

Clinical and Radiographic Outcomes of Pediatric Radial Head Fractures

Abstract

Background: The treatment of pediatric radial head fracture (RHF) is controversial, and the outcome is unpredictable. We aimed to evaluate the long term clinical and radiographic outcomes of patients with pediatric RHF. **Materials and Methods:** 24 patients with pediatric RHF operated between January 2004 and 2012 were included in this retrospective study. 17 patients had extra articular radial head (EARH) fractures and 7 had intraarticular radial head (IARH) fractures. The Mayo Elbow Performance Score (MEPS), Tibone and Stoltz classification, range of motion (ROM), and carrying angle (CA) were evaluated. The radial head diameter (RHD) and radial head height (RHH), neck shaft angle (NSA), and distance from the radial head to the radial tuberosity (RHRT) were measured and compared with the other side in simple anteroposterior views of elbow radiographs. **Results:** At the last followup, the mean MEPS was 100 and 97.9 in groups EARH and IARH, respectively. There were no clinically and radiographically significant differences between the groups. The injured elbows showed smaller ROMs than the uninjured elbows in flexion, supination, and pronation with statistically significant differences. However, the injured elbows showed larger extension ranges than the uninjured elbows with a statistical significance (all $P = 0.000$). CA, RHD, and RHH were higher in the injured elbows than in the uninjured elbows with statistically significant differences ($P = 0.006, 0.000, \text{ and } 0.011$) However, NSA and RHRT of both elbows were similar, with no statistically significant difference ($P = 0.810 \text{ and } 0.752$). **Conclusion:** All patients with pediatric RHF were satisfied with the long term clinical results. The injured elbows showed restricted ROMs compared with the uninjured elbows; however, the extension range increased.

Keywords: Child, elbow, fracture, prognosis, radius, range of motion

MeSH terms: Pediatrics, elbow, radius, prognosis

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Introduction

Pediatric radial head fractures (RHF) are rare injuries accounting for 4% to 20% of all pediatric elbow injuries.¹⁻⁵ They also account for <1% of total pediatric fractures.⁶ The treatment of RHF is still debated, considering the acceptable fracture alignments, reduction techniques, and unpredictable outcomes.^{7,8} Most pediatric RHF could be treated with immobilization alone, immobilization after closed reduction, and surgical treatment.⁹⁻¹¹ Percutaneous pin reduction, open reduction with or without internal fixation, and elastic stable intramedullary nailing were performed as the surgical methods.^{3,12-17}

The treatment outcomes of extra articular radial head (EARH) fractures are good as they were usually angulated mildly to moderately.¹⁸ On the other hand, the

treatment outcomes of intraarticular radial head (IARH) fractures are generally worse than those of EARH fractures.¹⁸⁻²⁰ The treatment of RHF remains as a challenging task and is not relatively well-studied in pediatric orthopedics.

There are many research papers on each treatment method,²¹⁻²³ but there are few studies comparing EARH and IARH fractures.²⁰ In addition, there are few studies on the range of motion (ROM) of pediatric RHF that are divided in detail. The purpose of this study is to evaluate the long term clinical and radiographic outcomes of patients with pediatric RHF. We also evaluated the correlation of the prognostic factors with the treatment outcomes.

Materials and Methods

Patient selection

24 patients with pediatric RHF operated between January 2004 and 2012 were included in this retrospective study.

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17 patients had extra articular radial head (EARH) fractures and 7 had intraarticular radial head (IARH) fractures. The study was registered in our Institutional Review Board. The inclusion criteria were all patients with RHF with open growth plates of the radial head (<16 years) and at least 3 years of followup. The exclusion criteria were <3 years of followup, and patients with previous opposite elbow injury whose clinical and radiographic results cannot be compared with the normal side results [Figure 1].

Because the majority of pediatric RHF's were associated with radial neck fractures, a classification system including radial neck fracture was needed. We classified the fractures of the patients according to the classification proposed by Ackerson *et al.* as EARH and IARH fractures.²⁰ The number of patients who were classified into group EARH was 17, and those who were classified into group IARH was 7. An IARH fracture involved the Salter-Harris (S-H) classification III or IV, and an EARH fracture involved the S-H classification I, II, or radial neck fracture.²⁴ The patients' demographics are shown in Table 1.

Treatment choices

All patients were managed by one surgeon at level I trauma center. A long arm cast was applied when the angulation was <30°. When the angulation was 30°–60°, we attempted to reduce the fracture using a closed method. When the fractures were not reduced using the closed method, an open surgery was performed. When the fractures were angulated more than 60° or severely comminuted or combined with an open wound, an open surgical treatment was performed initially. In group EARH, seven patients were managed with a simple cast immobilization; one patient underwent manipulative closed reduction with cast immobilization; three patients were managed with cast immobilization after reduction with the Kirschner wire (K-wire) leverage technique [Figure 2]; two patients were managed with closed reduction and fixation using the K-wire; and four patients were treated with open reduction. In group IARH, one patient underwent manipulative closed

reduction with cast immobilization; three patients were managed with closed reduction and K-wire fixation; and three patients were treated with an open surgery [Figure 3].

Operative procedure

Under general anesthesia, the patients were placed in a supine position with the injured superior limb placed on a radiolucent table. Under fluoroscopy, depending on patient age and size, a 1.4-mm to 1.8-mm K-wire was then introduced percutaneously. The K-wire was inserted percutaneously from proximal to distal RHF site, and used as a joystick (K-wire leverage technique) to partially reduce it. According to decision of an operator, K-wire was removed if the reduced fragment was stable. If not, the K-wire was advanced toward the ulnar side to impact the opposite cortex. The stability of reduction and forearm rotation were checked under fluoroscopic control. The K-wire was left protruding out of the skin and was bent over to prevent migration. A long arm cast with the forearm in a neutral position was applied.

When the operator decided to open, a pneumatic tourniquet was used during the surgery to minimize blood loss. Using lateral Kocher approach, the anconeus-extensor carpi ulnaris interval was used. The capsule is opened longitudinally, and the acceptable reduction was obtained using fingers of the periosteal elevator. Using K-wire, fractured fragments were fixed. A long arm cast was also applied as closed surgery.

Evaluation tool

Information about sex, age, body mass index (BMI), injured side, dominant hand, and associated olecranon fractures was collected [Table 1]. Angulation was measured between the fracture lines of the proximal and distal fragment.¹ Displacement was also measured as the extent of lateral shift of the fragment by the distance from the center of the radial head to a line along the axis of the upper radius [Figure 4].

Table 1: Patient's demographics

Variable	EARH (n=17)	IARH (n=7)	P
Sex (male:female)	12:5	3:4	0.208*
Age (year)	8.1±3.5	9.2±3.2	0.491††
BMI (kg/m ²)	17.9±4.4	20.0±6.2	0.260‡
Followup (year)	5.9±2.7	6.3±2.5	0.664‡
Angulation (mm)	31.8±25.7	42.9±30.0	0.366††
Displacement (mm)	36.4±21.0	46.9±19.1	0.269††
Accompanied olecranon fracture (with:without)	4:13	2:5	0.586*
Treatment (open:closed)	4:13	3:4	0.318*

*Fisher's exact test, †Mann-Whitney U-test, ††Student's t-test. Values are presented as mean±SD. EARH=Extra articular radial head, IARH=Intraarticular radial head, BMI=Body mass index, Open = open reduction with or without internal fixation, and elastic stable intramedullary nailing, Closed = Percutaneous pin reduction, SD=Standard deviation

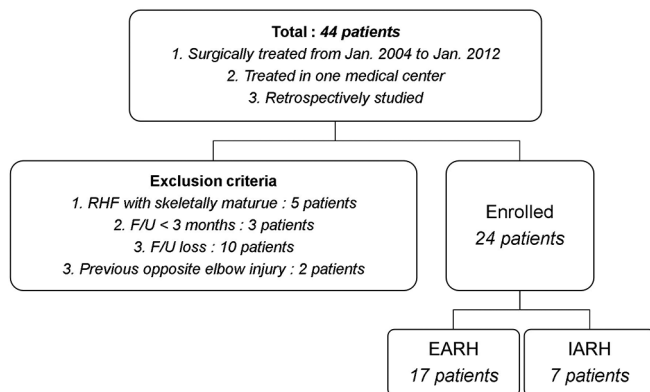


Figure 1: Flowchart of subjects enrollment

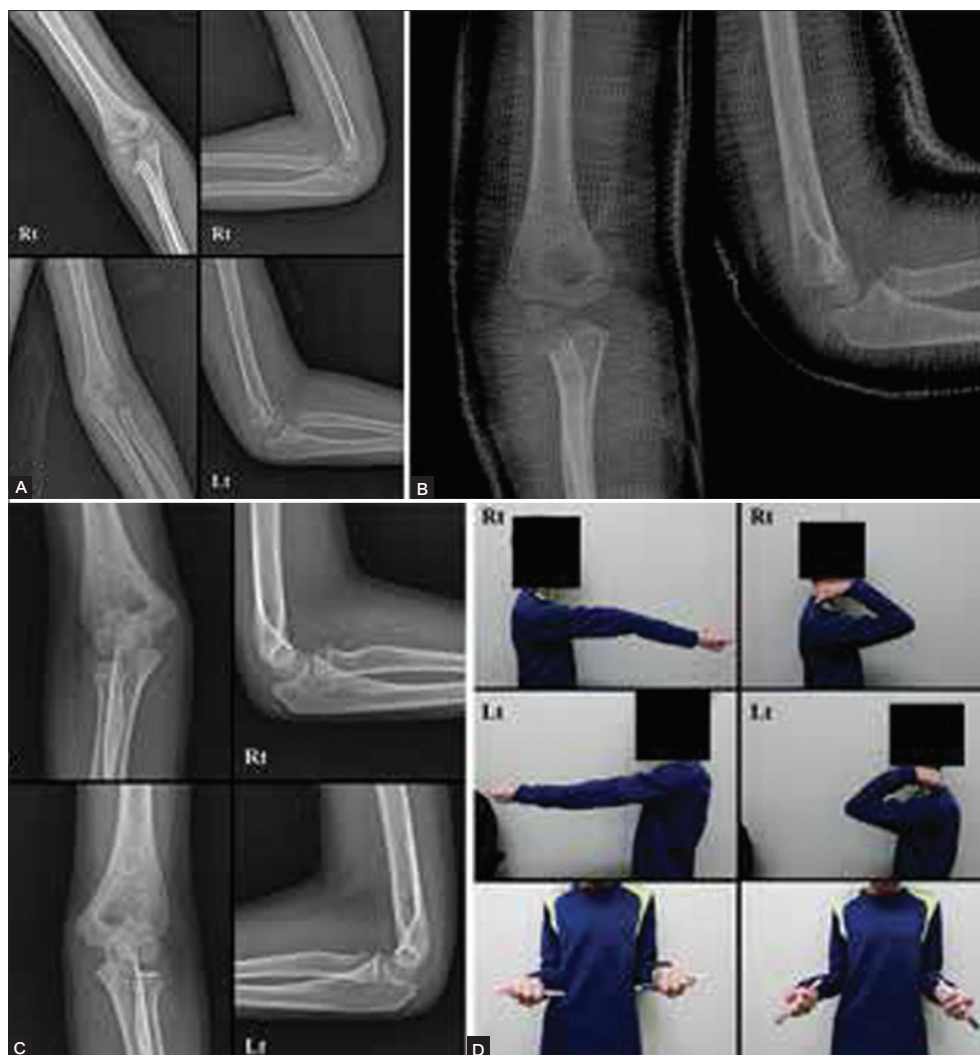


Figure 2: (a) Initial AP and lateral radiographs of elbow of a 5-year-old patient. Injured Rt side and uninjured Lt side. (b) Cast immobilization after reduction using the K-wire leverage technique. (c) AP and lateral radiographs of the same patient at 7 years of followup. The RHD and RHH of the injured Rt side are slightly enlarged compared to the uninjured Lt side. (d) Clinical photographs of the same patient showing the ROM of the elbow. The injured Rt side shows an increased extension and decreased flexion compared to the uninjured Lt side (AP = Anteroposterior, Rt = Right, Lt = Left; RHD = Radial head diameter, RHH = Radial head height)

After treatment, clinical and radiographic data were collected during the followup period. The patients were followed up monthly for up to 6 months after the injury and once a year thereafter. Clinically, the Mayo Elbow Performance Score (MEPS),²⁵ Tibone and Stoltz classification (Tibone),²⁶ ROM, and carrying angle (CA) were evaluated. In measuring the elbow extension, the positive extension was defined as the motion past 0° to hyperextension. Radiographically, the radial head diameter (RHD), radial head height (RHH), neck shaft angle (NSA), and distance from the radial head to the radial tuberosity (RHRT) were measured and compared with the other side in simple anteroposterior radiographs of the elbow.

Statistical analysis

The mean and range for all continuous variables were obtained using the IBM SPSS version 23.0 (IBM Co., Armonk, NY, USA). The Fisher's exact test, Student's *t*-test, and Mann-Whitney U-test were used to show the statistical differences

between groups EARH and IARH. The paired *t*-test and Wilcoxon rank sum test were also used to show the statistical differences of ROM, CA, and radiographic outcomes between the injured and uninjured elbows. To evaluate possible prognostic factors between clinical outcomes, a multiple linear regression analysis was used. All statistical analyses were performed using the IBM SPSS version 23.0, and a $P < 0.05$ was considered statistically significant.

Results

Patient characteristics

According to the patients' demographics, all preoperative factors were comparable in both groups. There were no significant differences in sex, age, BMI, duration of followup, angulation, displacement, accompanied olecranon fracture, and open reduction between the two groups [Table 1]. There were 18 patients with an injury in

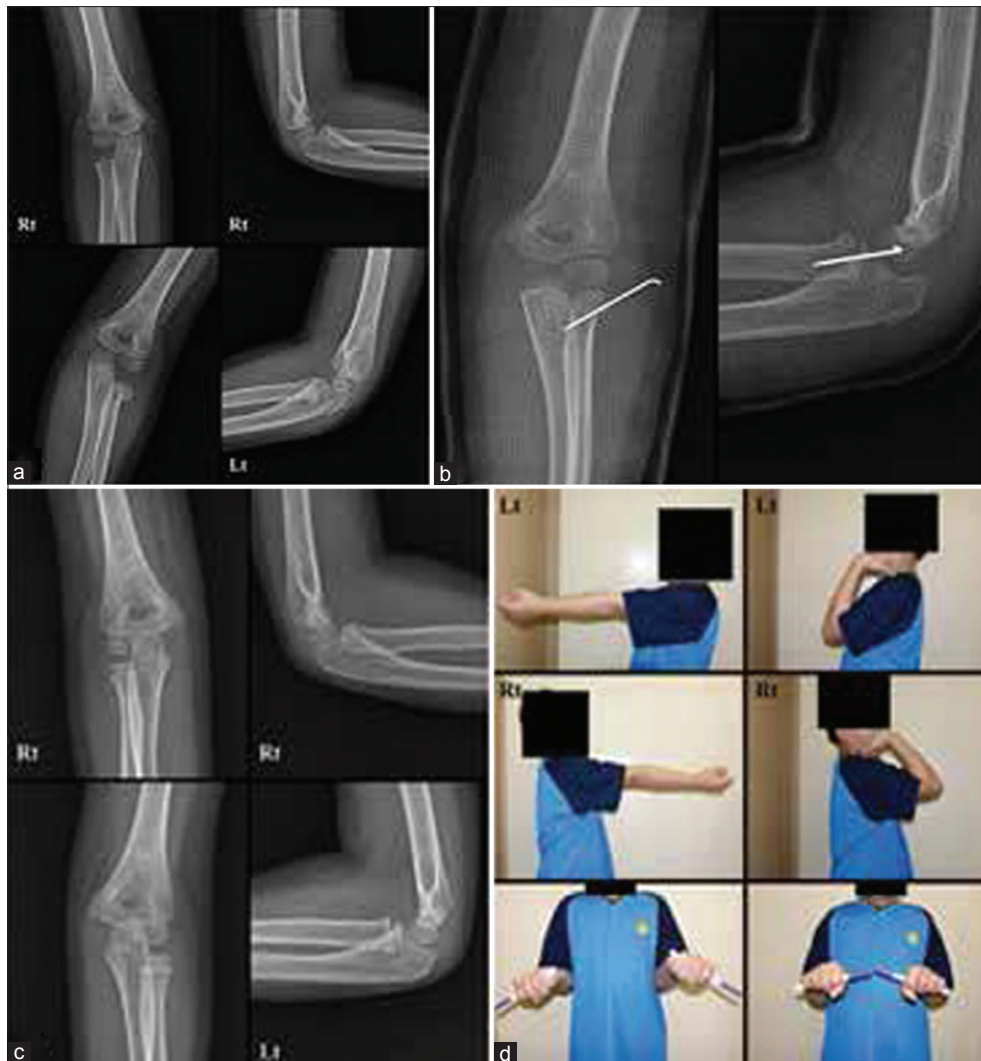


Figure 3: (a) Initial AP and lateral radiographs of elbow joint of a 6-year-old patient. Injured Lt side and uninjured Rt side. (b) Cast immobilization after open reduction and K-wire fixation. (c) AP and lateral radiographs of elbow joint of the same patient at 3 years of followup. The RHD and RHH of the injured Lt side are slightly enlarged compared to the uninjured Rt side. (d) Clinical photograph of the same patient showing the ROM of the elbow. The injured Lt side and uninjured Rt side show similar range of flexion and extension. AP = Anteroposterior, Rt = Right, Lt = left, RHD = Radial head diameter, RHH = Radial head height

the dominant hand and six patients with an injury in the nondominant hand, which was statistically significant using the Fisher's exact test ($P = 0.048$).

Treatment outcomes between groups extra articular radial head and intraarticular radial head

At the last followup, all the patients were satisfied generally with the long term clinical results; excellent results were observed in all patients, except for two patients [Table 2]. The mean MEPS was 100 and 97.9 in groups EARH and IARH, respectively, with no statistically significant difference ($P = 0.619$). In group EARH, all patients showed excellent Tibone scores; however, in group IARH, five patients showed excellent results, and two patients showed good results. The differences were not statistically significant either ($P = 0.076$). The differences in the ROM between the injured and uninjured elbows were

slightly lower in group IARH but were not statistically significant ($P = 0.757, 0.166, 0.389, \text{ and } 0.302$). Similarly, CA, RHD, RHH, NSA, and RHRT showed no statistically significant differences between the two groups ($P = 0.667, 0.181, 0.896, 1.000, \text{ and } 0.322$, respectively).

Treatment outcomes between the injured and uninjured elbows

At the last followup, the injured elbows showed smaller ROMs than the uninjured elbows in flexion, supination, pronation, and the differences were statistically significant (all $P = 0.000$) [Table 3]. However, the injured elbows showed larger extension ranges than the uninjured elbows with a statistical significance ($P = 0.000$). CA, RHD, and RHH were higher in the injured elbows than in the uninjured elbows, and the differences were statistically significant ($P = 0.006, 0.000, \text{ and } 0.011$). However,

NSA and RHRT of the injured and uninjured elbows were similar, and the difference was not statistically significant ($P = 0.810$ and 0.752) [Figures 2 and 3].

Regression model of the prognostic factors

To determine the correlation between the preoperative factors and clinical outcomes, we used the multiple linear regression analysis [Table 4]. As the Tibone scores were categorical data, we converted them to numerical data by weighting them by 1, 2, 3, and 4 points. Age, angulation, and associated olecranon fracture showed statistical significances with the MEPS ($\beta = -0.466$, $P = 0.035$; $\beta = -1.009$, $P = 0.003$; and $\beta = -0.517$, $P = 0.025$, respectively). Similarly, angulation, displacement, and articular involvement showed statistical significances with the Tibone score ($\beta = -0.877$, $P = 0.025$; $\beta = -0.765$, $P = 0.024$; and $\beta = -0.745$, $P = 0.038$, respectively). However, the preoperative factors and ROM showed no significant correlation ($P = 0.995$).

Discussion

The purpose of this study was to evaluate the long term clinical and radiographic outcomes of patients with pediatric RHF. All the patients were satisfied with the long term clinical results. The injured elbows showed restricted ROMs compared with the uninjured elbows; however, the extension range rather increased. We also attempted to evaluate the correlation of the prognostic factors with the treatment outcomes, and the angulation was recognized as the strongest factor for the clinical outcomes.

The treatment of pediatric RHF is still debated.⁹ In general, long arm cast immobilization is used to treat RHF when the angulation is $<30^\circ$.²³ Closed reduction is recommended when the angulation is $30^\circ-60^\circ$.²² Many authors advocate an open surgery for the treatment of completely or severely displaced radial neck fractures.^{13,15,21,27} We also performed the treatment following the formalized algorithm according to the degree of preoperative angulation.

Ackerson *et al.* also compared the treatment outcomes of groups EARH and IARH; group IARH showed poorer treatment outcomes and higher complication rates than group EARH.²⁰ Van Zeeland *et al.* also reported unsuccessful treatments of seven IARH fractures treated with nonsurgical methods.¹⁸ Although group IARH also showed poorer clinical outcomes than group EARH, there was no significant difference in the present study. Therefore, further studies are needed to investigate the differences in the treatment outcomes between group EARH and group IARH.

Tarallo *et al.* evaluated surgical treatment of 14 cases of Mason type III and six cases of type IV. They reported that mean MEPS of elastic stable intramedullary nailing was 91.00 and percutaneous pin reduction was 91.08, respectively.²⁸ Although clinical outcomes of the present study show slightly better, this seems to be due to the inclusion of less severe cases in the present study.

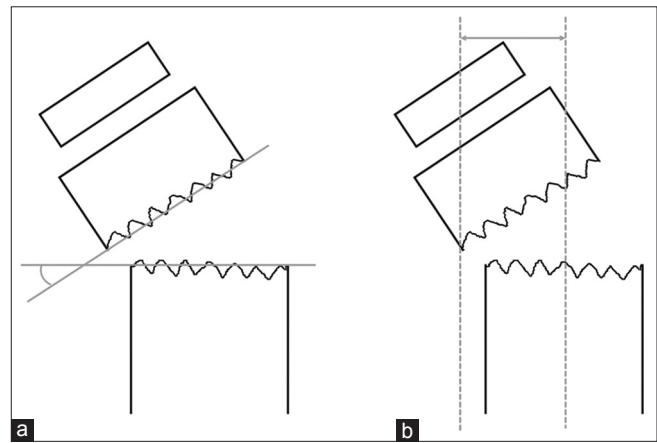


Figure 4: A line diagram showing (a) Angulation was measured between the fracture lines of proximal and distal fragment. (b) Displacement was measured as the extent of lateral shift of the fragment by the distance from the center of the radial head to a line along the axis of the upper radius

Table 2: Treatment outcomes between extra articular radial head and intraarticular radial head

Variable	EARH (n=17)	IARH (n=7)	P
MEPS	100.0±0	97.9±5.7	0.619*
Tibone	All excellent	5 excellent, 2 good	0.076†
Range of motion			
Δ Flexion	6.1±5.3	7.9±10.1	0.757*
Δ Extension	-9.6±8.7	-4.7±6.2	0.166*
Δ Supination	3.5±4.0	5.3±5.4	0.389††
Δ Pronation	3.4±3.5	5.6±6.6	0.302††
Δ Carrying angle	-2.7±2.7	-1.9±7.7	0.667††
Δ Radial head diameter	-1.2±0.6	-1.7±0.9	0.181††
Δ Radial head height	-0.6±0.7	-0.6±0.5	0.896††
Δ Neck shaft angle	-0.7±1.7	1.0±6.8	1.000*
Δ RHRT	-1.0±1.0	0.5±2.8	0.322††

*Mann-Whitney U-test, †Fisher’s exact test, ††Student’s t-test. Values are presented as mean±SD. MEPS=Mayo elbow performance score, Tibone=Tibone and stoltz classification, RHRT=Distance from radial head to radial tuberosity Δ: Uninjured elbow - injured elbow, SD=Standard deviation, EARH=Extra articular radial head, IARH=Intraarticular radial head

Table 3: Comparison of range of motion, carrying angle, and radiographic outcomes between injured elbow and uninjured elbow

Variable	Injured elbow	Uninjured elbow	P
Flexion	132.0±7.6	138.6±7.4	0.000*
Extension	8.9±7.6	0.7±4.8	0.000†
Supination	113.8±19.6	117.8±19.6	0.000*
Pronation	65.9±13.1	69.9±10.9	0.000*
Carrying angle	14.0±6.5	11.6±6.4	0.006†
Radial head diameter	19.9±3.7	18.6±3.6	0.000*
Radial head height	5.3±2.6	4.7±2.6	0.011*
Neck shaft angle	166.3±4.6	166.1±3.1	0.810*
RHRT	26.1±4.7	25.9±6.4	0.752*

*Paired t-test, †Wilcoxon rank sum test. Values are presented as mean±SD. RHRT=Distance from radial head to radial tuberosity, SD=Standard deviation

Table 4: Correlation between preoperative factors and clinical outcomes

Variable	MEPS		Tibone	
	Standardized β	P	Standardized β	P
Age (year)	-0.466	0.035	0.281	0.294
Angulation (mm)	-1.009	0.003	-0.877	0.025
Displacement (mm)	-0.042	0.777	-0.765	0.024
Accompanied olecranon fracture	-0.517	0.025	0.312	0.249
Articular involvement	0.380	0.071	-0.745	0.038
R^2, P	0.923, 0.005		0.909, 0.029	

MEPS=Mayo elbow performance score, Tibone=Tibone and stoltz classification

Many authors reported restriction of ROM or cubitus valgus deformity after healing of pediatric RHF.^{3,18,29} The patients in this study also showed reduced ROMs; however, the extension range rather increased in many patients regardless of the type of fracture (EARH or IARH). We attempted to determine the relationship between the change in the healing process of the radial head and elbow hyperextension. As Falciglia *et al.* reported, we could also observe an increased RHD.³⁰ We also evaluated the RHH, which also increased at the last followup. The increase of RHD and RHH means that the radial head is compressed, and it is considered that olecranon alone cannot prevent hyperextension during elbow extension. We suspect that RHD and RHH have a slight impact on hyperextension. However, these differences are $<10^\circ$, so they might not be clinically significant.

The multiple regression analysis showed that angulation was the only overlapped predictor and the strongest factor of the clinical outcome. Other factors, such as age, displacement, and accompanied olecranon fracture also showed negative correlations with the clinical results. Zimmerman *et al.* reported that age, fracture angulation, and fracture displacement were correlated with more invasive interventions.³¹ Tan and Mahadev. reported that worse treatment outcomes were associated with increased fracture severity, older age, and more invasive interventions.¹⁶

This study has several limitations. First, this was a retrospective study, and the sample size was small. Second, the final ROM was evaluated by two different physicians in an outpatient clinic, which might have affected the reliability in comparing the outcomes. Third, we did not investigate the relationship between the period when the growth plate was arrested and the radiographic change or ROM change. Finally, lack of statistical significance is likely due to small numbers for the comparison. However, the strength of this study is that we observed the long term clinical and radiographic outcomes of the patients with pediatric RHF.

All patients with pediatric RHF were satisfied with the long term clinical results. The injured elbows showed restricted ROM compared with the uninjured elbows; however, the extension range rather increased. Angulation is the strongest prognostic factor for the clinical outcomes of RHF.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

- O'Brien PI. Injuries involving the proximal radial epiphysis. *Clin Orthop Relat Res* 1965;41:51-8.
- Jeffery CC. Fractures of the head of the radius in children. *J Bone Joint Surg Br* 1950;32-B:314-24.
- D'souza S, Vaishya R, Klenerman L. Management of radial neck fractures in children: A retrospective analysis of one hundred patients. *J Pediatr Orthop* 1993;13:232-8.
- Henrikson B. Isolated fractures of the proximal end of the radius in children epidemiology, treatment and prognosis. *Acta Orthop Scand* 1969;40:246-60.
- Gaston SR, Smith FM, Baab OD. Epiphyseal injuries of the radial head and neck. *Am J Surg* 1953;85:266-76.
- Landin LA. Fracture patterns in children. Analysis of 8,682 fractures with special reference to incidence, etiology and secular changes in a Swedish urban population 1950-1979. *Acta Orthop Scand Suppl* 1983;202:1-109.
- Radomisli TE, Rosen AL. Controversies regarding radial neck fractures in children. *Clin Orthop Relat Res* 1998;353:30-9.
- Cha SM, Shin HD, Kim KC, Han SC. Percutaneous reduction and leverage fixation using K-wires in paediatric angulated radial neck fractures. *Int Orthop* 2012;36:803-9.
- Evans MC, Graham HK. Radial neck fractures in children: A management algorithm. *J Pediatr Orthop B* 1999;8:93-9.
- Brandao GF, Soares CB, Teixeira LE, Boechat Lde C. Displaced radial neck fractures in children: association of the Metaizeau and Bohler surgical techniques. *J Pediatr Orthop* 2010;30:110-4.
- Ugutmen E, Ozkan K, Ozkan FU, Eceviz E, Altintas F, Unay K, *et al.* Reduction and fixation of radius neck fractures in children with intramedullary pin. *J Pediatr Orthop B* 2010;19:289-93.
- Eberl R, Singer G, Fruhmann J, Saxena A, Hoellwarth ME. Intramedullary nailing for the treatment of dislocated pediatric radial neck fractures. *Eur J Pediatr Surg* 2010;20:250-2.

13. Endeale SM, Wirth T, Eberhardt O, Fernandez FF. The treatment of radial neck fractures in children according to Metaizeau. *J Pediatr Orthop B* 2010;19:246-55.
14. Futami T, Tsukamoto Y, Itoman M. Percutaneous reduction of displaced radial neck fractures. *J Shoulder Elbow Surg* 1995;4:162-7.
15. Schmittenbecher PP, Haevernick B, Herold A, Knorr P, Schmid E. Treatment decision, method of osteosynthesis, and outcome in radial neck fractures in children: A multicenter study. *J Pediatr Orthop* 2005;25:45-50.
16. Tan BH, Mahadev A. Radial neck fractures in children. *J Orthop Surg (Hong Kong)* 2011;19:209-12.
17. Metaizeau JP, Lascombes P, Lemelle JL, Finlayson D, Prevot J. Reduction and fixation of displaced radial neck fractures by closed intramedullary pinning. *J Pediatr Orthop* 1993;13:355-60.
18. Van Zeeland NL, Bae DS, Goldfarb CA. Intraarticular radial head fracture in the skeletally immature patient: Progressive radial head subluxation and rapid radiocapitellar degeneration. *J Pediatr Orthop* 2011;31:124-9.
19. Leung AG, Peterson HA. Fractures of the proximal radial head and neck in children with emphasis on those that involve the articular cartilage. *J Pediatr Orthop* 2000;20:7-14.
20. Ackerson R, Nguyen A, Carry PM, Pritchard B, Hadley-Miller N, Scott F, *et al.* Intraarticular radial head fractures in the skeletally immature patient: Complications and management. *J Pediatr Orthop* 2015;35:443-8.
21. Métaizeau JP. Reduction and osteosynthesis of radial neck fractures in children by centromedullary pinning. *Injury* 2005;36 Suppl 1:A75-7.
22. Wall L, O'Donnell JC, Schoenecker PL, Keeler KA, Dobbs MB, Luhmann SJ, *et al.* Titanium elastic nailing radius and ulna fractures in adolescents. *J Pediatr Orthop B* 2012;21:482-8.
23. Su Y, Xie Y, Qin J, Wang Z, Cai W, Nan G. Internal fixation with absorbable rods for the treatment of displaced radial neck fractures in children. *J Pediatr Orthop* 2016;36:797-802.
24. Salter RB. Injuries of the epiphyseal plate. *Instr Course Lect* 1992;41:351-9.
25. Turchin DC, Beaton DE, Richards RR. Validity of observer-based aggregate scoring systems as descriptors of elbow pain, function, and disability. *J Bone Joint Surg Am* 1998;80:154-62.
26. Tibone JE, Stoltz M. Fractures of the radial head and neck in children. *J Bone Joint Surg Am* 1981;63:100-6.
27. Okçu G, Aktuğlu K. Surgical treatment of displaced radial neck fractures in children with metaizeau technique. *Ulus Travma Acil Cerrahi Derg* 2007;13:122-7.
28. Tarallo L, Mugnai R, Fiacchi F, Capra F, Catani F. Management of displaced radial neck fractures in children: Percutaneous pinning vs. elastic stable intramedullary nailing. *J Orthop Traumatol* 2013;14:291-7.
29. Waters PM, Stewart SL. Radial neck fracture nonunion in children. *J Pediatr Orthop* 2001;21:570-6.
30. Falciglia F, Giordano M, Aulisa AG, Di Lazzaro A, Guzzanti V. Radial neck fractures in children: Results when open reduction is indicated. *J Pediatr Orthop* 2014;34:756-62.
31. Zimmerman RM, Kalish LA, Hresko MT, Waters PM, Bae DS. Surgical management of pediatric radial neck fractures. *J Bone Joint Surg Am* 2013;95:1825-32.