Operative Choice for Displaced Proximal Humeral Fractures in Adolescents with Open Visible Physis: A Comparative Study of External Fixator vs. Kirschner Wire

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Abstract

Background: For adolescents of severely displaced proximal humeral fracture (PHF), surgery is a good choice yielding excellent outcomes. Kirchner wire (KW) is a cost-effective choice for fixation, and this study aims to compare the clinical outcomes of external fixator (EF) vs. KW for the treatment of PHF in adolescents. To the best of our knowledge, it is the first report on external fixator for PHF in children and adolescents.

Methods: Patients of PHF operated in our institute, from January 2008 to January 2016, were reviewed retrospectively. Demographic data, including sex, age at the time of surgery, operated side, and hardware choice, were collected from the hospital database. Preoperative radiographs were reviewed and classified according to Neer-Horwitz classification. Shoulder function was evaluated during 12th month follow-up using rating scale of the American shoulder and elbow surgeons (ASES). Complications, including infection, malunion, nonunion, stiffness of the shoulder joint, and failure of fixation were also recorded.

Results: Thirty-five patients, including 23 males and 12 females, were included in the EF group, whereas 40 patients, including 25 males and 15 females, were included in the KW group ($P = 0.867$). The average age of patients in the EF group was 13.3 ± 1.7 years, and that of KW was 13.6 ± 1.8 years ($P = 0.409$). Patients in both groups were followed-up for at least 12 months. The operative time in the EF group (42.4 ± 11.2 , min) was significantly shorter than those in the KW group (54 ± 13.6 , min), $P < 0.001$. The frequency of fluoroscopy in the EF group (12 ± 2.4) was significantly less than those in the KW group (17 ± 2.8), $P < 0.001$. The rate of open reduction was significantly higher in KW (35%) group than those in the EF group (0%), $P < 0.001$. There was no nonunion, malunion cases in both groups.

Conclusion: External fixator is superior to Kirschner wire in the treatment of proximal humeral fractures in adolescents with shorter operative time, lower rate of ORIF and comparable clinical outcomes.

Background

Proximal humeral fractures (PHF) in children are relatively scarce, accounting for less than 3% of all fractures in pediatric population[1]. Because of high remodeling potential, nonoperative method remains the primary choice for PHF in children[2]. In literature, the majority of studies focus on the non-adolescent patients, and even the poorly reduced fractures were well tolerated by the patients in the long run because of remarkable remodeling potential and compensatory mechanism of shoulder and elbow joint[3, 4, 5]. However, in adolescents with severely displaced PHF, non-anatomically reduced fractures can lead to long term limited mobility and pain[6, 7]. Besides, more and more adolescents participate in the sports game and have high demand on the shoulder function[8].

For adolescents of severely displaced PHF, surgery is a good choice yielding excellent outcomes[2, 6, 9, 10]. Kirchner wire (KW) is a cost-effective choice for fixation[6], and this study aims to compare the clinical outcomes of external fixator (EF) vs. KW for the treatment of PHF in adolescents. To the best of our knowledge, it is the first report on external fixator for PHF in children and adolescents.

Methods

Patients of PHF operated in our institute, from January 2008 to January 2016, were reviewed retrospectively. Inclusion criteria were: 1) Patients managed with open reduction/closed reduction, and fixation with either the use of EF or KW, 2) presentation within the period of 2 weeks after the trauma, 3) availability of both the clinical and radiological data, 4) the follow-up period of 12 months or more, and 5) age between 12 and 16 years old at the time of surgery with open visible physis.

The exclusion criteria were: 1) patients managed with conservative methods, 2) open or pathological fracture, and 3) previous shoulder or humerus fracture or instrumentation.

The patient's legal guardians were thoroughly explained about the risks and benefits of conservative method and operative choice, and let them choose. The choice of hardware was decided by the surgeon in charge.

The patients were divided into two groups, the EF group and KW group. The EF group consisted of 35 patients, whereas the KW group consisted of 40 patients. Demographic data, including sex, age at the time of surgery, operated side, and hardware choice, were collected from the hospital database. Preoperative radiographs were reviewed and classified according to Neer-Horwitz classification[11]. Shoulder function was evaluated during 12th month follow-up using rating scale of the American shoulder and elbow surgeons (ASES)[12]. Complications, including infection, malunion, nonunion, stiffness of the shoulder joint, and failure of fixation were also recorded.

Surgical technique in EF group

Under fluoroscopy, the physis was identified, and two Schanz pins were inserted in the proximal fragment, while 2 other Schanz pins were placed in the distal part. After reduction, and possibly using the “joystick technique”, the Schanz pins were connected with rods and clamps (See Fig. 1, 2).

Surgical technique in KW group.

Closed reduction was performed before pinning, and after satisfactory reduction, 2–3 wires were inserted in retrograde fashion. If closed reduction failed, then anterior delto-pectoral approach was chosen to remove the interposed tissues and facilitate reduction. After satisfactory reduction, percutaneous pinning was performed thereafter (See Fig. 3).

Postoperative care and follow-up

Sling was used for 1–2 weeks for pain relief, and then active exercises were encouraged with tolerable pain. Follow-up at out-patient was scheduled for every 3 weeks. The EF or KW was routinely removed during out-patient visits about 5–8 weeks after surgery. After the removal of hardware, the follow-up was scheduled every 3 months in the first year, and then annually after the first year.

Statistical analysis

SPSS statistical package program (SPSS 19.0 version; SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The categorical data were analyzed using the Chi-square (χ^2) test, and the continuous data were analyzed using Student's t-test. Fisher exact test was used under those circumstances with fewer subjects in groups of interest. Data were presented as mean $\pm$ SD (range), median (range), or n (%). $P < .05$ was considered significantly different.

Result

As shown in Table 1, there was no significant difference between the two groups concerning sex and age. Thirty-five patients, including 23 males and 12 females, were included in the EF group, whereas 40 patients, including 25 males and 15 females, were included in the KW group ($P = 0.867$). The average age of patients in the EF group was 13.3 ± 1.7 years, and that of KW was 13.6 ± 1.8 years ($P = 0.409$). Patients in both groups were followed-up for at least 12 months. The fracture classification and duration from injury to surgery showed no significant difference between both groups.

Table 1
Demographics of the patients

Demographics of the patients				
Parameters		EF (n = 35)	KW (n = 40)	P value
Age(y)		13.3 ± 1.7	13.6 ± 1.8	0.409
Sex (male/female)		23/12	25/15	0.867
Side (left/right)		18/17	21/19	0.621
From injury to surgery (d)		3.2 ± 1.0	3.4 ± 1.1	0.610
Neer-Horwitz Classification	III	21(60.0%)	25(62.5%)	0.576
	IV	14(40.0%)	15(37.5%)	
EF = external fixator; KW = Kirschner wire				

As shown in Table 2, the operative time in the EF group (42.4 ± 11.2 , min) was significantly shorter than those in the KW group (54 ± 13.6 , min), $P < 0.001$. The frequency of fluoroscopy in the EF group (12 ± 2.4) was significantly less than those in the KW group (17 ± 2.8), $P < 0.001$. The rate of open reduction was significantly higher in KW (35%) group than those in the EF group (0%), $P < 0.001$.

Table 2
Operative parameters of the patients

Parameters	EF (n = 35)	KW (n = 40)	P value
Operative time, min	42.4 ± 11.2	54 ± 13.6	< 0.001
Fluoroscopy times	12 ± 2.4	17 ± 2.8	< 0.001
Open reduction	0	14 (35%)	< 0.001
LHS, day	3.4 ± 1.1.	3.5 ± 1.2	0.476
LHS = length of hospital stay			

As shown in Table 3, the postoperative neck-shaft angle (NSA) showed no significant difference between the two groups (P = 0.401). The function of shoulder joint at 6th month follow-up showed no significant difference between the EF group (93.6 ± 2.4) and the KW group (93.7 ± 2.3), P = 0.739.

Table 3
Clinical outcome of the patients

Clinical outcomes	EF (n = 35)	KW (n = 40)	P value
Pre-op NSA (degree)	97 ± 13.2	94 ± 13.6	0.386
Post-op NSA (degree)	139 ± 6.3	137 ± 6.8	0.401
NSA at 6 th Mo (degree)	139.1 ± 5.6	136.7 ± 7.0	0.560
ASES at 6 th Mo	93.6 ± 2.4	93.7 ± 2.3	0.739
ASES = American Shoulder and Elbow Surgeons (ASES) Society Standardized Shoulder Assessment Form			

Table 4
Complications of the patients until last follow-up

Complications	EF (n = 35)	KW (n = 40)	P value
Nonunion	0	0	1
Malunion	0	0	1
Revision	0	0	1
Unresolved stiffness	0	0	1
Hardware irritation	10 (28.6%)	11 (27.5%)	0.479
Superficial infection	13 (37.1%)	15 (37.5%)	0.636

There was no nonunion, malunion cases in both groups. Patients in both groups displayed normal range of motion (ROM) of shoulder joint at the same level as before injury at 6th month follow-up. The hardware

irritation showed no significant difference between the EF group (28.6%) and KW group (27.5%), $P = 0.479$. The superficial infection displayed no significant difference between the EF group (37.1%) and the KW group (37.5%), $P = 0.636$.

Discussion

EF proves to be a valuable choice for adolescents with Neer-Horwitz type 3 and 4 PHF, with comparable clinical outcomes to KW, but with lower rate of ORIF and without the necessity of penetrating physis.

KW pinning and retrograde elastic stable intramedullary nail (ESIN) have been reported for the treatment of severely displaced PHF[9, 12, 13, 14]. Although ESIN was reported be a safe method with early return to preinjury function[15], but ESIN is not superior to KW regarding the clinical outcomes according to several comparative studies[9, 14]. Besides, ESIN requires additional surgery for hardware removal. Therefore, ESIN was not the preferred choice at our institute.

KW is a cost-effective choice for PHF, and usually is performed in percutaneous fashion[16]. However, sometimes entrapment of the tendon of long head of biceps and periosteum might hinder the manual reduction[17, 18], and ORIF has to be done to facilitate the reduction followed by KW pinning[1, 2]. In contrast, the threaded Schanz screws proved to be useful in “joystick technique”, and the incidence of open reduction was nil in EF group, significantly lower than KW group. Besides, there were reports about serious complications in the treatment of PHF using KW, including KW migrating from proximal humerus to the chest and even perforating the aorta[19, 20, 21]. Thus, KW was unburied and bent at the tail at our institute for monitoring the possible migration and loosening. Moreover, in order to provide sufficient stability, KW has to penetrate the physis. The incidence of growth disturbance in patients treated by pinning is rare[1, 2, 9], possibly because of small diameter of KW and the near skeletal maturity of adolescents. In contrast, in EF group, Schanz screw did not penetrate the physis under the guidance of fluoroscopy, and raised no concern about iatrogenic injury to growth plate.

As shown in our study, the clinical outcome of patients in KW group was satisfactory, consistent with previous studies[1, 2, 22]. In our study, patients in EF groups displayed similar and excellent clinical outcomes and radiographic parameters, with shorter operative time and lower rate of open reduction. Pin tract infection (PTI) is a common complication of external fixator and percutaneous pinning[23], and the rate of PTI was similarly within an acceptable range in both groups without serious complications requiring revision surgery or intravenous antibiotic therapy.

EF has been reported in the treatment for proximal humeral fractures in adults[24], but to the best of our knowledge, this study is the first to report the application of EF in the treatment of proximal humeral fractures in adolescents with open visible physis.

There were several limitations in our study. It was a investigation in retrospective fashion, and the result should be interpreted with caution. The allocation of patient to either KW or EF group was partly dependent on the preference of surgeon in charge, and this possibly led to allocation bias. The cost-effective analysis remains to be investigated, because EF is more expensive than KW.

Conclusion

External fixator is superior to Kirschner wire in the treatment of proximal humeral fractures in adolescents with shorter operative time, lower rate of ORIF and comparable clinical outcomes.

Abbreviation

EF = external fixator; PHF = proximal humeral fracture; KW = Kirschner wire; ASES = American shoulder and elbow surgeons; PTI = Pin tract infection.

Declarations

Ethics Approval and Consent to Participate

Not applicable. Since this study was a retrospective investigation, the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology ruled that no formal ethnics approval was required. Written consents to participate in this study were obtained from the legal guardians of every patient.

Consent for publication

Written consents were obtained from the legal guardians of every patient in this study for publication of this paper.

Availability of data and material

The datasets supporting the conclusion of this article are included within the article. Upon request, raw data can be provided by the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

JL* is in charge of the main idea and is the guarantor of integrity of the entire clinical study; PH and JL are in charge of the study concepts, design, manuscript preparation and editing; PH and SR are in charge of the language polishing and the grammar revision; RKL and HBQ is in charge of the collection of the study data. All authors read and approved the final manuscript.

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Figures

Figure 1

Twelve year-old boy with left proximal humerus fracture treated with external fixator A. AP view of upper arm before surgery B. Placement of 2 Schanz screws in the proximal fragment C. AP view of shoulder joint after surgery D. Lateral view of shoulder joint after surgery E. AP view of upper arm at 3th week follow-up F. Lateral view of upper arm at 3th week follow-up G. AP view of upper arm after hardware removal H. Lateral view of upper arm after hardware removal

Figure 2

Twelve year-old boy of left proximal humeral fracture treated with EF A. AP view of humerus before surgery B. Lateral view of humerus after surgery C. AP view of humerus after surgery D. Lateral view of humerus after surgery E. AP view of humerus after hardware removal F. Lateral view of humerus after hardware removal

Figure 3

Thirteen year-old boy of right proximal humeral fracture treated with KW A. AP view of shoulder joint before surgery B. AP view of shoulder joint after surgery C. Lateral view of shoulder joint after surgery