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Efficacy of Percutaneous Lever Reduction with Kirschner Wires in the Treatment of Gartland Type III Supracondylar Humerus Fractures in Children

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Research Article

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Abstract

Objective: To evaluate the efficacy of percutaneous lever reduction with Kirschner wires (K-wires) in the treatment of Gartland type III supracondylar humerus fractures in children.

Methods: A retrospective analysis was conducted on the clinical data of 49 pediatric patients with Gartland type III supracondylar humerus fractures who met the inclusion criteria and were treated between July 2024 and December 2025. The patients were divided into two groups according to the surgical reduction technique employed: the experimental group (n=24) underwent percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation, while the control group (n=25) received routine closed reduction and percutaneous K-wire internal fixation. The two groups were compared regarding gender, age, operative time, number of intraoperative fluoroscopic exposures, number of cases converted to open reduction, Baumann's angle, the proportion of cases in which the anterior humeral line (AHL) passed through the middle one-third of the humeral head, fracture healing time, complication rate, range of motion (ROM) of elbow flexion-extension at the last follow-up, and Flynn functional grading system.

Results: No significant differences were found between the two groups in gender or age ($P > 0.05$). Closed reduction was successfully achieved in all patients in both groups, and no case required conversion to open reduction. However, the experimental group demonstrated significantly better outcomes than the control group in mean operative time (39.21 ± 8.56 min vs. 56.68 ± 14.59 min) and mean number of fluoroscopic exposures (29.17 ± 12.18 vs. 44.52 ± 13.63), with statistically significant differences ($P < 0.05$). No significant differences were observed between the two groups in postoperative Baumann's angle measurements or in the proportion of cases with AHL passing through the middle one-third of the humeral head ($P > 0.05$). The mean postoperative follow-up duration was 9.09 ± 2.47 months in the experimental group and 9.14 ± 2.74 months in the control group. Fracture healing was achieved in all patients within 4 to 6 weeks postoperatively in both groups, with a mean healing time of 5.11 ± 0.83 weeks in the experimental group and 5.24 ± 0.56 weeks in the control group; the difference was not statistically significant ($P > 0.05$). At the last follow-up, there were no significant differences between the two groups in elbow ROM or Flynn functional grading ($P > 0.05$), and both groups achieved satisfactory elbow function. One patient in the experimental group developed a postoperative pin tract infection, which was successfully managed with symptomatic treatment.

Conclusion: For the treatment of Gartland type III supracondylar humerus fractures in children, percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation can achieve favorable reduction quality and therapeutic outcomes compared with routine closed reduction and percutaneous K-wire internal fixation. Moreover, this technique offers the advantages of shorter operative time and a reduced risk of intraoperative radiation exposure.

Background

The distal humerus in children comprises the medial epicondyle, lateral epicondyle, trochlea, capitellum, and olecranon fossa. The supracondylar region is a transitional zone where the tubular humeral shaft narrows and flattens into the distal humerus, representing a structurally vulnerable area. Anteriorly lies the coronoid fossa and posteriorly the olecranon fossa, with only a thin layer of cortical bone between them, rendering this region susceptible to fracture following trauma. Supracondylar humerus fractures are the most common type of elbow fracture in children, accounting for 60% of all pediatric elbow fractures[1]. They predominantly occur in active children aged 3 to 10 years, with a higher prevalence in boys[2]. These fractures are typically caused by a fall from a height with the arm outstretched, whereby the force is transmitted through the forearm to the weak olecranon fossa. Based on the elbow position (extension versus flexion) at the time of injury and the direction of the impacting force, supracondylar humerus fractures are classified as extension-type or flexion-type. According to the Gartland classification system, supracondylar humerus fractures are categorized into types I, II, and III. Type III fractures are characterized by complete disruption of both the anterior and posterior cortices, complete displacement of the fracture fragments with no cortical contact, and are frequently accompanied by vascular and nerve injuries[3]. The Gartland classification has long been considered a crucial reference for assessing fracture severity and guiding treatment decisions[4].Gartland type III supracondylar humerus fractures generally require surgical intervention. However, due to the marked displacement and instability of the fracture fragments, closed reduction is not only difficult to achieve but also challenging to maintain satisfactory fracture alignment afterward. Inappropriate treatment may lead to long-term complications, including elbow deformity, elbow stiffness, and myositis ossificans[5]. A variety of surgical techniques are available for the management of supracondylar humerus fractures. Traditional open reduction and internal fixation is associated with drawbacks such as extensive surgical trauma, the need for soft tissue stripping around the fracture site, and an increased risk of infection. In contrast, closed reduction and percutaneous K-wire internal fixation offers the advantages of minimal surgical invasiveness, preservation of the soft tissue envelope, and effective maintenance of blood supply to the fracture fragments, and has therefore become the preferred surgical approach for these fractures[6, 7]. In Gartland type III fractures, the distal humeral cortex is completely disrupted with displacement, and the periosteal hinge is partially or completely torn, resulting in multidirectional instability. Consequently, closed reduction is challenging and may yield suboptimal results or necessitate conversion to open reduction[8, 9]. For such difficult-to-reduce supracondylar humerus fractures, percutaneous insertion of a K-wire into the dorsal aspect of the fracture site for lever-assisted reduction can effectively improve both the quality of reduction and surgical efficiency[10]. The present study was designed to evaluate the clinical application of percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation in the treatment of pediatric supracondylar humerus fractures by analyzing the clinical and radiographic data, and to assess the clinical efficacy of this technique. The results are reported as follows.

Materials and Methods

General Information

The inclusion criteria were as follows: (1) age ≤ 14 years; (2) confirmation of Gartland type III supracondylar humerus fracture by preoperative or intraoperative imaging; (3) follow-up duration ≥ 12 weeks; (4) treatment with either closed reduction and percutaneous K-wire internal fixation or percutaneous K-wire lever reduction technique.

The exclusion criteria were as follows: (1) open fractures; (2) pathologic fractures; (3) old fractures; (4) concomitant other elbow fractures or polytrauma; (5) preexisting elbow deformity; (6) incomplete clinical data.

A total of 49 pediatric patients with Gartland type III supracondylar humerus fractures who met the above inclusion criteria and were treated between July 2024 and December 2025 were enrolled. The patients ranged in age from 3.16 to 12.42 years, with a mean age of 7.52 ± 2.61 years. There were 31 males (63.27%) and 18 females (36.73%). The patients were divided into two groups according to the surgical technique employed: the experimental group (n = 24) underwent percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation, while the control group (n = 25) received routine closed reduction and percutaneous K-wire internal fixation.

Surgical Technique

Preoperative preparation: After preoperative assessment, general anesthesia or brachial plexus block anesthesia was administered. The patient was placed in the supine position, with lead aprons and lead caps applied to protect the vital organs. The affected upper limb was abducted and positioned on a radiolucent operating table, with the elbow centered under the image intensifier. The limb was sterilized and draped in a sterile manner.

Control group: The proximal humerus of the affected limb was stabilized by an assistant. The elbow was placed in approximately 10° of mild flexion, and continuous longitudinal traction was applied to the forearm for approximately 3 to 5 minutes to correct shortening displacement. The medial and lateral epicondyles were compressed to correct coronal plane varus or valgus displacement, and forearm pronation or supination was performed to correct rotational deformity. After fluoroscopic confirmation that shortening, rotational, and varus/valgus displacements had been corrected, the elbow was gradually flexed, and reduction was achieved by pushing the olecranon anteriorly to correct sagittal plane displacement. If fluoroscopy after elbow flexion revealed that the distal fragment remained posteriorly displaced, that shortening persisted, or that muscle or periosteal tissue was interposed at the fracture site, traction and reduction were repeated; the "milking maneuver" could be employed to release the entrapped muscle and periosteal tissue[11]. After fluoroscopic confirmation of satisfactory reduction, the lateral epicondyle was selected as the entry point. Under fluoroscopic guidance, 2 to 3 K-wires (1.5 mm or 2.0 mm) were inserted through the lateral epicondyle. Alternatively, with the elbow in semi-extension

and the ulnar nerve protected, 1 K-wire was inserted through the medial epicondyle to achieve cross-fixation with the lateral K-wires.

Experimental group (percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation): The closed reduction procedure was the same as that in the control group. When fluoroscopy after elbow flexion revealed that the distal fragment remained posteriorly displaced, that length recovery was insufficient, or that muscle or periosteal tissue was entrapped at the fracture site, percutaneous K-wire lever-assisted closed reduction was performed. The forearm of the affected limb was placed in the sagittal position. A 2.0 mm K-wire was percutaneously inserted into the fracture site from the posterior aspect of the elbow, and the distal fragment was levered into reduction using the K-wire as a fulcrum, while simultaneously correcting coronal and rotational displacements. The elbow was then flexed to complete the reduction and correct sagittal displacement. After fluoroscopic reconfirmation of satisfactory reduction, percutaneous K-wire internal fixation was performed (using the same technique as in the control group) (Fig. 1).

Finally, fluoroscopy was performed in both the coronal and sagittal views to assess fracture reduction and fixation. Satisfactory reduction and fixation having been confirmed, the K-wires were bent and cut short, sterile dressings were applied, and the elbow was immobilized with a long-arm plaster splint at 90° of flexion with the forearm in a neutral position.

Postoperative Management

After surgery, the affected limb was suspended and immobilized. The degree of limb swelling, digital capillary refill, skin sensation, and finger motion were closely monitored. The dressing was kept dry and clean, and regular wound disinfection and dressing changes were performed. The pin tracts were observed for any exudate or signs of skin irritation. At 4 to 6 weeks postoperatively, anteroposterior and lateral radiographs of the elbow were obtained. If fracture healing was satisfactory, with continuous callus formation across the three cortices on radiographs, the plaster splint was removed and the K-wires were extracted. Patients and their parents were instructed on active and passive elbow range-of-motion exercises, and regular outpatient follow-up was scheduled.

Outcome Measures

(1) Perioperative indicators: operative time and number of intraoperative fluoroscopic exposures, defined as the time and fluoroscopy counts from the initiation of closed reduction to the completion of satisfactory reduction and percutaneous K-wire fixation; and the number of cases in which closed reduction failed and conversion to open reduction was required.

(2) Radiographic evaluation indicators. Baumann's angle: measured on standard anteroposterior radiographs of the elbow as the angle between the longitudinal axis of the humeral shaft and the epiphyseal line of the lateral humeral condyle. The normal range is 64° to 80°, and the criterion for

satisfactory reduction is a Baumann's angle of < 80°; a value exceeding this threshold may lead to cubitus varus deformity[12]. Anterior humeral line (AHL): The AHL normally passes through the middle one-third of the humeral head. Deviation of the AHL from the center of the humeral head indicates suboptimal reduction, which may adversely affect elbow function.

(3) Elbow function evaluation indicators: including elbow range of motion (ROM) of flexion-extension and the Flynn functional grading system.

(4) Fracture healing evaluation indicators: fracture healing time and complication rate. Complications included ulnar nerve injury, compartment syndrome, K-wire tail irritation or pin tract infection, nonunion or delayed union, and cubitus varus deformity, among others.

Statistical Analysis

Statistical analyses were performed using SPSS software (version 25.0, IBM Corporation, Armonk, NY, USA). Categorical data were presented as counts (%) and analyzed using the chi-square test or Fisher's exact test. Continuous data were expressed as $\bar{x} \pm s$. Normality and homogeneity of variance were assessed prior to analysis. Between-group comparisons were performed using the independent-samples *t*-test for data following a normal distribution, and the Mann-Whitney *U* test for data not following a normal distribution. A *P*-value < 0.05 was considered statistically significant.

Results

The mean follow-up duration was 9.09 ± 2.47 months in the experimental group and 9.14 ± 2.74 months in the control group. No statistically significant differences were observed between the two groups in age, sex distribution, or follow-up duration (*P* > 0.05) (Table 1).

Table 1
Comparison of age, sex, and follow-up duration between the two groups

Variable	Experimental group	Control group	Test statistic	*P*-value
Sex (n)	Male 15	Male 16	χ^2=0.0222	0.882
	Female 9	Female 9		
Age (years)	7.26 ± 2.60	7.18 ± 2.17	*t* = 0.12	0.904
Follow-up (months)	9.09 ± 2.47	9.14 ± 2.74	*U* = 295.5	0.922

The mean operative time was 39.21 ± 8.56 min in the experimental group and 56.68 ± 14.59 min in the control group, and the mean number of fluoroscopic exposures was 29.17 ± 12.18 in the experimental group and 44.52 ± 13.63 in the control group. Compared with the control group, the experimental group had significantly shorter operative time and fewer fluoroscopic exposures, with statistically significant

differences ($P < 0.05$). Closed reduction was successfully achieved in all patients in both groups, and no case required conversion to open reduction (Table 2).

Table 2
Comparison of operative time and intraoperative fluoroscopic exposures between the two groups

Variable	Experimental group	Control group	Test statistic	*P*-value
Operative time (min)	39.21 ± 8.56	56.68 ± 14.59	$t = -5.10$	< 0.001
Fluoroscopic exposures (times)	29.17 ± 12.18	44.52 ± 13.63	$t = -4.20$	< 0.001

Intraoperatively, the Baumann's angle was 72.96 ± 1.94° in the experimental group and 73.24 ± 2.07° in the control group, with no statistically significant difference between the two groups ($P > 0.05$). The AHL passed through the middle one-third of the humeral head in 23 cases (23/24, 95.83%) in the experimental group and in 23 cases (23/25, 92.00%) in the control group, with no statistically significant difference ($P > 0.05$). The quality of intraoperative fracture reduction was comparable between the two groups, and the Baumann's angle returned to the normal range in all patients (Table 3).

Table 3
Comparison of radiographic evaluation indicators between the two groups

Variable	Experimental group	Control group	Test statistic	*P*-value
Baumann's angle (°)	72.96 ± 1.94	73.24 ± 2.07	$U = 279.5$	0.675
AHL (%)	(23/24, 95.83%)	(23/25, 92.00%)	-	1.000*
Note: *Fisher's exact test was used for comparison of AHL (%).				

Fracture healing was achieved in all patients in both groups within 4 to 6 weeks postoperatively, with a mean healing time of 5.11 ± 0.83 weeks in the experimental group and 5.24 ± 0.56 weeks in the control group. At the last follow-up, the elbow range of motion and Flynn functional grading were comparable between the two groups, with no statistically significant differences ($P > 0.05$). One patient in the experimental group developed a postoperative pin tract infection, which resolved after symptomatic treatment. No iatrogenic ulnar nerve injury, compartment syndrome, nonunion, or cubitus varus deformity occurred in either group (Table 4).

Table 4
Comparison of postoperative follow-up outcomes between the two groups

Variable		Experimental group	Control group	Test statistic	*P*-value
Fracture healing time (weeks)		5.11 ± 0.83	5.24 ± 0.56	$t = -0.63$	0.532
Elbow ROM (°)	Hyperextension	1.29 ± 4.06	0.96 ± 3.38	$U = 288.0$	0.793
	Flexion	138.8 ± 4.07	138.2 ± 3.79	$U = 265.0$	0.406
Flynn grading		Excellent 20, Good 2, Fair 2	Excellent 20, Good 2, Fair 3	$U = 288.0$	0.792
Complications		1/24	0/25	-	0.490*
Note: *Fisher's exact test was used for comparison of complications.					

Discussion

Supracondylar humerus fractures are a common type of elbow injury in children. Gartland type III, flexion-type, and high supracondylar humerus fractures are associated with substantial injury to the periosteum and muscle tissue at the fracture site, with severe disruption of the periosteal hinge, rendering closed reduction particularly challenging. For children with severe limb swelling or those who are obese and older, closed reduction and percutaneous K-wire internal fixation may be technically difficult. To achieve satisfactory fracture alignment, open reduction and internal fixation is often required[13, 14]; however, this approach is associated with disadvantages including extensive surgical trauma, increased blood loss, visible scarring, and potential impairment of joint function[15]. In markedly displaced Gartland type III fractures, the primary reasons for failed closed reduction include complete displacement resulting in an unstable fracture, the proximal fragment penetrating the brachialis muscle, posterior displacement and significant shortening of the distal fragment, and interposition of periosteum and muscle tissue between the fracture fragments that impedes reduction[16]. The key principle of closed reduction and percutaneous K-wire internal fixation is continuous longitudinal traction along the axis of the affected limb to correct shortening. However, in patients with severe limb swelling or obesity, satisfactory reduction may not be achieved, necessitating repeated attempts at manual reduction under fluoroscopic guidance. Such repeated manipulations may increase the risk of soft tissue injury at the fracture site, and if closed reduction ultimately fails, conversion to open reduction is required[9]. Previous studies have reported that trans-capitellum K-wire-assisted reduction or the olecranon joystick technique can improve the success rate of closed reduction for supracondylar humerus fractures[17, 18]. However, these techniques are procedurally complex, require repeated fluoroscopic confirmation, and involve invasive penetration of the olecranon or capitellum, which may cause damage to the articular cartilage and physis. In the present study, the percutaneous K-wire lever-assisted closed reduction technique involved insertion of a K-wire into the fracture site from the posterior aspect of the elbow, using the K-wire as a lever to reduce the distal fragment. This approach effectively released soft tissue entrapment, reduced

soft tissue injury caused by repeated traction and reduction, caused no damage to the distal humeral physis, significantly improved reduction quality, and was particularly effective for difficult-to-reduce supracondylar humerus fractures, reducing the incidence of conversion to open reduction.

In the present study, no statistically significant differences were observed between the experimental group and the control group in fracture healing time, radiographic evaluation indicators, or elbow function at the last follow-up ($P > 0.05$). However, the experimental group had significantly shorter operative time and fewer intraoperative fluoroscopic exposures ($P < 0.05$). For difficult-to-reduce Gartland type III supracondylar humerus fractures, surgeons often need to perform repeated reductions with fluoroscopic confirmation to achieve satisfactory fracture alignment during surgery, which inevitably prolongs operative time and increases the number of fluoroscopic exposures, thereby increasing radiation exposure for both surgeons and patients[19, 20]. In contrast, in the experimental group, the K-wire could be percutaneously inserted into the fracture site without fluoroscopic guidance in most cases, with fluoroscopy being used only after reduction to confirm the position and adjust the K-wire as needed. The lever effect of the K-wire reduced the duration of continuous traction, effectively improved both reduction quality and efficiency, shortened operative time, and decreased the risk of intraoperative radiation exposure.

Conclusions

In summary, compared with routine closed reduction and percutaneous K-wire internal fixation, percutaneous K-wire lever-assisted closed reduction and percutaneous K-wire internal fixation for Gartland type III supracondylar humerus fractures can shorten operative time and reduce intraoperative fluoroscopic exposures, without increasing the complication rate, and achieves satisfactory clinical outcomes. The present study has certain limitations, including a relatively small sample size and its single-center design. Further studies with larger sample sizes and multicenter collaborations are warranted to validate the efficacy of this technique.

Declarations

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Authors' contributions

ZH-Z and P-L conceived and designed the study. ZH-Z, DE-H, and XL-C collected and organized the data. ZH-Z performed the statistical analysis and drafted the manuscript. P-L critically revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Clinical trial number

Not applicable.

Ethics approval and consent to participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki and Good Clinical Practice. The study protocol was approved by the Medical Ethics Committee of People's Hospital of Ningxia Hui Autonomous Region (approval number:2026-LL-238). All participants in this study were under the age of 16. Written informed consent to participate was obtained from the parents or legal guardians of all individual participants prior to enrollment.

Consent for publication

Written informed consent for publication of clinical details and/or clinical images was obtained from the parents or legal guardians of all individual participants included in this study.

Competing interests

The authors declare no competing interests.

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Figures

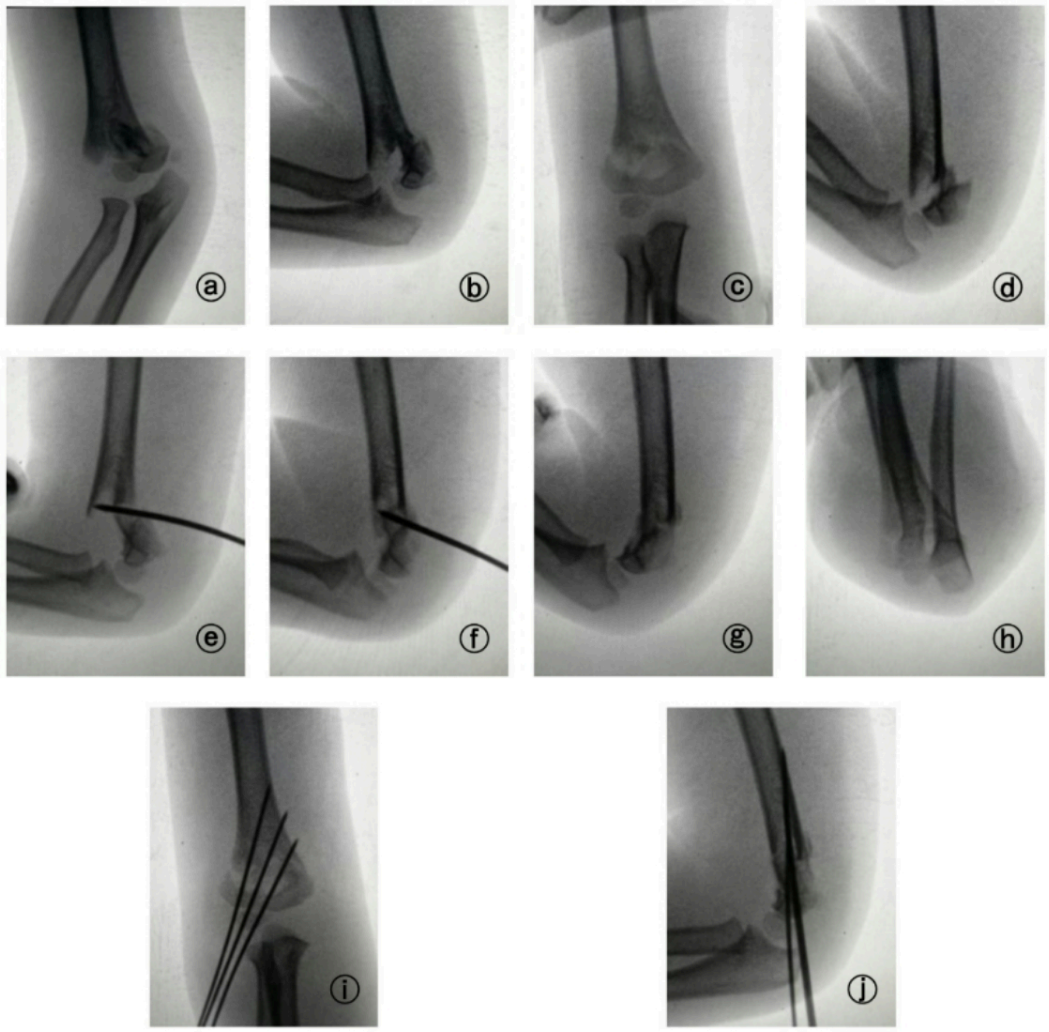

Figure 1

A 4-year-old patient with Gartland type III supracondylar humerus fracture. (a, b) Preoperative anteroposterior and lateral radiographs of the elbow showing marked fracture displacement. (c, d) After initial intraoperative reduction, the anteroposterior view showed satisfactory fracture alignment, while the lateral view revealed shortening and impaction of the fracture fragments, impeding reduction. (e, f) A K-wire was percutaneously inserted into the fracture site and used as a lever to reduce the fracture fragments. (g) After removal of the K-wire, the lateral view showed correction of shortening and

impaction with satisfactory reduction. (h) The Jones view of the elbow demonstrated satisfactory fracture reduction. (i, j) Intraoperative percutaneous fixation with three K-wires inserted through the lateral humeral epicondyle; satisfactory fracture reduction and good position of the internal fixation were achieved.