

# Retrospective study of open reduction and internal fixation of lateral humeral condyle fractures with absorbable screws and absorbable sutures in children

Yuxi Su, PhD, MD<sup>a</sup>, Kai Chen, PhD, MD<sup>b</sup>, Jiaqiang Qin, MD<sup>c,\*</sup>

## Abstract

**Background:** Lateral humeral condyle fractures are the second most common elbow fracture in children. Displaced and rotated fractures require stabilization and reduction. Kirschner wires (K-wires) are most commonly used in the fixation of these fractures. Here, we introduce a new fixation method that uses an absorbable screw. We aim to determine if it is feasible to treat lateral humeral condyle fractures with an absorbable screw by comparing functional outcomes following absorbable screw fixation vs. K-wire fixation.

**Methods:** Between May 2007 and September 2010, 86 patients were treated with absorbable screws (43 patients) or K-wire (43 patients). All patients had been diagnosed with lateral condyle fractures that were classified as either Jacob type II (unstable) or III. One absorbable screw (3.5 mm-diameter) was used for fixation in 1 group, while two 1.6 to 1.8 mm K-wires were used in the other group. Patients were followed 6 months about the elbow function according to Broberg and Morrey standard. On 5–7 years, the patients were followed about the carrying angle (valgus deformities and varus deformities), range of motion (flexion loss and extension loss), prominent lateral condyle, symptomatic implants, and fishtail deformity.

**Results:** Anatomic reduction was achieved in all patients. Each group had one radial nerve injury that were present preoperatively. Nerve function recovered spontaneously within 3 to 4 weeks of surgery in both patients. No patient developed necrosis of the capitulum in both groups. Nine patients in K-wires group and 2 in absorbable screw group developed symptomatic implants ( $P = .048$ ). On the sixth month, there was no significant difference on elbow function according to Broberg and Morrey standard. On 5 to 7 years (average,  $6.7 \pm 1.3$  years), valgus deformities was  $6.8 \pm 1.2$  vs  $5.7 \pm 0.8$ , varus deformities was  $7.2 \pm 1.5$  vs  $5.1 \pm 1.9$ , flexion loss was  $12.4 \pm 2.2$  vs  $9.5 \pm 3.1$ , extension loss was  $11.1 \pm 3.1$  vs  $10.2 \pm 2.7$ , prominent lateral condyle was 27.9% vs 37.2%, fishtail deformity was 7.3% vs 4.9%, no significant difference between these groups.

**Conclusions:** Open reduction with absorbable screw fixation is feasible and safe for the treatment of lateral condyle fractures of the humerus in children.

**Level of Evidence:** Therapeutic III.

**Abbreviations:** AP = anteroposterior, K-wires = Kirschner wires, SR-PDLLA = poly-DL-lactic acid, SR-PLA = self-reinforced polylactide, SR-PLLA = self-reinforced poly-L-lactic acid.

**Keywords:** absorbable screw, children, fractures, internal fixation, lateral condyle fracture

Editor: Johannes Mayr.

This work was supported in part by research grants from the Natural Science Foundation of China (#81001197 to YS), The Fifth batch of outstanding talents support program for universities in Chongqing Natural Science. Chongqing health and family planning commission with science and technology commission (2019MSXM081), Chongqing science and technology commission project (#cstc2017jcyjAX0010, #cstc2018jcyjAX0143). The authors report no conflicts of interest.

<sup>a</sup> Department II of Orthopaedics, Chongqing Key Laboratory of Pediatrics, Ministry of Education Key Laboratory of Child Development and Disorders, China International Science and Technology Cooperation base of Child development and Critical Disorders, the Children's Hospital of Chongqing Medical University,

<sup>b</sup> Department II of Orthopaedics, Chongqing Key Laboratory of Pediatrics, Ministry of Education Key Laboratory of Child Development and Disorders, China International Science and Technology Cooperation base of Child development and Critical Disorders, the Children's Hospital of Chongqing Medical University,

<sup>c</sup> Department II of Orthopaedics, Chongqing Key Laboratory of Pediatrics, Ministry of Education Key Laboratory of Child Development and Disorders, China International Science and Technology Cooperation base of Child development and Critical Disorders, the Children's Hospital of Chongqing Medical University, Chongqing, China.

\* Correspondence: Jiaqiang Qin, Department II of Orthopaedics, Chongqing Key Laboratory of Pediatrics, Ministry of Education Key Laboratory of Child Development and Disorders, China International Science and Technology Cooperation base of Child development and Critical Disorders, the Children's Hospital of Chongqing Medical University, Yuzhong District Zhongshan 2 road 136#, Chongqing, 400014, China (e-mail: 400835@hospital.cqmu.edu.cn).

Copyright © 2019 the Author(s). Published by Wolters Kluwer Health, Inc.

This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

How to cite this article: Su Y, Chen K, Qin J. Retrospective study of open reduction and internal fixation of lateral humeral condyle fractures with absorbable screws and absorbable sutures in children. *Medicine* 2019;98:44(e17850).

Received: 1 December 2018 / Received in final form: 1 October 2019 / Accepted: 9 October 2019

<http://dx.doi.org/10.1097/MD.00000000000017850>

## 1. Introduction

Fractures of the lateral humeral condyle represent the second most common elbow fracture in children and usually occur between the ages of 6 and 10 years. These fractures account for 17% of all distal humeral condyle fractures and are the most common physeal injuries of the elbow.<sup>[1,2]</sup> Several classification systems have been developed for this type of fracture, including those reported by Milch<sup>[3]</sup> (fracture line location) and Jakob et al.<sup>[4]</sup> The Milch classification is widely used and divides fractures into types I and II based on whether the fracture line exits through the capitellar–trochlear groove or through the trochlea. The Jakob classification dictates whether surgical intervention is required. A Jacob I fracture is non-displaced, while a Jacob II fracture is less than 2 mm displaced but not malrotated. A Jacob III fracture involves displacement and malrotation.<sup>[4]</sup> Open reduction and internal fixation remain the most common method for surgical stabilization of displaced pediatric lateral humeral condyle fractures. Non-displaced extra-articular fractures were managed conservatively, while displaced or intra-articular fractures with displacement of >2 mm require surgical intervention.<sup>[5–7]</sup> Kirschner wires (K-wires) are the most common and cost-effective tool for fracture fixation, but there is some dispute over whether the wires used for fixation should protrude out of the skin or be buried subcutaneously.<sup>[8–10]</sup> Metallic lag screws have also been used for fracture fixation.<sup>[11]</sup> Immobilization time and infection rates are lower following the use of metallic lag screws compared with K-wires, but these screws sometimes need to be removed in a second operation.<sup>[12]</sup>

We hypothesize that the use of absorbable screws for fracture fixation would overcome the major shortcoming of metallic lag screw fixation that needs to be removed in a second operation while still retaining its advantages. To test our hypothesis, we analyzed the data of 86 children with lateral humeral condyle fractures that were treated with open reduction and internal fixation with K-wires or absorbable screws at our hospital. By comparing the functional outcomes and long-time complications of patients who underwent internal fixation with absorbable screws vs K-wires, we aim to determine whether internal fixation with absorbable screws is feasible and safe in the treatment of lateral humeral condyle fractures in children.

## 2. Patients and methods

### 2.1. Patients

This is a retrospective study, and the study involved 86 patients (52 boys and 34 girls) aged 1.6 to 13 years (average,  $6.7 \pm 1.8$  years) treated from May 2007 to September 2010. There were 31 male and 12 female patients (mean age  $6.2 \pm 1.7$ ) in K-wire group and 25 male and 18 female (mean age  $6.8 \pm 2.1$ ) in absorbable group. All patients were diagnosed with lateral condyle fractures that were substantially displaced (Jacob type II or III). There were 16 type II and 27 type III patients in K-wire group and 13 type II and 30 type III patients in absorbable group. Two patients had radial nerve injuries that were present preoperatively. In 74 patients, surgery was performed within 3 days of injury. In 12 patients, surgery was performed more than 7 but less than 10 days after injury, as these patients presented late to our outpatient department after previously receiving an incorrect diagnosis at their local hospital. In 4 of these patients, closed reduction had been previously attempted but failed. Overall, 81 injuries had been due to a fall, while 5 were from traffic accidents.

The ethics committee of our hospital approved the study on the 15th Feb 2007 and the file number is 070215006. The parents or guardians of the patients signed an informed consent form before study participation and authorized the publication of study results and the use of photographs of their children. The registration is on ClinicalTrials.gov Identifier: NCT02733666.

### 2.2. Absorbable screws

The absorbable screws were made of self-reinforced polylactide (SR-PLA), which is a composite of self-reinforced poly-L-lactic acid (SR-PLLA) and poly-DL-lactic acid (SR-PDLLA) plus SR-PLLA. The molecular mass of PLLA is 260,000(Mr), while that of PDLLA is 100,000(Mr). A special drill, depth scale and booster were used. The absorbable screw had a diameter of 3.5 mm and a length of 3.5 to 4.5 cm.

### 2.3. Surgical technique

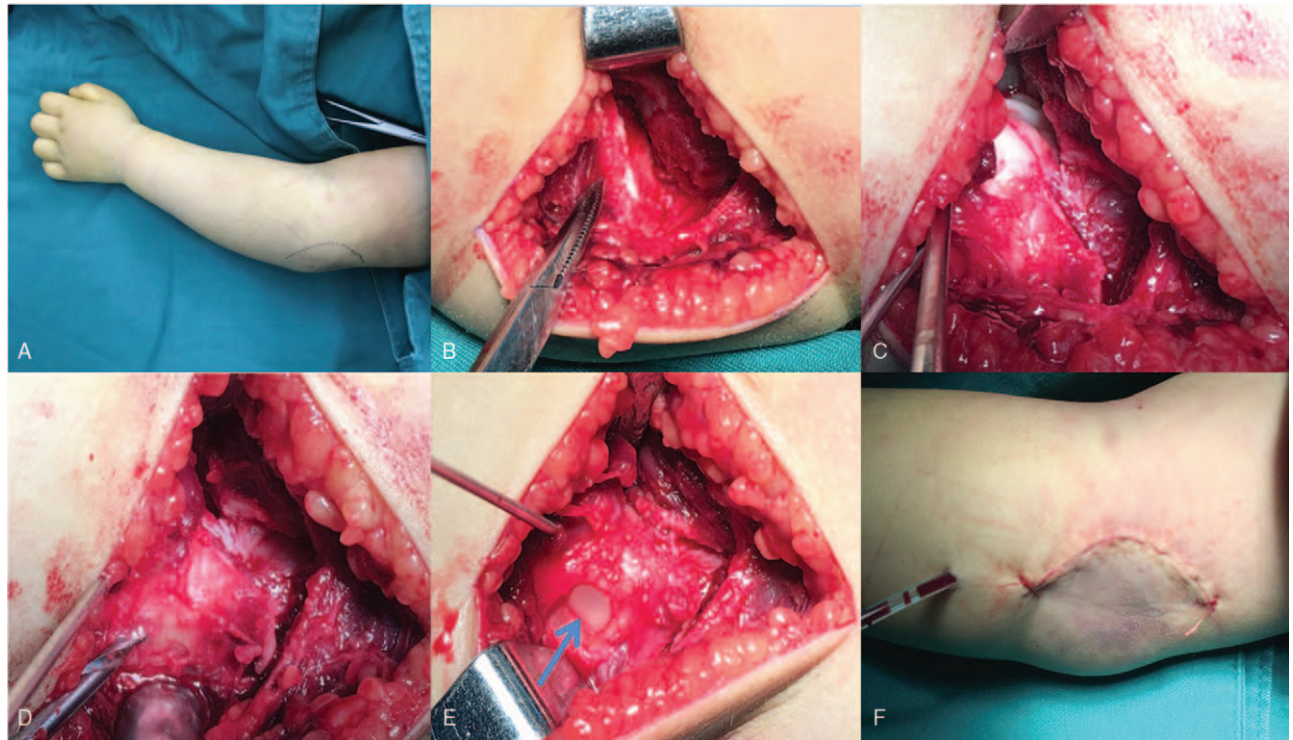
A pneumatic tourniquet was used during surgery to minimize blood loss. Under general anesthesia or basal and brachial plexus anesthesia, a closed reduction was attempted in all patients and checked under C-arm fluoroscopy. Fixation was performed if the reduction was ideal, and these patients were excluded from the study. In patients that failed closed reduction, an incision was made on the lateral part of the elbow, exposing the lateral and anterior capitulum (Fig. 1A, B). Attention was paid to the radial nerve to prevent additional trauma to an already contused nerve. In the K-wire group, the capitulum was anatomically reduced and fixed with two K-wires (diameter, 1.6 or 1.8 mm), the K-wires tails were left outside the skin. In the absorbable screw group, a 1.5-mm K-wire was used for temporary fixation after anatomic reduction (Fig. 1C). The lateral and posterior capitulum were then exposed, and a hole was made in the metaphysis of the distal humerus (Fig. 1D). An electric drill was used to tunnel through the capitulum to the cortical bone of the humeral shaft. Screw length was determined, and a 3.5-mm absorbable screw was used for fixation (Fig. 1E). Size 2 to 0 absorbable sutures were used to strengthen the fracture fixation and to prevent rotation of the capitulum (Fig. 1E). Finally, the incision was closed (Fig. 1F). The elbow joint was immobilized in a functional position with a plaster cast. Figure 2 is a schematic diagram, and during the whole procedure we tried to avoid trans-physeal screw fixation.<sup>[13]</sup>

### 2.4. Postoperative care and follow-up

The plaster support was removed 4 weeks after surgery in the absorbable screw group and K-wire group. For the K-wire group the K-wires were removed 4 to 6 weeks after surgery based on callus growth. The patients started elbow flexion and extension exercise after the plaster cast removal.

### 2.5. Outcomes assessment

Functional outcomes were assessed 6 months after surgery using the Broberg and Morrey standard.<sup>[14]</sup> This standard assesses elbow range of motion, including humeral motion and forearm rotation. Scores are classified as follows: 95 to 100 points, excellent; 94 to 80, good; 79 to 60, fair; and 59 to 0, poor.<sup>[14]</sup> On 5 to 7 years, the patients were followed about the carrying angle (valgus deformities and varus deformities), range of motion



**Figure 1.** A 4-year-old boy with a lateral humeral condyle fracture fixed with an absorbable screw. A. Lateral incision at elbow region. B. The unstable Jacob type II fracture is exposed. C. The fracture is reduced, and a 1.5-mm K-wire is used for temporary fixation. D. A hole is drilled into the metaphysis of the distal humerus. E. A 3.5-mm-wide and 3.6-cm-long absorbable screw was used to fix the fracture. F. The incision is closed.

(flexion loss and extension loss), prominent lateral condyle, symptomatic implants, and fishtail deformity. Cutaneous infection was defined as redness, irritation, pain, and secretion on the surface of the skin.

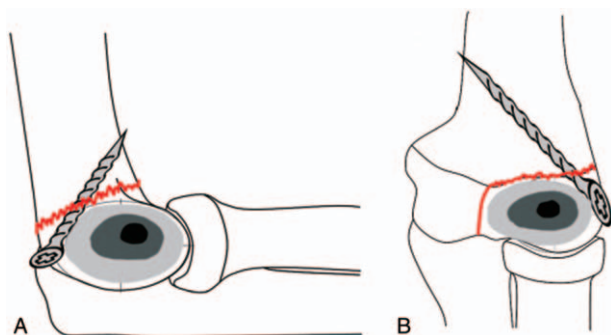
### 2.6. Statistical analysis

Statistical analysis was performed by the first author using the SPSS 10.0 software package (SPSS, Chicago, IL). Student *t* test was used for the comparison of continuous variables and the X<sup>2</sup> test for the comparison of categorical variables, if the categorical variables less than 5, the Fisher exact test were used to compare the complications such as prominent lateral condyle, symptom-

atic implants and fishtail deformity between these 2 groups. A value of  $P < .05$  was considered statistically significant.

### 3. Results

A total of 86 patients were included in this study, with 43 patients in each group. There was no significant age, gender and fracture type difference between these 2 groups (Table 1), both groups were followed for 5 to 7 years (average,  $6.7 \pm 1.3$  years), no fracture nonunion or secondary displacement after anatomic reduction was observed in either group, the healing time was 4 to 6 weeks in both groups. In total, 2 patients (1 in the K-wire group and 1 in the absorbable screw group) had radial nerve injuries that were present preoperatively; both of the patients had limited dorsal extension of the thumb. Nerve function recovered spontaneously within 3 to 4 weeks of surgery in both patients. No incidence of capitulum necrosis was noted in either group. During the first 6 weeks, 9 patients developed pin tract infection affecting only the superficial layers; they all recover after removing the K-wires. Two patients had cutaneous irritation with pain caused by screws; both of them recover within 1 month. No infections occurred in the absorbable screw group. This difference in symptomatic implants rate was significant ( $P = .048$ ) (Table 1). In the K-wire group, all patients began elbow flexion and extension exercise at 4 weeks after surgery and the K-wires were removed once a callus was observed on X-ray. In the absorbable screw group, all patients also began elbow flexion and extension exercise at 4 weeks after surgery. On the sixth month, according to the Broberg and Morrey standard,<sup>[14]</sup> functional outcomes were rated excellent in 35 patients, good in 7 patients, fair in 1 patient and poor in 0 patients in the K-wire group. In the



**Figure 2.** A schematic diagram showing how the screw was placed in the anteroposterior and lateral projections. This schematic diagram also depicts the location of the developing capitellar ossification center with age. The red line shows the fracture line.

**Table 1**  
**Patients' age, gender, fracture characteristics, and complications of pediatric lateral condyle fractures.**

	K-wire	Absorbable screw	P value <sup>†</sup>
Age			
Mean age (years)	6.2±1.7	6.8±2.1	.36
Gender			
Male	31	25	.17
Female	12	18	
Fracture characteristics			
Jakob classification			
Jakob Type 1	0	0	
Jakob Type 2	16	13	.49
Jakob Type 3	27	30	
postoperative scores* (on 6th month)			
Excellent	32	35	.55
Good	8	7	
Fair	3	1	
Poor	0	0	
Complications (6.7±1.3 years)			
Comparing to the normal elbow (degrees)			
Valgus deformities	6.8±1.2	5.7±0.8	.19
Varus deformities	7.2±1.5	5.1±1.9	.27
Range of motion (degrees)			
Flexion loss	12.4±2.2	9.5±3.1	.22
Extension loss	11.1±3.1	10.2±2.7	
Prominent lateral condyle	27.9%	37.2%	.35
Symptomatic implants	20.9%	6.98%	.048
Fishtail deformity	7.3%	4.9%	.644

\* according to the Broberg and Morrey evaluation standard.

<sup>†</sup> P<.05 was considered statistically significant.

absorbable screw group, functional outcomes were rated excellent in 37 patients and good in 6 patients; no patients had fair or poor outcomes (Table 1). There was no significant difference in functional outcomes between these groups ( $P = .5485$ ).<sup>[14]</sup> On 5 to 7 years (average,  $6.7 \pm 1.3$  years), all the patients were followed on the carrying angle (valgus deformities and varus deformities), range of motion (flexion loss and extension loss), prominent lateral condyle, symptomatic implants, fishtail deformity (Table 1). The valgus deformities was  $6.8 \pm 1.2$  vs  $5.7 \pm 0.8$ , varus deformities was  $7.2 \pm 1.5$  vs  $5.1 \pm 1.9$ , flexion loss was  $12.4 \pm 2.2$  vs  $9.5 \pm 3.1$ , extension loss was  $11.1 \pm 3.1$  vs  $10.2 \pm 2.7$ , prominent lateral condyle was 27.9% vs

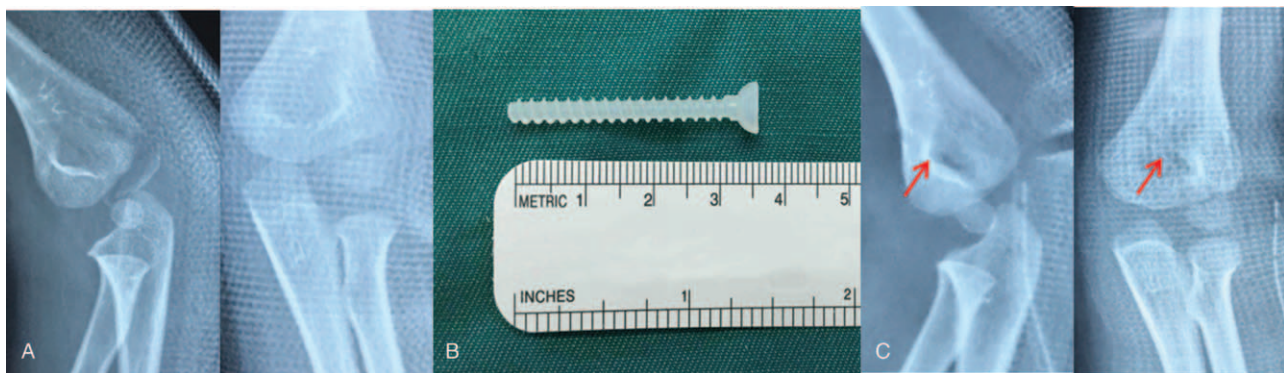
37.2%, fishtail deformity was 7.3% vs 4.9%. We noted no significant difference except the symptomatic implants.

#### 4. Discussion

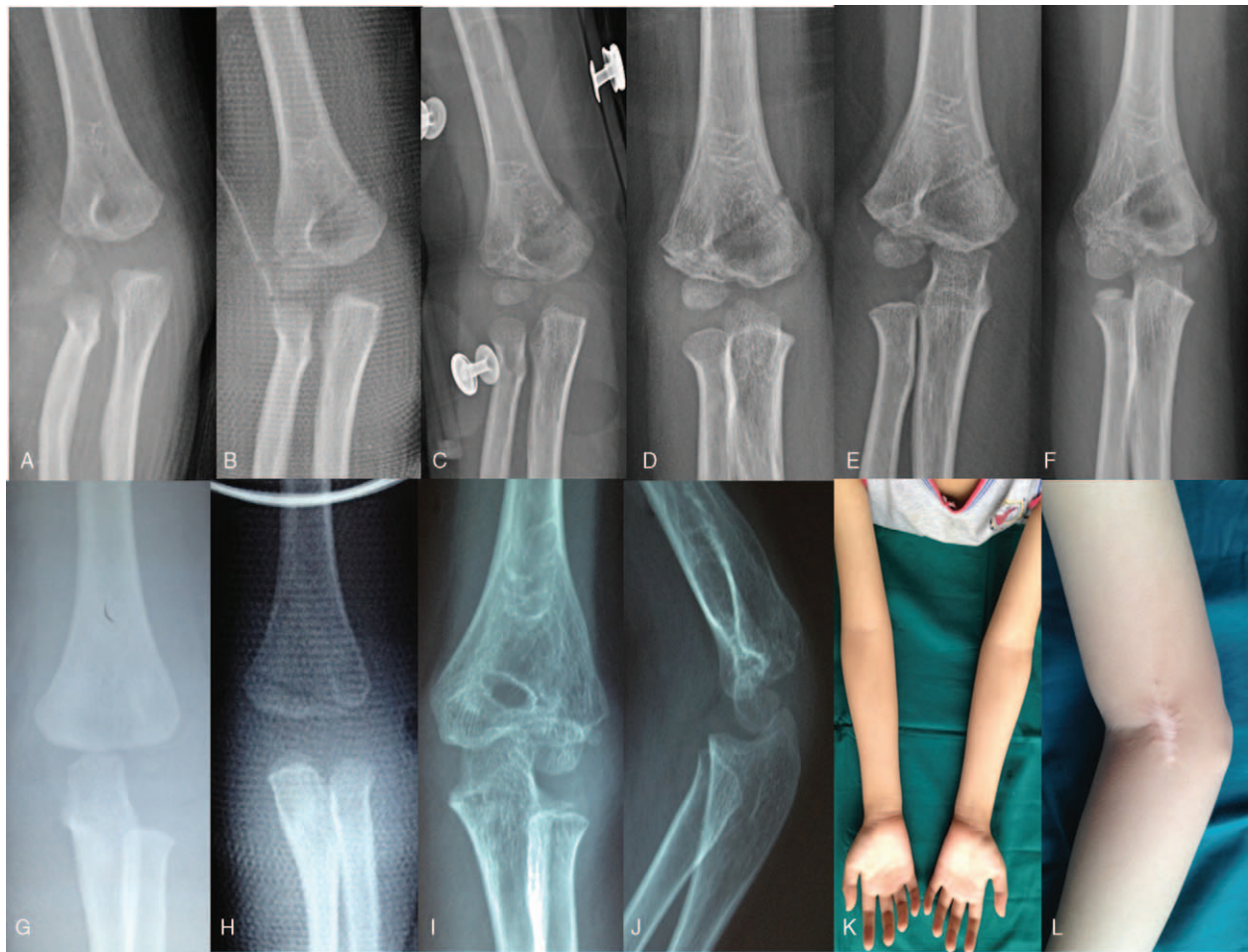
Lateral humeral condyle fractures are the second most common elbow injury in children. Good outcomes following Jacob type II and III fractures have been achieved using open reduction and fixation with either K-wires or metallic lag screws/cannulated screws. Although very effective and associated with excellent functional outcomes and few complications, fixation with metallic screws must be followed by hardware removal under general anesthesia, which may add to the physical and psychological trauma experienced by these children. In the case of K-wire fixation, elbow flexion and extension activity may be affected by K-wires. We introduced an innovative method that uses absorbable screws instead of K-wires or metallic screws. In this technique K-wire/screw fixation removal was not required.<sup>[15]</sup> With our technique, surgeons can easily decide to remove the plaster. In the case of K-wire fixation, a callus must be observed on X-ray prior to removing the K-wires. In the case of metallic screw fixation, rehabilitation can be started early, but the screws were buried subcutaneously.

In our study, we used screws made of SR-PLA, which is an absorbable polymer.<sup>[16]</sup> Animal studies have shown that SR-PLA does not cause a toxic reaction and has good histocompatibility.<sup>[17,18]</sup> The SR-PLA screw expands vertically and shrinks horizontally after immersion in water, and these properties help increase fixation strength. The screw is completely absorbed within 2 to 4 years, which is long enough to permit lateral condyle fracture healing. Follow-up examination in the absorbable screw group showed that no patient had a growth arrest or obvious cubitus valgus after at least 5 years. Only one screw was used for fixation in each patient, and 2 to 0 sutures were used to fix the fracture in order to avoid rotation. No fractures showed postoperative displacement after fixation by absorbable screws. Figure 4 showed two 2-years old male patients with Jacob's type 2 and 3 fractures. The absorbable screw shadow can still be seen in the 4th year, it disappeared in the 6th year with no obvious growth arrest, and normal range of motion and carrying angle.

Screw fixation requires good technical skills, especially when performed in a young patient. Once anatomic reduction is achieved, the fracture must be stabilized with a K-wire until final



**Figure 3.** X-rays and implants used in the same 4-year-old boy with a lateral humeral condyle fracture. A. Preoperative X-rays (first day after injury) show a Jacob type II fracture. B. An SR-PLA absorbable screw with a diameter of 3.5 mm and a length of 3.6 cm. C. Postoperative X-rays (2nd post-operative day) show that anatomic fracture reduction has been achieved. The red arrow points towards the absorbable screw.



**Figure 4.** Two patients were followed for 4 years and 6 years. (A) AP - X-ray view of the elbow of a boy aged 2.5 years; (B) postoperative X-ray image (1st day); (C) postoperative X-ray image (6th month); (D) postoperative X-ray image (2nd month); (E) postoperative X-ray image (6th month); (F) postoperative X-ray image (4th year) show fracture changes. Boy aged 2.7 years at the time of injury: (G) Preoperatively obtained AP - X-ray images; (H) Postoperatively obtained AP X-ray images (1st day); (I) postoperative X-ray images (6th month) showing fish tail deformity, (J) Lateral view, obtained 6th year postoperatively; (K) appearance of the patient 6th year postoperatively; (L) scar at the elbow, 6th year postoperatively.

fixation with the absorbable material. Since the fixation area is very small in pediatric patients, the operating surgeon needs to be skilled to achieve a good fixation (Fig. 3). In young children, fracture fixation with absorbable screws may affect subsequent growth, especially when the diameter of the screw is 3.5 mm. It has been reported that when screw fixation is performed at the epiphysis, the screw diameter should not be greater than 2 mm.<sup>[19]</sup> Although we used larger screws in this study, no patient developed an obvious growth abnormality. This is consistent with the results of Shirley et al, who evaluated the efficacy of screw fixation of lateral condyle fractures and found that screw fixation posed a low risk of iatrogenic physal damage.<sup>[12]</sup> Schlitz et al analyzed screw versus K-wire fixation of lateral humeral condyle fractures using 4.0-mm lag screws and found these to be safe.<sup>[11]</sup> Stein et al used 4.5-mm lag screws to fix displaced pediatric lateral humeral condyle fractures and confirmed that these were safe and reliable.<sup>[20]</sup> Fishtail deformity is a concavity visible on radiographs and it is caused by disrupted blood supply to the trochlea and the lateral trochlear ossification center fails to develop.<sup>[21]</sup> This is a late manifestation, usually occurring 4 to 8 years after the initial injury.<sup>[22]</sup> In this study, the K-wires group

had 3 and absorbable group had 2 severe fishtail deformity, there was no significant difference between these groups ( $P = .644$ ). We had no cases of bone bridge formation in our study. The absorbable screws degraded gradually within 2 to 4 years (Fig. 4). In our study, the screws occupied no more than 10% of the epiphyseal area,<sup>[23]</sup> and most importantly, the majority of the screw did not pass through the epiphysis but rather through the metaphysis of the lateral humerus.

## 5. Limitations

A longer follow-up until maturity is required. More precise imaging, such as magnetic resonance imaging or computed tomography should be performed in these patients. In our study, as the appearance of all patients' elbows was normal and no severe functional loss or bony nonunion were observed on X-ray, no patients required the above examinations. Screw fixation requires technical skills as the metaphyseal bone segment is very small, making it more difficult than K-wire fixation for inexperienced surgeons. Finally, the absorbable screw was more expensive (400–600 dollars) than K-wires (a few dollars).

## 6. Conclusion

Open reduction and internal fixation with absorbable screws is feasible and safe in the treatment of lateral condyle fractures of the distal humerus in children. This technique can avoid a second surgery, as well as pin infections, and may be used to treat lateral condyle fractures in children.

## Author contributions

**Data curation:** Kai Chen.

**Formal analysis:** Yuxi Su.

**Funding acquisition:** Yuxi Su.

**Project administration:** Jiaqiang Qin.

**Resources:** Kai Chen.

**Supervision:** Jiaqiang Qin.

**Writing – original draft:** Yuxi Su.

**Writing – review & editing:** Yuxi Su, Kai Chen.

## References

- [1] Rutherford A. Fractures of the lateral humeral condyle in children. *J Bone Joint Surg Am* 1985;67:851–6.
- [2] Papavasiliou VA, Beslikas TA. Fractures of the lateral humeral condyle in children—an analysis of 39 cases. *Injury* 1985;16:364–6.
- [3] Milch H. Fractures and fracture dislocations of the humeral condyles. *J Trauma* 1964;4:592–607.
- [4] Jakob R, Fowles JV, Rang M, et al. Observations concerning fractures of the lateral humeral condyle in children. *J Bone Joint Surg Br* 1975;57:430–6.
- [5] Tan S, Dartnell J, Lim A, et al. Paediatric lateral condyle fractures: a systematic review. *Arch Orthop Trauma Surg* 2018;138:809–17.
- [6] Pennock AT, Salgueiro L, Upasani VV, et al. Closed reduction and percutaneous pinning versus open reduction and internal fixation for type II lateral condyle humerus fractures in children displaced > 2 mm. *J Pediatr Orthop* 2016;36:780–6.
- [7] Knapik DM, Gilmore A, Liu RW. Conservative management of minimally displaced ( $\leq 2$  mm) fractures of the lateral humeral condyle in pediatric patients: a systematic review. *J Pediatr Orthop* 2017;37:e83–83e87.
- [8] McGonagle L, Elamin S, Wright DM. Buried or unburied K-wires for lateral condyle elbow fractures. *Ann R Coll Surg Engl* 2012;94:513–6.
- [9] Chan LW, Siow HM. Exposed versus buried wires for fixation of lateral humeral condyle fractures in children: a comparison of safety and efficacy. *J Child Orthop* 2011;5:329–33.
- [10] De SD, Bae DS, Waters PM. Displaced humeral lateral condyle fractures in children: should we bury the pins. *J Pediatr Orthop* 2012;32:573–8.
- [11] Schlitz RS, Schwertz JM, Eberhardt AW, et al. Biomechanical analysis of screws versus k-wires for lateral humeral condyle fractures. *J Pediatr Orthop* 2015;35:e93–7.
- [12] Li WC, Xu RJ. Comparison of Kirschner wires and AO cannulated screw internal fixation for displaced lateral humeral condyle fracture in children. *Int Orthop* 2012;36:1261–6.
- [13] Fader LM, Laor T, Eismann EA, et al. MR imaging of capitellar ossification: a study in children of different ages. *Pediatr Radiol* 2014;44:963–70.
- [14] Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. *Clin Orthop Relat Res* 1987;109–19.
- [15] Andrey V, Tercier S, Vauclair F, et al. Lateral condyle fracture of the humerus in children treated with bioabsorbable materials. *ScientificWorldJournal* 2013;2013:869418.
- [16] Chao EY, An KN, Askew LJ, et al. Electrogoniometer for the measurement of human elbow joint rotation. *J Biomech Eng* 1980;102:301–10.
- [17] Hollinger JO, Battistone GC. Biodegradable bone repair materials. Synthetic polymers and ceramics. *Clin Orthop Relat Res* 1986;290–305.
- [18] Nordström P, Pihlajamäki H, Toivonen T, et al. Tissue response to polyglycolide and polylevolactide pins in osteotomized cancellous bone. *Clin Orthop Relat Res* 2001;247–57.
- [19] Hajdu S, Schwendenwein E, Kaltenecker G, et al. The effect of drilling and screw fixation of the growth plate—an experimental study in rabbits. *J Orthop Res* 2011;29:1834–9.
- [20] Stein BE, Ramji AF, Hassanzadeh H, et al. Cannulated lag screw fixation of displaced lateral humeral condyle fractures is associated with lower rates of open reduction and infection than pin fixation. *J Pediatr Orthop* 2017;37:7–13.
- [21] Narayanan S, Shailam R, Grottkau BE, et al. Fishtail deformity—a delayed complication of distal humeral fractures in children. *Pediatr Radiol* 2015;45:814–9.
- [22] Abzug JM, Dua K, Kozin SH, et al. Current concepts in the treatment of lateral condyle fractures in children. *J Am Acad Orthop Surg* 2019;1–11.
- [23] Janarv PM, Wikström B, Hirsch G. The influence of transphyseal drilling and tendon grafting on bone growth: an experimental study in the rabbit. *J Pediatr Orthop* 1998;18:149–54.