 3 for "more than 3 months") were treated as ordinal variables. The other variables were treated as binary variables.

Table 1. Demographic and clinical characteristics of the 39 eligible children

	K-wire (N = 19)	Nail (N = 20)	*P*
Age at treatment (y) (Mean ± S.D.)	6.3 ± 3.7	5.6 ± 3.5	0.538
Sex (F/M)	5/14	7/13	0.731
Injury side (Left/Right)	10/9	13/7	0.523
Causes of injury (Fall/Traffic accident)	15/4	18/2	0.407
Associated injuries (Yes/No)	4/15	6/14	0.716
Surgical blood loss (mL) (Mean ± S.D.)	66.3 ± 34.1	22.8 ± 12.6	< 0.001
Operation time (min) (Mean ± S.D.)	92.1 ± 31.4	41.9 ± 13.8	< 0.001
Heal time (mon) (Mean ± S.D.)	2.8 ± 0.9	1.7 ± 0.4	< 0.001
Follow-up	14.4 ± 3.2	14.3 ± 2.8	0.903
Cubitus varus	6/19	1/20	0.044

Fisher's exact test of or McNemar's test for correlated proportions was performed for qualitative data comparison. Paired *t*-test and one-way ANOVA were used for quantitative data comparison. Multiple liner regression model using stepwise-selection procedure was utilized to find the possible factors influencing surgical blood loss, operation time and fracture healing time. The variables used for the liner regression model were age, sex, injury side, fracture causes, associated injuries, fracture healing time and fixation methods. A *P*-value of ≤ 0.05 (2-tailed) was considered statistically significant.

Results

Thirty-nine children were diagnosed with distal humeral MDJ fracture and treated via K-wire or FIN in our hospital over a 3-year period. The average follow-up was 14.3 ± 3.0 months. Nineteen children received K-wire and twenty children received FIN. Six children in the K-wire group and one child in the FIN group was found to have postoperative cubitus varus during the follow-up (**Table 1**).

Multivariate logistic regression analysis showed that fixation method was an independent risk factor for postoperative cubitus varus (P = 0.001), the odds ratio (OR) for FIN versus K-wire was 0.024 (95% confidence interval (CI) = 0.003 to 0.226).

A matched case-control study was conducted to further clarify the relationship between fixation methods and cubitus varus. By matching age, sex, injury side, fracture causes and associated injuries, seven case-control pairs were identified. As seen in **Table 2**, six of the seven controls selected K-wire for their fractures. No difference was found between cases and controls in age, sex, injury side, fracture causes and associated injuries. McNemar's test revealed that patients with cubitus varus were more likely to receive K-wire rather than FIN ($X^2_{(1)}$ = 6.25, P = 0.041). Odds ratio was not calculated due to that no paired patients was found when a child receiving FIN developed cubitus varus and the other child receiving K-wire was normal.

We further tried to identify the relationship between fixation methods and perioperative outcomes including operation time, surgical blood loss and postoperative healing time utilizing the multiple liner regression model. The results suggested that fixation methods contributed significantly to operation time (t = 6.519, P < 0.001), surgical blood loss (t = 5.349, P < 0.001) and postoperative fracture healing time (t = 4.940, P < 0.001). FIN was inversely related with operation time, surgical blood loss and fracture healing time. Besides fixation methods, patients who suffered from traffic accident-induced fractures experienced longer healing time than patients who had fractures due to fall (t = -2.287, P = 0.028).

Discussion

In this retrospective analysis, we found that: (1) FIN was related with lower incidence of postoperative cubitus varus in children with MDJ fractures of the distal humerus compared to K-wire. (2) FIN appeared to be superior to K-wire in treating children distal humeral MDJ fractures with shorter operation time, less surgical blood loss and shorter fracture healing time.

MDJ fractures of the distal humerus were uncommon elbow fractures in children that should be differentiated from the more commonly seen supracondylar humeral fracture [2]. In 1962, Lagrange and Rigault described the supracondylar humeral fracture with diaphyse-

Table 2. Detailed demographic and clinical data of the 7 case (cubitus varus)-control pairs

Pair no.	Cubitus varus	Fixation method	Age (y)	Sex	Injury side	Fracture causes	Associated injuries	Blood loss (ml)	Operation time (min)	Healing time (months)	Follow-up (months)
1	Yes	K-wire	6	M	L	Fall	No	100	100	4.5	12
1	No	FIN	6	M	L	Fall	No	5	20	2	12
2	Yes	K-wire	8	M	L	Fall	No	110	150	3.5	24
2	No	FIN	9	M	L	Fall	No	50	60	2	18
3	Yes	K-wire	1	M	L	Fall	No	40	95	2	12
3	No	FIN	1	M	L	Fall	No	40	40	1	12
4	Yes	K-wire	12	M	L	Fall	No	70	70	2.5	15
4	No	FIN	10	M	L	Fall	No	20	64	2	18
5	Yes	FIN	4	M	R	Fall	No	20	60	1.5	12
5	No	FIN	5	M	R	Fall	No	10	55	2	18
6	Yes	K-wire	4	M	L	Fall	Radial nerve injury	60	80	1	12
6	No	FIN	3	M	L	Fall	Radial nerve injury	20	30	1	14
7	Yes	K-wire	6	M	R	Fall	No	80	100	3.5	15
7	No	FIN	6	M	R	Fall	No	15	25	2	12

K-wire indicates Kirschner wire fixation; FIN indicates flexible intramedullary nailing.

al extension as a rare fracture which was also difficult to treat due to the instability and tendency to develop postoperative complications [3, 9]. The treatment of these fractures consisted of both conservative non-operative and operative strategies. In some patients with stable fractures, non-operative therapy might be possible with the careful use of a well molded cast or splint. However, for most patients, the adjacency of the fracture sites to the muscle origins on the epicondyles made their fractures unstable. Moreover, the additional supination and pronation added more possibility to develop varus malunion in these fractured children [10]. To solve these problems, surgical treatments with K-wire [2], external fixation [11, 12] or FIN [3, 13] had been tried in recent years. Our current study further compared the early clinical outcomes and complications of K-wire and FIN.

Fayssoux *et al.* reported that the incidence of loss of fixation, reoperation, pin migration, cubitus varus deformity, and prolonged loss of motion was higher in children with these fractures, especially the transverse fractures [2]. Similarly, our study had seen seven cases of cubitus varus in the 39 consecutive case series. Moreover, we found that children receiving FIN were less likely to experience cubitus varus compared to that with K-wire. However, as the sample size was small, more data were needed to support this finding.

Surgeons from France firstly described the fixation of distal humeral MDJ fractures using flexible intramedullary nailing techniques [3, 9]. Over the last 30 years, the FIN method has become a standard surgical procedure for the treatment of diaphyseal fractures in both children and adolescents. Results from several studies with different follow-up time supported the superiority of FIN to other techniques [7, 14-16]. Elastic nails could also be used to stabilize supracondylar fractures [3, 9, 14]. In our study, most of the patients in the FIN group (17/20) were treated by two or three retrograde intramedullary nails, which differed from the classic anterograde nailing method. In one patient, we used anterograde nails but a cubitus varus deformity occurred as the medial column nail lessened. After that, we changed the entry sites of the flexible nails to the distal medial and lateral epicondyles. We found that retrograde intramedullary nails could hold the distal fragments of the fractures and stabilize the medial and lateral column of the distal humerus more firmly compared to the anterograde nails and K-wires. That might help explain the generally better outcomes in children receiving FIN compared with K-wire.

Disclosure of conflict of interest

None.

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